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(54) **EBULLIENT COOLING DEVICE**

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(57) **ABSTRACT**

An ebullient cooling device includes a chamber, a heat sink, a heat receiving member, and a heat dissipating member. The chamber includes a heat conducting plate with a heat generating body on an outer side surface thereof, and an airtight space filled with coolant that undergoes a phase change between liquid and gas, on an inner side of the heat conducting plate. The heat sink is provided on the outer side surface of the heat conducting plate. The heat receiving member is provided on an inner side surface of the heat conducting plate so as to oppose the heat generating body with the heat conducting plate sandwiched therebetween, and transfers heat generated at the heat generating body to the coolant. The heat dissipating member is provided on the inner side surface of the heat conducting plate, receives heat transferred by the coolant, and dissipates the heat to the heat sink.

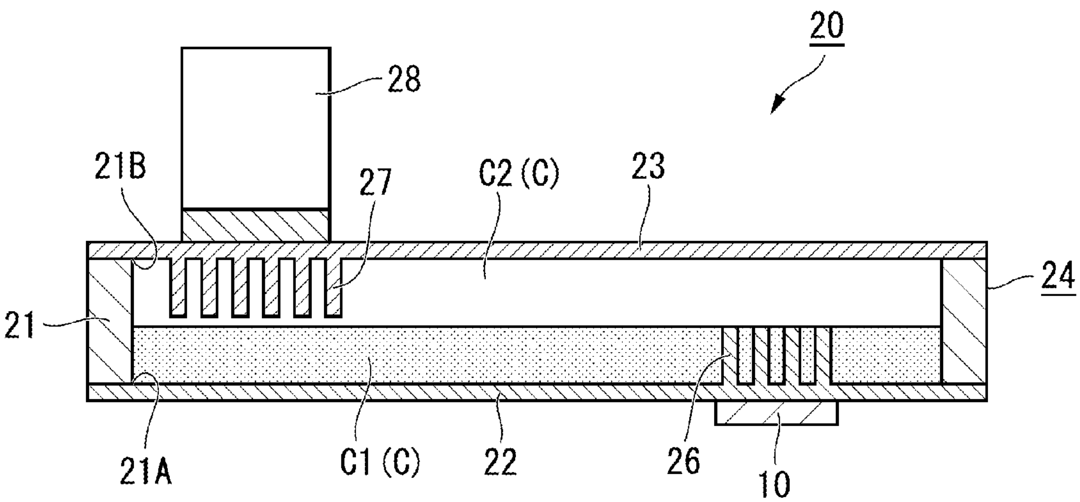


FIG. 1

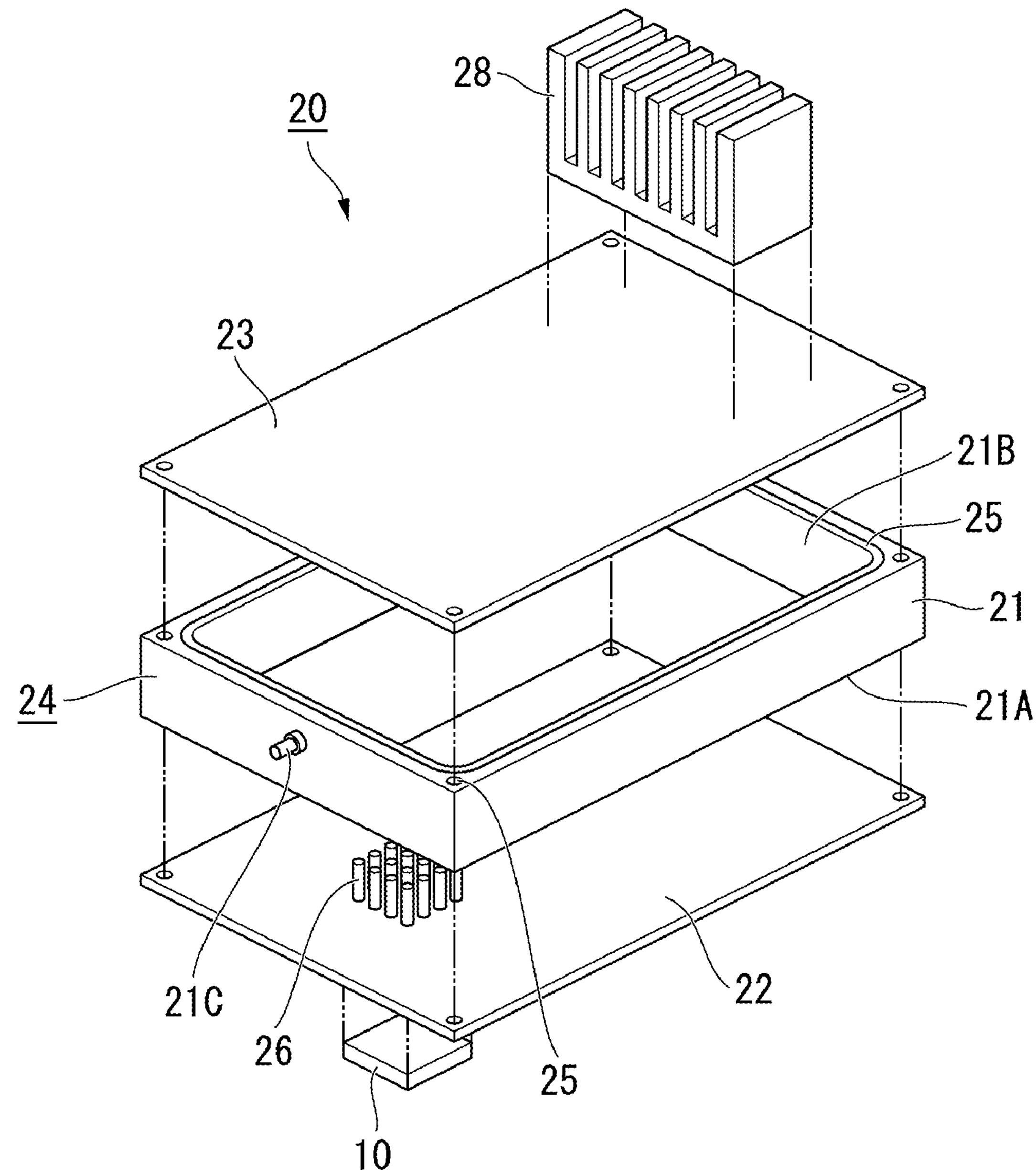


FIG. 2

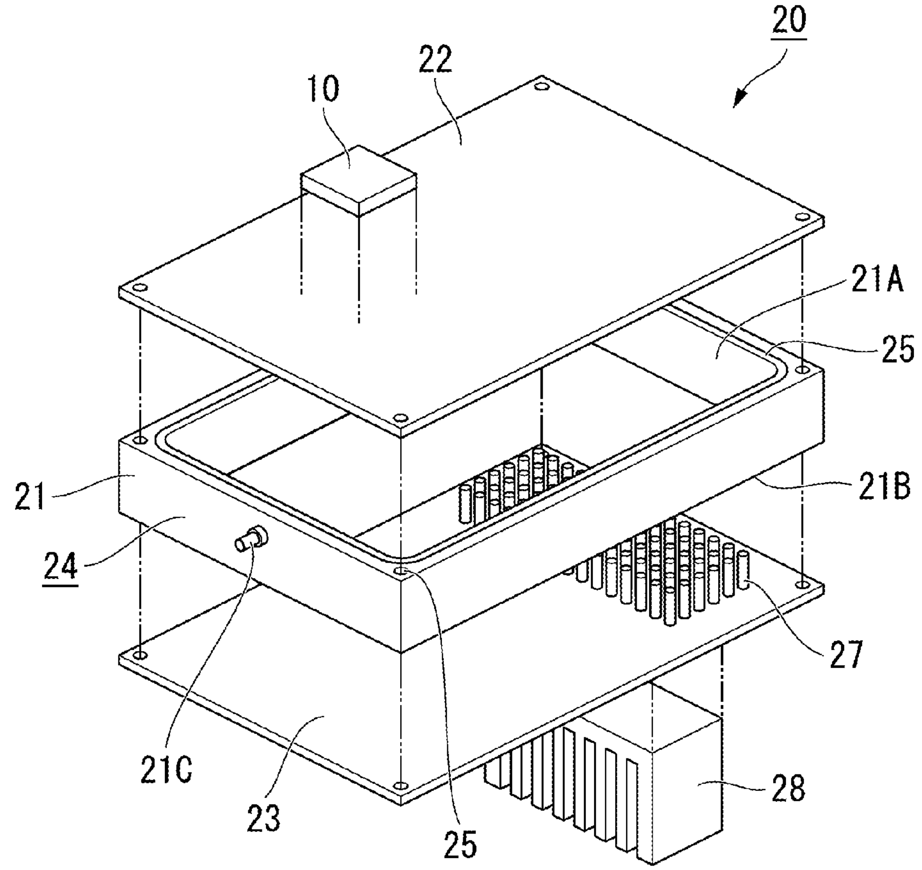

20
22
10
21A
25
21
21B
24
27
21C
23
25
28

FIG. 3

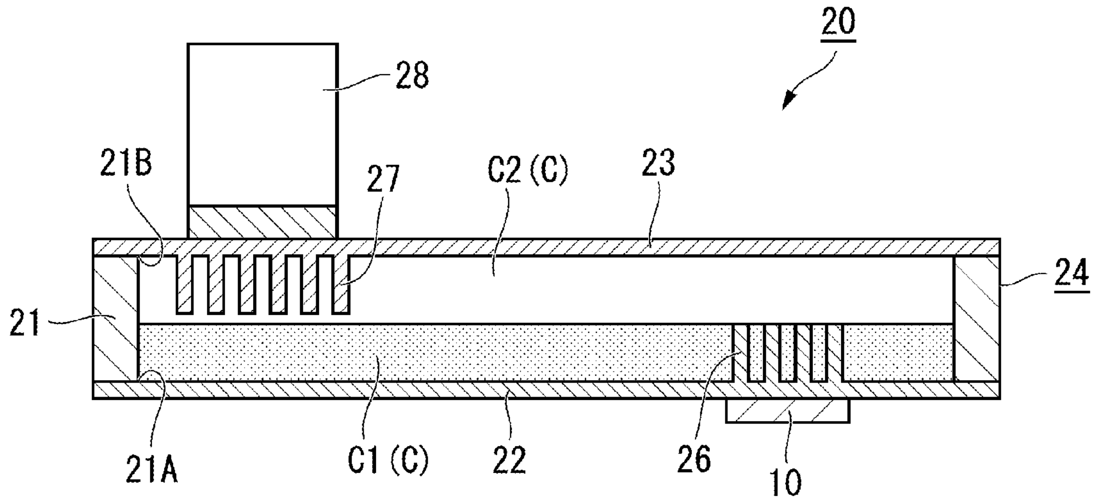

20
28
21B
27
C2 (C)
23
24
21
21A
C1 (C)
22
26
10

FIG. 4

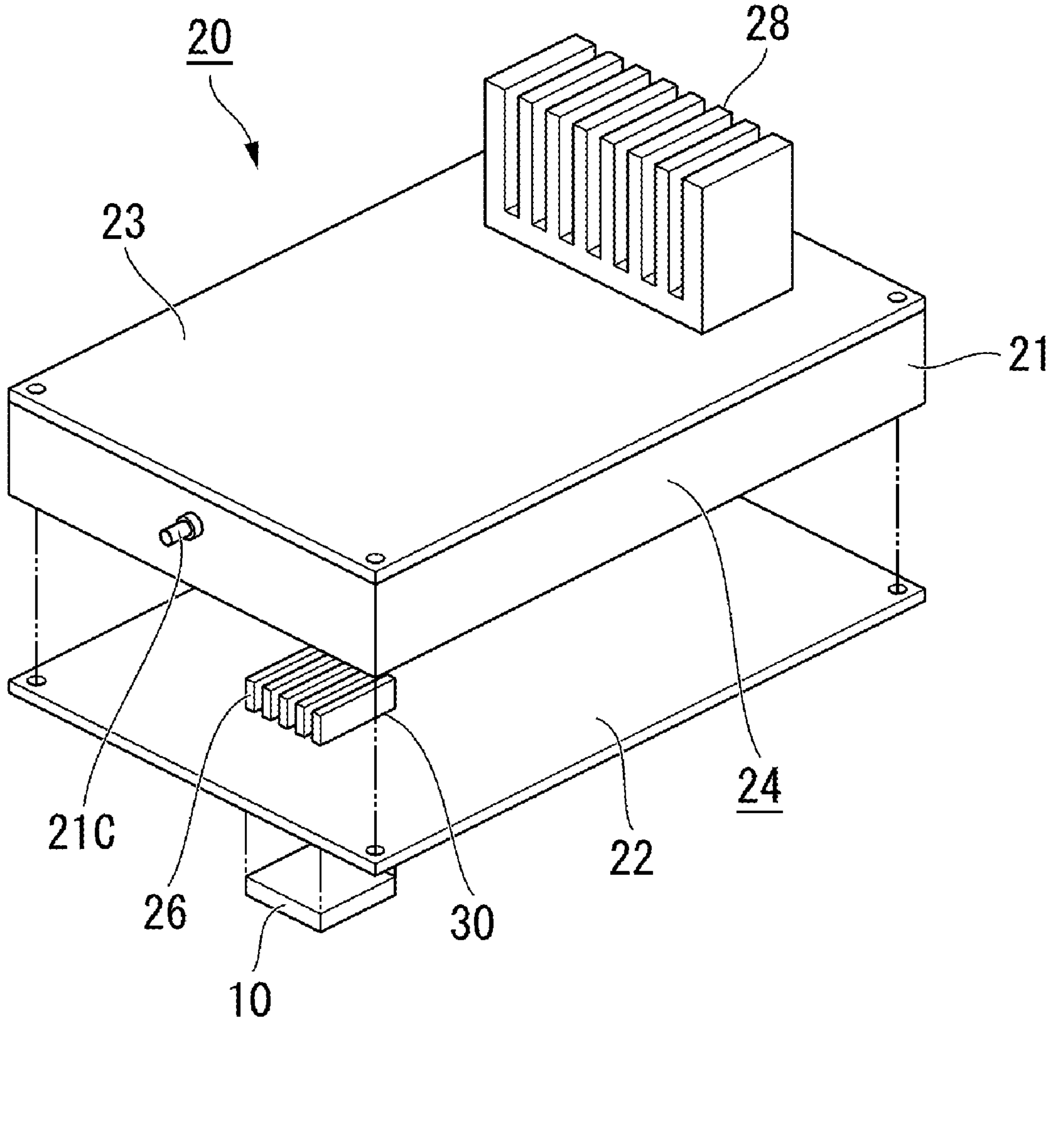


FIG. 5

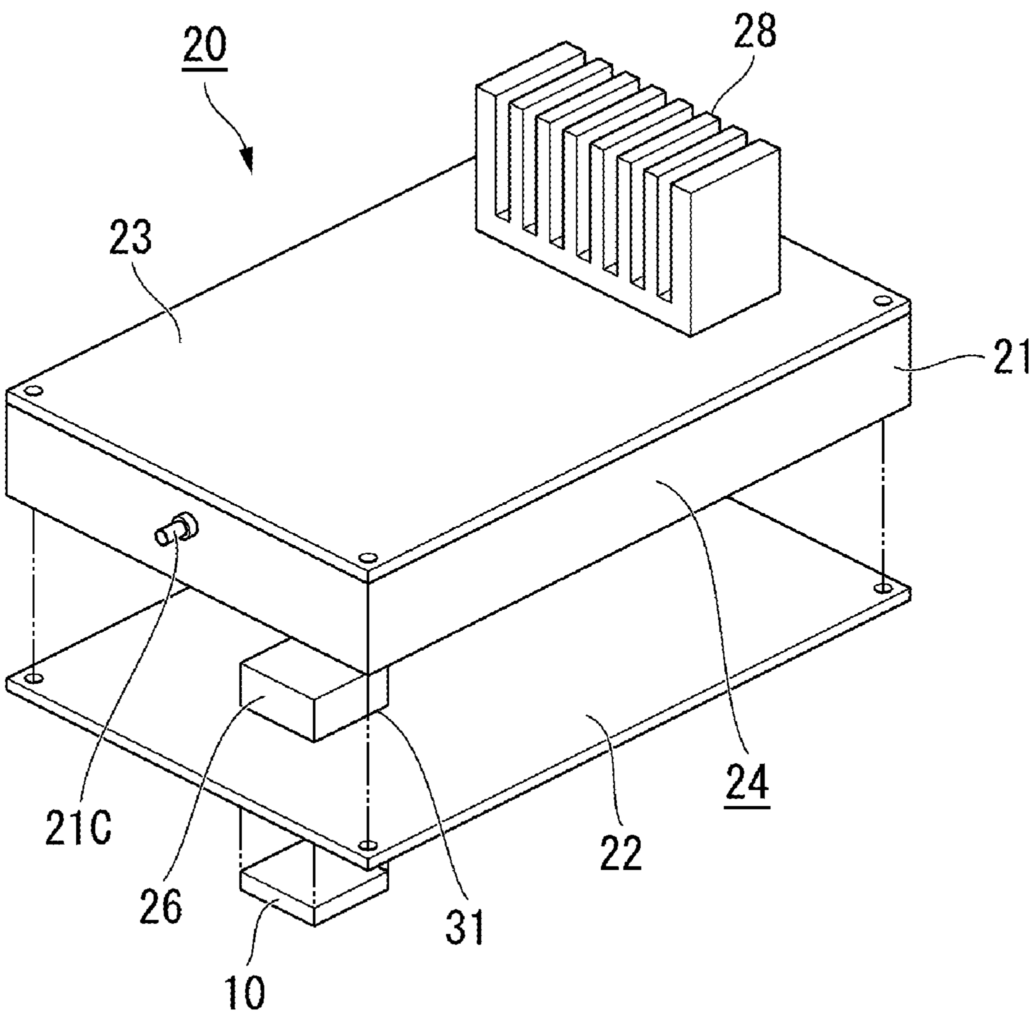


FIG. 6

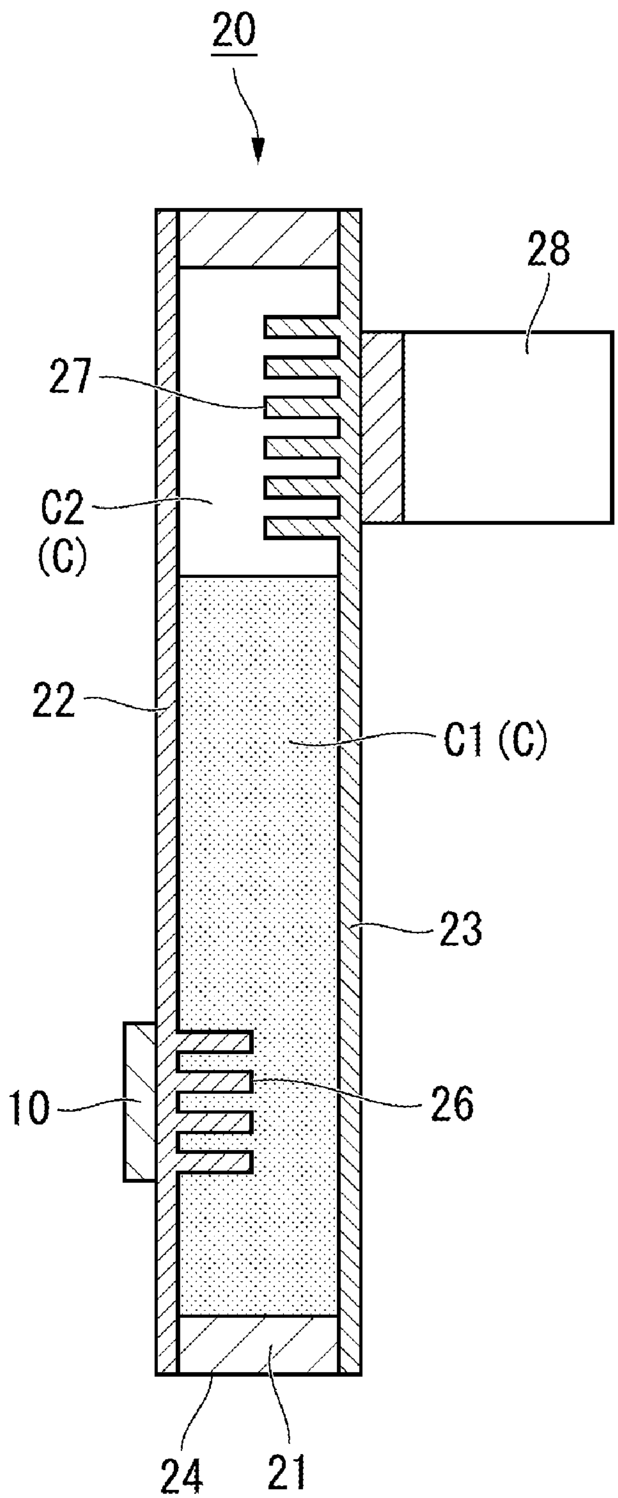


FIG. 7

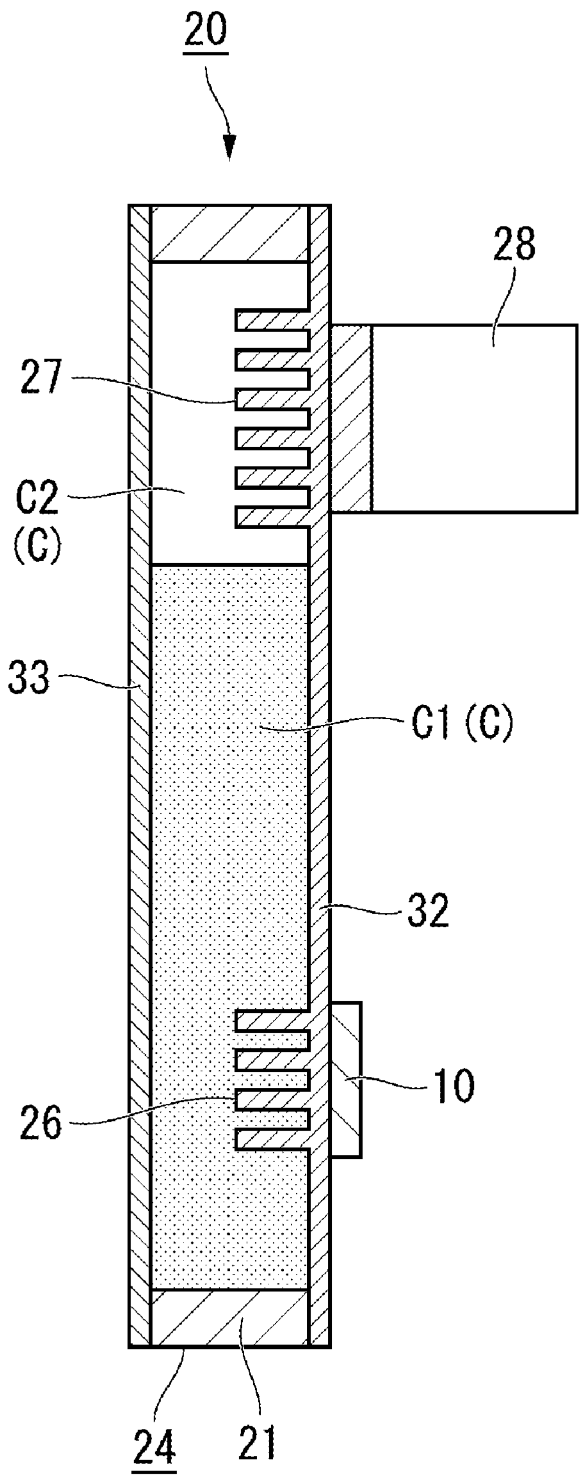


FIG. 8

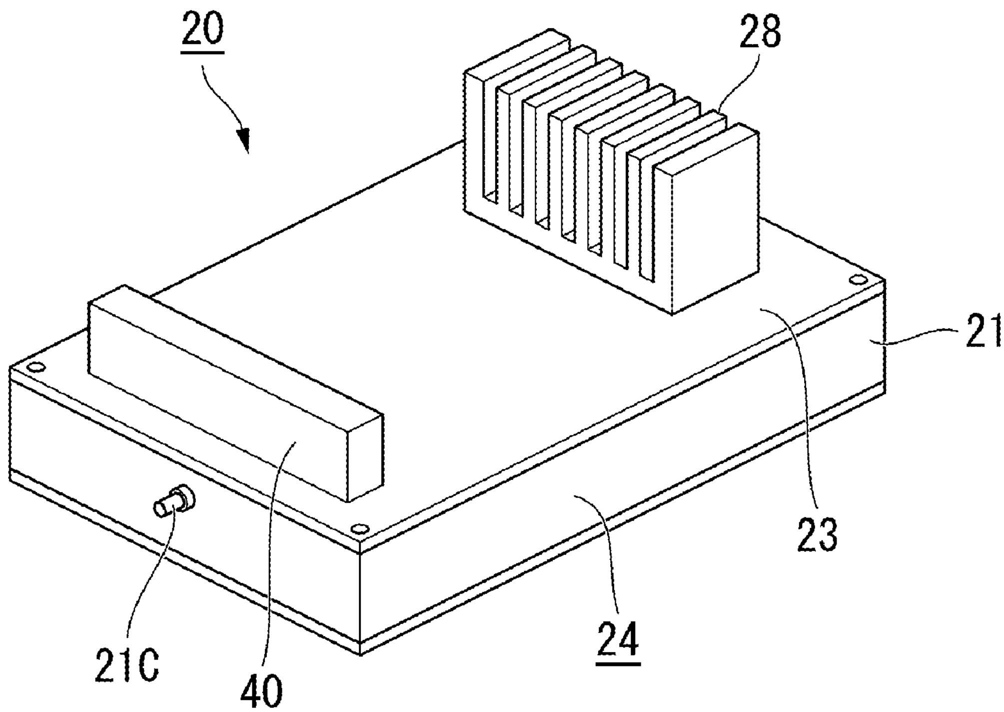


FIG. 9

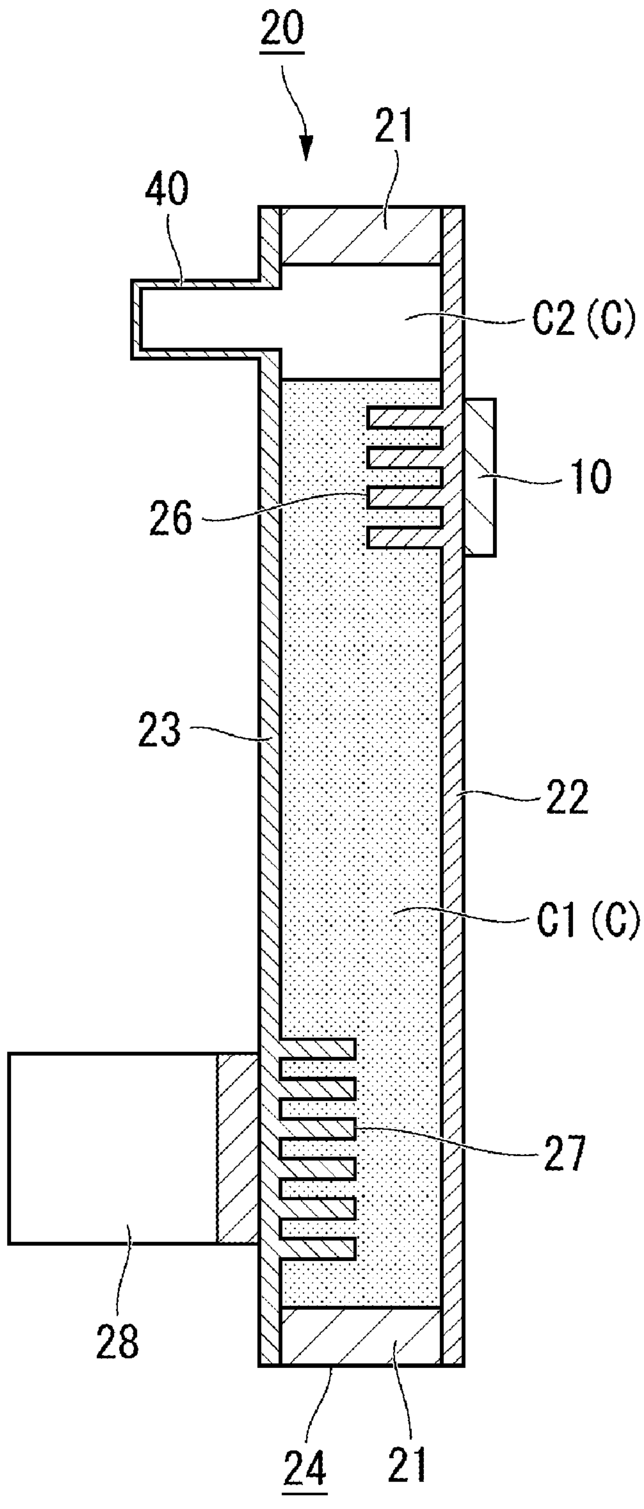


FIG. 10

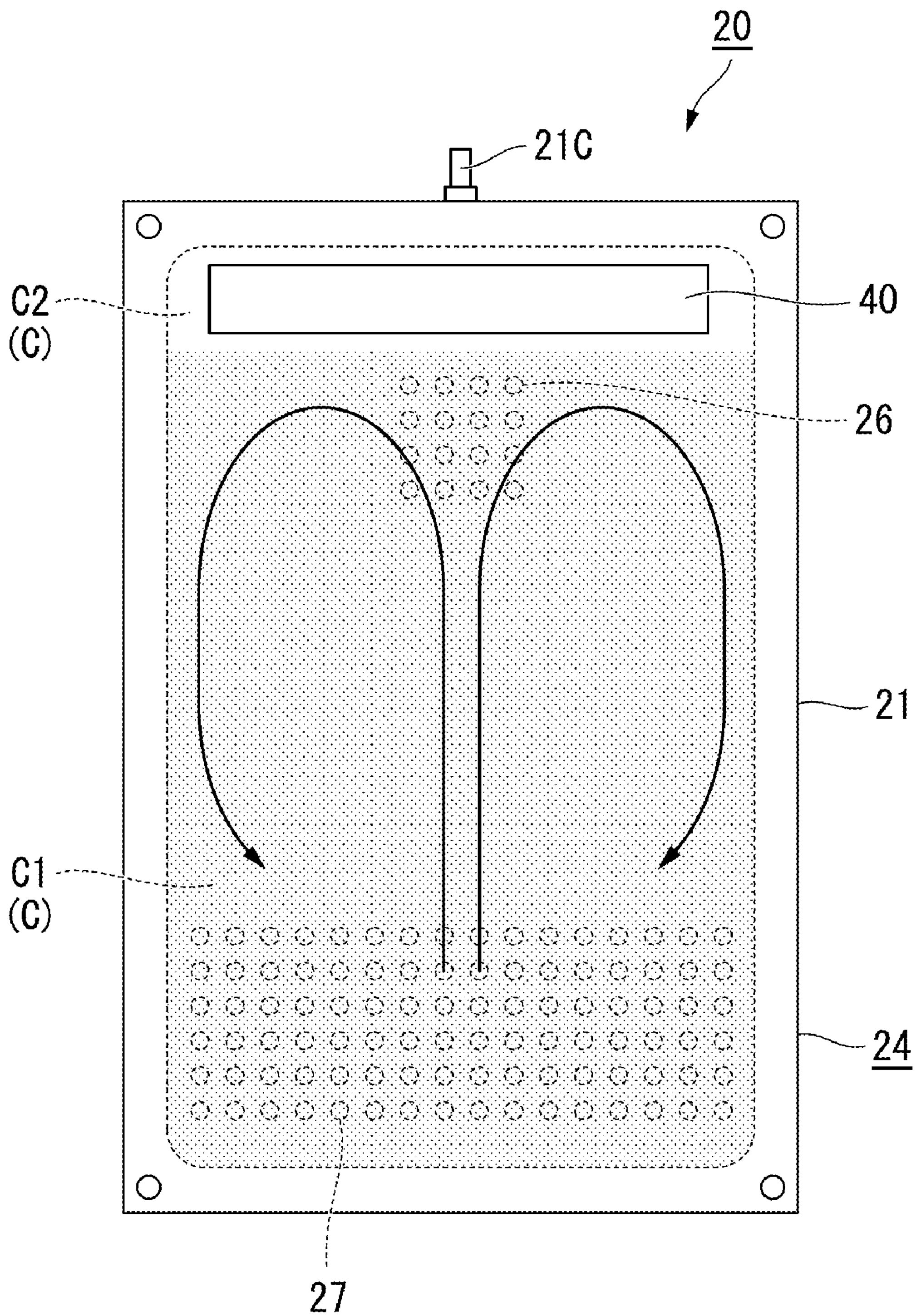


FIG. 11

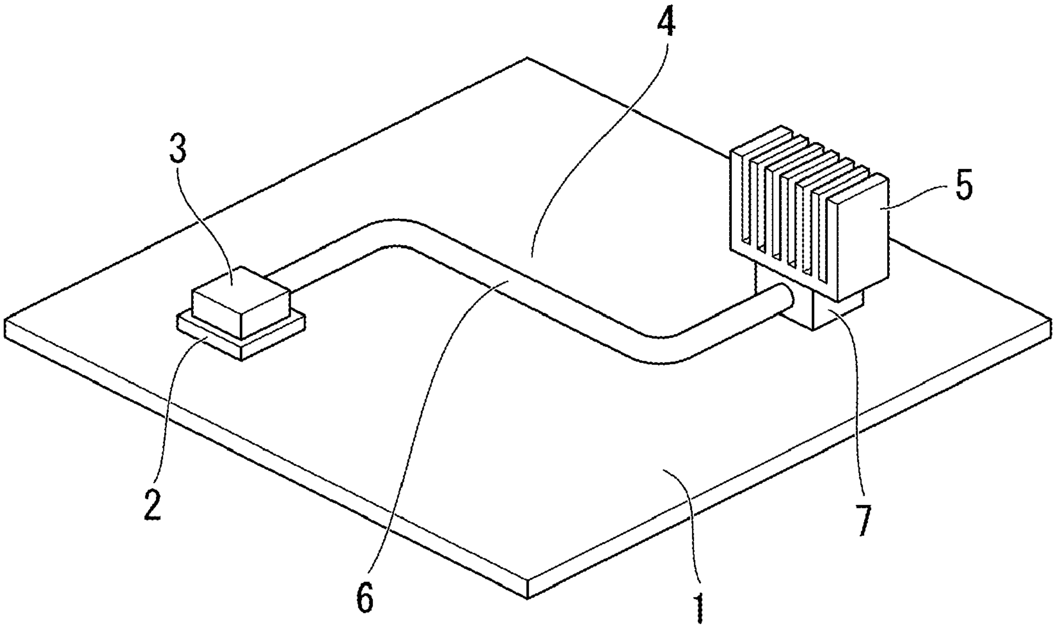
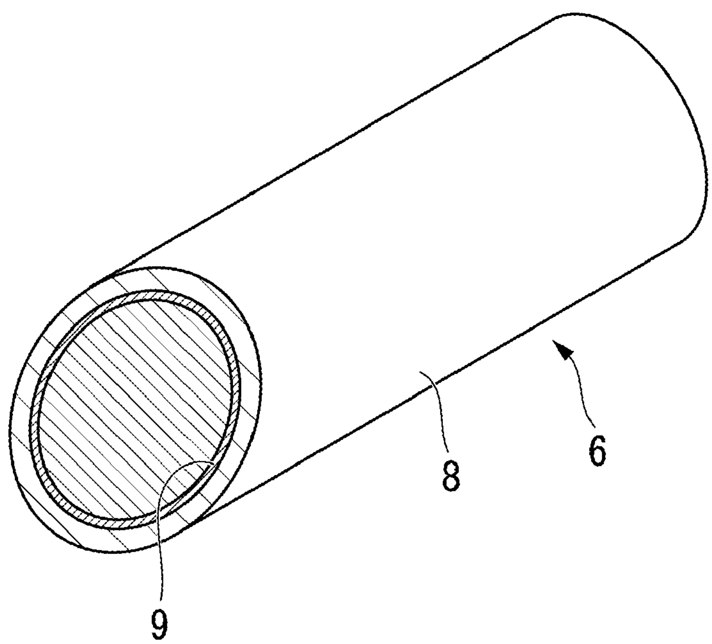


FIG. 12



EBULLIENT COOLING DEVICE

TECHNICAL FIELD

[0001] The present invention relates to an ebullient cooling device that, in an electronic device in which an LSI or IC is mounted, in particular suppresses heat generation of the LSI or IC by utilizing the phase change phenomenon of a coolant that is boiled and liquefied.

BACKGROUND ART

[0002] In an LSI and IC to be used in an electronic device such as a computer or the like, circuit integration is increasing in an accelerated manner in each circuit generation. Moreover, in recent years, demands for a reduction in size and thickness of devices are increasing. For this reason, the heat generation density of LSIs and ICs is on track to keep increasing from now on. In order to operate these LSIs and ICs at a high speed and in a stable manner, it is necessary to control the operating temperature so as to be a given temperature or less. A cooling method compatible with the amount of heat of the LSI or IC is therefore employed. However, when attempting to reduce the size and thickness of a device, for a cooler such as a heat sink that is to be mounted on the LSI or IC, the current situation is that it is not possible to secure a size that is compatible with the amount of heat generated.

[0003] Therefore, an ebullient cooling device has been proposed that includes a heat receiving plate **3**, a heat transfer means **4**, and a heat sink **5**, as shown in FIG. **11**. This small heat receiving plate **3** is arranged on a heat generating body **2** such as an LSI or IC that is installed on a substrate **1**, and absorbs the heat of that heat generating body **2**. The heat that the heat receiving plate **3** has absorbed is transported to the heat sink **5** that is mounted at a location of the substrate **1** wider than the heat generating body **2**, via the heat transfer means **4**.

[0004] As the aforementioned heat transfer means **4**, a metal having high thermal conductivity such as aluminum and copper may be used. However, as the heat transfer means **4**, it is preferable to use a heat pipe **6** that has a more outstanding heat transfer performance. This heat pipe **6** uses the phase change phenomenon in which a coolant gasifies at the heat receiving plate **3** that is in contact with the heat generating body **2**, and this gasified coolant liquefies at a heat dissipating plate **7** that is provided under the heat sink **5**. The heat pipe **6**, utilizing this phase change phenomenon, moves the heat that is generated at the heat generating body **2** such as an LSI or IC to the heat sink **5**.

[0005] The structure of the heat pipe **6** shall be described referring to the cross-sectional pattern diagram of FIG. **12**. This heat pipe **6** is constituted by a hollow tube-shaped container **8** that is comprised by a metal having high heat conductivity such as aluminum or copper, and a coolant that is sealed inside this container **8**. The heat receiving plate **3** that is in contact with the heat generating body **2** such as an LSI or IC is coupled to one end portion of the heat pipe **6**. The heat dissipating plate **7** that is in contact with the heat sink **5** serving as a cooler is coupled to the other end portion of the heat pipe **6**.

[0006] While the coolant undergoes a phase change from a liquid to a gas at the heat receiving plate **3**, the coolant undergoes a phase change from a gas to a liquid at the heat dissipating plate **7**. For this reason, in this kind of heat pipe **6**, the vaporized coolant that is produced at the heat receiving plate **3** moves to the heat dissipating plate **7** side due to the pressure at the heat receiving plate **3** side being high. Also, the liquid coolant that is produced at the heat dissipating plate **7** side circulates to the heat receiving plate **3** by passing through a fine mesh called a wick **9** that is attached to the inner face of the heat pipe **6**. The gaps in the mesh are formed to be extremely narrow. By utilizing the surface tension of the liquid coolant, the coolant passes through the gaps of the mesh and is circulated to the heat receiving plate **3** side. By repeating these phenomena, thermal transport with the heat pipe **6** is enabled. By utilizing the phase change of the coolant in this manner, the heat pipe **6** can achieve a far higher thermal conductivity compared to metal such as aluminum or copper having a high thermal conductivity.

[0007] However, when circulating the liquefied coolant that is produced at the heat dissipating plate **7** to the heat receiving plate **3** by the heat pipe **6**, since it goes through the fine mesh wick **9**, it is not possible to increase the amount of heat transport. Accordingly, it is difficult to cool a heat generating body **2** having a large amount of heat.

[0008] For this reason, in Patent Document 1, an ebullient cooling device is proposed based on a method that boils a coolant with a heat-receiving plate, and circulates the liquid that is produced at a heat-dissipating plate by gravity. In thermal transport that utilizes this boiling, there is a characteristic of the thermal transport capability being larger due to using more of the coolant than a heat pipe and circulating it by gravity. In Patent Document 1, a loop-shaped flow passage is formed in a flat plate. This constitution separates the flow passage through which the gas coolant passes and the flow passage through which the liquid coolant that is produced at the heat dissipating plate circulates, reduces the pressure loss that occurs due to the collision between the two, and increases the equivalent thermal conductivity.

[0009] In Patent Document 2, the surface area of the heat receiving plate that comes into contact with the coolant is increased by placing a boiling promotion structure at the heat receiving plate. By enhancing the thermal transmittance from the heating generating portion to the coolant, boiling is promoted, and the equivalent thermal conductivity is increased.

[0010] Patent Document 3 discloses a structure that provides fins having a partial cutaway in the heat dissipating wall, and so the surface area that performs condensation is increased, and the equivalent thermal conductivity is increased by raising the condensation effect.

[0011] In Patent Document 4, a constitution is shown in which wave-shaped fins having a low height are arranged in two stages (or three or more stages), with the wave-shaped fins being joined by matching the positions of the bent-back parts so as to be able to mutually transmit heat.

[0012] In Patent Document 5, a constitution is shown in which chevron-shaped first fins are respectively arranged to the inner side of a heat receiving plate and a heat dissipating plate, and chevron-shaped second fins are arranged via a wire mesh support member or the like to the inner side of the first fins.

PRIOR ART DOCUMENTS

Patent Documents

[0013] [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2006-344636

[0014] [Patent Document 2] Japanese Unexamined Patent Application, First Publication No. H07-161888

[0015] [Patent Document 3] Japanese Unexamined Patent Application, First Publication No. 2000-74536

[0016] [Patent Document 4] Japanese Unexamined Patent Application, First Publication No. H10-209356

[0017] [Patent Document 5] Japanese Unexamined Patent Application, First Publication No. H11-31768

SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

[0018] However, as shown in Patent Document 1, adopting a structure that separates the flow passages of the gas and liquid coolant for ebullient cooling as a method of increasing the equivalent thermal conductivity of the plate-shaped ebullient cooling device leads to the problem of the design of the flat plate used for ebullient cooling becoming complicated. That is to say, when the flow passages are separated, it is necessary to finely adjust the flow passages of each device, and so general versatility is impaired.

[0019] Also, as shown in Patent Documents 2 to 5, in methods of increasing the surface area that is contact with the coolant via fins at the heat receiving plate and the heat dissipating plate, it is only possible to increase the region where boiling and condensation occurs by the amount of the increased surface area, and so it is not possible to expect a large improvement in the equivalent thermal conductivity.

[0020] Moreover, in the technology that is disclosed in Patent Documents 2 to 5, the fins that are arranged in the heat receiving plate and the heat dissipating plate (heat receiving member, heat dissipating member) interfere with each other. This has led to the problem of a drop in the efficiency of boiling and condensing the coolant.

[0021] The present invention has been achieved in view of the above circumstances. An exemplary object of the present invention is to provide an ebullient cooling device that can efficiently perform heat dissipation with a simple constitution, and be compatible with LSIs and ICs having a large amount of heat generation.

Means for Solving the Problem

[0022] In order to solve the aforementioned issues, an ebullient cooling device of the present invention includes a chamber, a heat sink, a heat receiving member, and a heat dissipating member. The chamber includes a heat conducting plate with a heat generating body provided on an outer side surface thereof, and an airtight space provided on an inner side of the heat conducting plate, the airtight space filled with a coolant that undergoes a phase change between liquid and gas. The heat sink is provided on the outer side surface of the heat conducting plate. The heat receiving member is provided on an inner side surface of the heat conducting plate so as to oppose the heat generating body with the heat conducting plate sandwiched therebetween, and transfers heat generated at the heat generating body to the coolant. The heat dissipating member is provided on the inner side surface of the heat conducting plate, receives the heat transferred by the coolant, and dissipates the heat to the heat sink. The heat receiving member and the heat dissipating member are arranged spaced apart from each other in a surface direction of the heat conducting plate. The heat receiving member is immersed in the coolant in a liquid state.

Effect of the Invention

[0023] According to the present invention, the coolant that is sealed in the airtight space of the chamber undergoes a phase change between liquid and gas between the heat receiving member and the heat dissipating member, whereby it is possible to transport the heat that is generated at the heat generating body to the heat sink. Also, the heat receiving member and the heat dissipating member are arranged spaced apart from each other in the surface direction of the heat conducting plate. That is to say, the heat receiving member and the heat dissipating member are arranged in a positional relation of not facing each other. For that reason, it is possible to maintain the heat conduction efficiency at a high level without the movement of the coolant that becomes a gas at the heat receiving member being impeded. Accordingly, it is possible to efficiently dissipate heat with a simple structure, and it is possible to make it compatible with LSIs and ICs having a large amount of heat generation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] FIG. **1** is an exploded perspective view of an ebullient cooling device according to a first exemplary embodiment of the present invention.

[0025] FIG. **2** is an exploded perspective view of the ebullient cooling device shown in FIG. **1** seen from the reverse side.

[0026] FIG. **3** is a longitudinal cross-sectional view of the ebullient cooling device according to the first exemplary embodiment of the present invention.

[0027] FIG. **4** is an exploded perspective view of an ebullient cooling device according to a second exemplary embodiment of the present invention.

[0028] FIG. **5** is an exploded perspective view of an ebullient cooling device according to a third exemplary embodiment of the present invention.

[0029] FIG. **6** is a longitudinal cross-sectional view of an ebullient cooling device according to a fourth exemplary embodiment of the present invention.

[0030] FIG. **7** is a longitudinal cross-sectional view of an ebullient cooling device according to a fifth exemplary embodiment of the present invention.

[0031] FIG. **8** is a perspective view of an ebullient cooling device according to a sixth exemplary embodiment of the present invention.

[0032] FIG. **9** is a longitudinal cross-sectional view of the ebullient cooling device according to the sixth exemplary embodiment of the present invention.

[0033] FIG. **10** is a transparent elevational view for describing the flow of a coolant in the ebullient cooling device according to the sixth exemplary embodiment of the present invention.

[0034] FIG. **11** is a perspective view of a conventional ebullient cooling device.

[0035] FIG. **12** is a cutaway view that shows the internal structure of a heat pipe.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

First Exemplary Embodiment

[0036] A first exemplary embodiment of the present invention shall be described with reference to FIG. **1** to FIG. **3**.

[0037] FIG. **1** to FIG. **3** show an ebullient cooling device **20** according to the first exemplary embodiment of the present invention. A heat generating body **10** which is an LSI or IC, for example is joined to the ebullient cooling device **20**. More specifically, the heat generating body **10** is joined to a heat receiving plate **22** of the ebullient cooling device **20** by a thermally conductive grease or a thermally conductive sheet. At this time, the heat generating body **10** may be bonded with solder.

[0038] The ebullient cooling device **20** has a plate-shaped hollow chamber **24**. This chamber **24** has a side wall portion **21** that is formed in the shape of a quadrilateral frame, a heat receiving plate (heat conducting plate) **22** that covers an upper opening **21**A of the side wall portion **21**, and a heat dissipating plate (heat conducting plate) **23** that covers a lower opening **21**B of the side wall portion **21**.

[0039] The heat receiving plate **22** and the heat dissipating plate **23** are formed with a metal such as copper or aluminum having high thermal conductivity. The heat receiving plate **22** and the heat dissipating plate **23** are arranged to face each other in the thickness direction of the chamber **24**. Due to the upper opening **21**A and the lower opening **21**B of the side wall portion **21** being blocked by the heat receiving plate **22** and the heat dissipating plate **23**, an airtight space is formed within the side wall portion **21**. A coolant C is filled in this airtight space. As this coolant C, a liquid coolant C**1** and a gas coolant C**2** coexist in the airtight space. The coolant C can undergo a phase change between liquid and gas.

[0040] A coolant injection port **21**C for injecting the coolant C into the airtight space is provided in the side wall portion **21** of the chamber **24**.

[0041] After separately manufacturing the side wall portion **21**, the heat receiving plate **22**, and the heat dissipating plate **23**, the chamber **24** may be formed by joining them by brazing or the like. Alternatively, the chamber **24** may be formed by integrally forming either one of the heat receiving plate **22** and the heat dissipating plate **23** with the side wall portion **21**. An O-ring **25** may be arranged at the periphery of the upper opening **21**A and the periphery of the lower opening **21**B of the side wall portion **21**. The upper opening **21**A and the lower opening **21**B may be blocked by the heat dissipating plate **23** and the heat receiving plate **22** via this O-ring **25**, and moreover, the heat dissipating plate **23** and the heat receiving plate **22** may be attached to the side wall portion **21** by screws or the like. In this way, in the case of using the O-ring **25**, removal of the heat receiving plate **22** and the heat dissipating plate **23** is easy. As a result, it is possible to improve the workability when mounting the heat generating body **22** and a heat sink **28** described later.

[0042] The heat generating body **10** such as an LSI or IC that serves as a heat source is arranged on the outer surface of the airtight space at the heat receiving plate **22**. A heat receiving member **26** is fixed on the inside surface of the location on the heat receiving plate **22** where the heat generating body **10** is arranged. The heat receiving member **26** transmits heat that is produced by the heat generating body **10** to the coolant C.

[0043] The heat receiving member **26** is constituted by a plurality of fins that are arranged and fixed at a specified interval on the inside surface of the heat receiving plate **22**. The plurality of fins (pin fins in the present exemplary embodiment) are comprised by cuboid rectangular fins or pin fins with their surfaces roughened in order to promote boiling.

[0044] In the case of installing a plurality of heat generating bodies **10** on the outer surface of the heat receiving plate **22**, heat receiving members **26** are arranged at locations corresponding to the heat generating bodies **10** or in the vicinity thereof. It is preferable for the heat receiving member **26** to be integrally molded with the heat receiving plate **22** by machining or forging in order to reduce thermal resistance. On the other hand, from the viewpoint of productivity, it is preferable to separately manufacture the plurality of fins that constitute the heat receiving member **26**, and braze them to the heat dissipating plate **23**.

[0045] In the heat receiving member **26** that is composed of pin fins, the plurality of pin fins are arranged in a matrix pattern in order to as much as possible not impede the flow of the gasified coolant C**1** and the coolant C**2** that is liquefied and flowed back. In order for the separation of air bubbles that are generated during boiling at the heat receiving member **26** to be undisturbed, it is preferable to ensure the interval between the pin fins is from 1 mm to several millimeters. In the case of using rectangular fins that are composed of cuboid members, from the viewpoint of increasing surface area, it is conceivable to install more fins by reducing the thickness. On the other hand, in the case of the fins being thinner, due to the thermal capacity of the fins being less, it is not preferable from the viewpoint of cooling efficiency. Moreover, in the case of the fins being thin, fabrication is difficult. Therefore, it is desirable for the fins to at least have a thickness of 1 mm to several millimeters.

[0046] The height of the fins, that is to say, the height from the inside surface of the heat receiving plate **22** at the heat receiving member **26** is preferably set to the dimension of approximately one-half of the thickness of the chamber **24**, that is to say, the facing distance between the heat receiving plate **22** and the heat dissipating plate **23** (the distance between the heat receiving plate **22** and the heat dissipating plate **23**). This is in order to immerse the entirety of the heat receiving member **26** in the liquid coolant C**1** to make use of the entire surface area of the fins for boiling.

[0047] It is preferable that a roughening process be performed on each fin of the heat receiving member **26**, with the surface roughening being in the roughness range of 1 μm to 100 μm. Thereby, it is possible to form on the surface of the heat receiving member **26** a plurality of sharp angled-shapes that serve as nuclei when bubbles are produced by the heat reception of the coolant C**1**. As a result, it is possible to promote boiling of the liquid coolant C at the surface of the heat receiving member **26**.

[0048] A heat dissipating member **27** for snatching heat from the gasified coolant C**2** is provided on the inner side of the heat dissipating plate **23**. This heat dissipating member **27** is installed spaced apart from the heat receiving member **26** in the surface direction of the heat receiving plate **22** and the heat dissipating plate **23** (that is to say, in the direction perpendicular to the thickness direction of the heat receiving plate **22** and the heat dissipating plate **23**). That is to say, the heat dissipating member **27** is arranged so as not to be mutually opposed to the heat receiving member **26**. The heat sink **28** is provided as a cooling device at the outside surface of the location on the heat dissipating plate **23** where the heat dissipating member **27** is arranged.

[0049] This heat sink **28** may be integrally molded with the heat dissipating plate **23** by machining or forging. Alternatively, after separately manufacturing the heat sink **28** from the heat radiating plate **23**, both may be connected with a thermally conductive grease or a thermally conductive sheet and the like.

[0050] The heat dissipating member **27** is constituted by a plurality of fins that are arranged at a fixed interval. The plurality of pins are composed of a plurality of cuboid members or pin fins (pin fins in the present exemplary embodiment) that have been subjected to surface roughening in order to promote condensation of the coolant C2 that has become a gas. At the heat receiving member **26** that are composed of the pin fins, a plurality of the pin fins are preferably arranged in a matrix pattern in order to increase the flowability of the coolant C.

[0051] The coolant C to be filled in the chamber **24** may be water, which is easy to obtain. In the case of being used in an electronic device, it is preferable to use an organic coolant that has insulation properties. This is so that, in the event of the coolant C coming into contact with electronic components or the substrate in the case of a leakage of the coolant C, it has no effect on those electronic components or the substrate, and they can be reused. Moreover, many organic coolants have a lower surface tension than water, and so their boiling point is lower than water. For this reason, it is possible to keep the temperature of the heat generating body **10** lower than the boiling point of water.

[0052] After pouring the coolant C in the chamber **24**, by creating a vacuum in the interior of the chamber **24**, it is possible to make the boiling point lower. As a result, it is possible to maintain the temperature of the heat generating body at an even lower temperature. After creating a vacuum in the interior of the chamber **24**, the coolant injection port **21**C is caulked and hermetically sealed. Alternatively, the interior may be hermetically sealed by plugging the coolant injection port **21**C with an attachment stopper.

[0053] Regarding the positional relation of the heat receiving member **26** and the heat dissipating member **27**, as stated above, the heat receiving member **26** and the heat dissipating member **27** are installed spaced apart in the surface direction of the heat receiving plate **22** and the heat dissipating plate **23**. That is to say, the heat dissipating member **27** is not provided directly above the heat receiving member **26**. The reason for this is that when the heat receiving member **26** and the heat dissipating member **27** are in close proximity, the gas produced by the heat receiving member **26** immediately has its heat snatched away by the heat dissipating plate, causing droplets being produced, and this becomes a loss of pressure and impedes the movement of the gas that is produced by the heat receiving member **26**. The separation distance of the heat receiving member **26** and the heat dissipating member **27** is preferably at least equal to or more than the width dimension of the heat generating body **10**.

[0054] The height of the heat receiving member **26** is preferably set so as to be spaced 1 mm or more away from the facing surface of the heat dissipating plate **23** that is oppositely positioned, in consideration of the heat conduction efficiency to the coolant C. In the same way, the height of the heat dissipating member **27** is preferably set so as to be spaced 1 mm or more away from the facing surface of the heat receiving plate **22** that is oppositely positioned, in consideration of the heat conduction efficiency to the coolant C.

[0055] Next, action of the ebullient cooling device **20** of the present exemplary embodiment shall be described in detail.

[0056] The coolant C that is sealed in the chamber **24** becomes a saturated vapor pressure due to the creation of the vacuum, and so its reaches boiling point at room temperature. The saturated vapor pressure is the maximum pressure that occurs in a space at a certain temperature, in a sealed space in which only a substance such as water exists. Thereby, in the airtight space within the chamber **24**, the liquid coolant C**1** and the gas coolant C**2** coexist. The liquid coolant C**1** exists at the lower portion of the airtight space, while the gas coolant C**2** exists in the upper portion of the airtight space.

[0057] When the heat generating body **10** such as an LSI or IC generates heat, the heat passes through the heat receiving plate **22** and reaches the heat receiving member **26** in the chamber **24**, and imparts the heat to the liquid coolant C**1** surrounding the heat receiving member **26**. When the coolant C**1** that has been heated reaches boiling point, air bubbles are formed, with the sharp-angled shapes serving as nuclei.

[0058] When the heat is additionally imparted from the heat receiving member **26** to the liquid coolant C**1**, the bubbles develop. When the bubbles become a certain size, the buoyant force of the bubbles becomes greater than the absorbing power of the surface of the heat receiving member **26** due to the surface tension. As a result, the bubbles separate. At this time, since the space of the region where the bubbles had existed is released, the surrounding liquid coolant C**1** flows in, and new boiling starts to occur.

[0059] As described above, due to the surface roughing process that is performed on the surface of the heat receiving member **26**, numerous sharp-angled shapes exist, and so boiling occurs over the entire fin surface in the heat receiving member **26**. By this boiling, the liquid coolant C**1** undergoes a phase change to the gas coolant C**2**. At this time, the volume of the coolant C increases several hundred times, and so the pressure of the airtight space in the chamber **24** rises. Thereby, the gas coolant C**2** moves to the upper heat dissipating member **27** side. In this way, the gas coolant C**2** that has moved to the heat dissipating member **27** has its heat snatched by contact with the fins of the heat dissipating member **27** and condenses. Thereby, drops are generated centered on nuclei at the sharp-angled shapes that are formed on the surface of the fins.

[0060] When the drops grow and the gravity of those drops become greater than the absorbing power due to the surface tension of the heat dissipating member **27**, the drops head downward from the heat dissipating member **27** and separate. Due to this separation, since the region where the drops had been adhering is made available, the gas coolant C makes contact with the fin surface of the heat dissipating member **27**, and new condensation occurs. Since the surface roughening treatment has been performed on the fin surfaces that constitute the heat dissipating member **27**, numerous sharp-angled shapes exist, and so condensation occurs over all the fins of the heat dissipating member **27**.

[0061] The drops that are produced by condensation at the heat dissipating member **27** are returned to the liquid coolant C**1** that exists below the heat dissipating member **27**, and furthermore by being transported to the heat receiving member **26**, the liquid coolant C**1** again undergoes a phase change to the gas coolant C**2**. On the other hand, the heat that was snatched away from the gas coolant C**1** at the heat dissipating member **27** is released into the air via the heat sink **28** that is attached to the outer surface of the chamber **24**.

[0062] In this manner, by utilizing the phase change and volumetric change of the coolant C, the coolant C is made to move while producing a pressure differential between the heat receiving member **26** and the heat dissipating member **27**, whereby it is possible to obtain a thermal transport capability ranging from several times to several hundred times compared to copper, which is a metal with good heat conduction efficiency.

[0063] Also, the heat receiving member **26** and the heat dissipating member **27** are arranged spaced mutually apart in the surface direction of the heat receiving plate **22** and the heat dissipating plate **23**, that is, in a positional relation of not facing each other. For this reason, the heat receiving member **26** and the heat dissipating member **27** are not affected by each other, and optimal and unrestricted setting of the contact position with the coolant and the contact surface area becomes possible.

[0064] In the case of the heat receiving member **26** and the heat dissipating member **27** being in close proximity, the gas that is produced by the heat receiving member **26** has its heat snatched away by the heat dissipating member **27** that is located nearby, and so drops may be produced.

[0065] In contrast, in the ebullient cooling device **20** of the present exemplary embodiment, the heat receiving member **26** and the heat dissipating member **27** are arranged in a positional relation of not facing each other. For this reason, it is possible to prevent a reduction in the heat conduction efficiency as a result, without impeding the flow of the gas that is produced by the heat receiving member **26**.

[0066] In the ebullient cooling device **20** that is shown in the present exemplary embodiment as described in detail hereinabove, the coolant C that is sealed in the airtight space of the chamber **24** is made to change phase to liquid/gas between the heat receiving member **26** and the heat dissipating member **27**. Thereby, it is possible to efficiently convey the heat that is produced at the heat generating body **10** to the heat sink **28**. Also, the heat receiving member **26** and the heat dissipating member **27** are arranged spaced apart in the surface direction of the heat receiving plate **22** and the heat dissipating plate **23**. That is to say, the heat receiving member **26** and the heat dissipating member **27** are arranged in a positional relation of not facing each other. With this constitution, it is possible to maintain the heat conduction efficiency at a high level without the movement of the coolant C**1** that becomes a gas being impeded at the heat receiving member **26**. Accordingly, it is possible to efficiently dissipate heat with a simple constitution, and compatibility with a heat generating body **10** having a large amount of heat generation becomes possible.

[0067] Also, along with the heat receiving plate **22** and the heat dissipating plate **23** being arranged facing each other, the heat generating body **10** and the heat receiving member **26** are provided on the heat receiving plate **22**, and the heat dissipating member **27** and the heat sink **28** are provided on the heat dissipating plate **23**. With this constitution, it is possible to reliably cause the coolant C to change phase to a liquid/gas between the heat receiving member **22** and the heat dissipating member **23**.

[0068] If the heat that is produced by the heat generating body **10** such as an LSI or IC that is mounted at a high heat generation density is not immediately transported away, its temperature rises and a malfunction occurs, and according to the circumstances, will be a factor leading to loss of operation. With regard to this point, in the present exemplary embodiment, by raising the equivalent thermal conductivity, it is possible to rapidly transport the heat that is produced at the heat generating body **10**. Thereby, even if the heat generating body **10** is mounted at a high heat generation density, that heat efficiently diffuses without remaining at a particular location, and so it is possible to lower the temperature of the heat generating body **10**.

[0069] Also, there is no need to separate the flow passage of the coolant C**1** in which a phase change is performed between the heat receiving plate **22** and the heat dissipating plate **23**. That is to say, there is no need to consider a coolant transfer path from the heat receiving plate **22** to the heat dissipating plate **23**, and a coolant transfer path from the heat dissipating plate **23** to the heat receiving plate **22**. When considering such coolant transfer paths, fine adjustment is required each time the design is modified. However, in the present exemplary embodiment, consideration need only be given to the placement of the heat receiving plate **22** and the heat dissipating plate **23**. Accordingly, no design difficulties arise, and it is possible to simplify the overall configuration.

[0070] In addition, in the aforementioned ebullient cooling device **20**, by using a heat transport device having a flat plate shape, heat transport simultaneously from a plurality of heat generating bodies becomes possible. For this reason, a plurality of components for transporting heat becomes unnecessary. Moreover, it becomes possible to consolidate a plurality of cooling devices such as heat sinks that had been needed into one, and so it is possible to eliminate heat sinks and fans. Thereby, a reduction in size and thickness of an entire device becomes possible.

Second Exemplary Embodiment

[0071] Next, a second exemplary embodiment of the present invention shall be described with reference to FIG. **4**.

[0072] In the ebullient cooling device **20** of the first exemplary embodiment described above, the heat receiving member **26** is constituted by a plurality of columnar pin fins with their surfaces roughened being provided on the heat receiving plate **22** on which the heat generating body **10** is arranged. The heat receiving member **26** may also be constituted with rectangular fins **30** in which a plurality of cuboid members are arranged at a fixed interval as shown in FIG. **4**.

[0073] In the heat receiving member **26** that is constituted with this rectangular fin, it is constituted with cuboid members that have their surfaces roughened, and overall is formed in a comb-like shape.

[0074] Although the greater the surface area of the heat receiving member **26** that is in contact with the coolant C, the better, the surface area in contact with the liquid coolant C and the boiling performance are not proportional. When the pin fin of the first exemplary embodiment is replaced with the rectangular fin **30**, it has been confirmed that the surface area in contact with the coolant C decreases, but the boiling performance does not significantly decrease. Also, in terms of productivity, the rectangular fin **30** is more advantageous than the pin fin. The rectangular fin **30** may be manufactured by machining or forging. Alternatively, after separately manufacturing the cuboid members of the rectangular fins **30**, they may be welded by brazing or the like to the heat receiving plate **22**, and then a process of roughening the surface to a roughness of 1 μm to 100 μm may be performed. This kind of rectangular fin **30** may also be applied to the heat dissipating member **27** that is connected to the heat sink **28**.

Third Exemplary Embodiment

[0075] Next, a third exemplary embodiment of the present invention shall be described with reference to FIG. **5**.

[0076] In the ebullient cooling device **20** of the first exemplary embodiment, a plurality of columnar pin fins with their surfaces roughed are made to serve as heat receiving member **26** on the heat receiving plate **22** on which the heat generating body **10** is arranged. The heat receiving member **26** may also be constituted with a cuboid-shaped heat dissipating block **31** that has its surfaces roughened as shown in FIG. **5**.

[0077] Even if this heat receiving member **26** is formed in a block shape, there is no significant drop in the boiling performance.

[0078] When considering the productivity, a block shape is easier to manufacture than a pin fin or rectangular fin, and so is advantageous in terms of manufacturing. This heat receiving member **26** may be manufactured integrally with the heat receiving plate **22** by machining or forging. Alternatively, a block that is separately fabricated may be welded to the heat receiving plate **22** by brazing or the like, and then subjected to a process of roughening its surfaces to a roughness of 1 μm to 100 μm.

[0079] This kind of heat radiating block **31** may also be applied to the heat dissipating member **27** that is connected to the heat sink **28**.

Fourth Exemplary Embodiment

[0080] Next, a fourth exemplary embodiment of the present invention shall be described with reference to FIG. **6**.

[0081] In the ebullient cooling device **20** of the first exemplary embodiment, the chamber **24** is arranged so as to be horizontal, but it is not limited thereto. The ebullient cooling device **20** may also be arranged in a vertical manner as shown in FIG. **6**. That is to say, the heat receiving member **26** and the heat dissipating member **27** may be positioned so as to be in a positional relation in which the normal of the heat receiving member **26** and the heat dissipating member **27** is perpendicular to the heat receiving plate **22** and the heat dissipating plate **23** in the vertical direction. In this case, among the heat receiving member **26** and the heat dissipating member **27**, at least the heat receiving member **26** is immersed in the liquid coolant C**1**. With such a constitution, it is possible to increase the degree of freedom of the design.

[0082] In the example of the ebullient cooling device **20** shown in FIG. **6**, the heat receiving member **26** that is connected to the heat generating body **10** is, in the vertical direction, provided lower than the heat dissipating member **27** that is connected to the heat sink **28**. With such a constitution, the heat receiving member **26** that receives the heat of the heat generating body **10** generates bubbles by causing the coolant C**1** to undergo a phase change by transmitting heat to the liquid state coolant C**1**. Here, the bubbles that are generated move upward in the vertical direction by the buoyant force, and by making contact with the heat dissipating member **27** that is connected to the heat sink **28**, the heat is snatched away. Thereby, the gas coolant C**2** condenses and becomes drops.

[0083] Regarding the positional relation of the heat receiving member **26** and the heat dissipating member **27**, the heat dissipating member **27** may be below with respect to the heat receiving member **26**, or the heat dissipating member **27** may be above with respect to the heat receiving member **26**.

[0084] However, at the least, it is necessary to pour in the coolant C to the height of the heat receiving member **26**, so as to immerse the heat receiving member **26** in the liquid coolant C**1**. Thereby, regardless of the positional relationship, the heat receiving member **26** on which the heat generating body **10** is mounted is immersed in the liquid coolant C. Boiling occurs due to the heat receiving member **26**, circulation occurs utilizing the phase change, and the heat is transmitted through the entire chamber **24**, and dissipated via the heat sink **28**.

Fifth Exemplary Embodiment

[0085] Next, a fifth exemplary embodiment of the present invention shall be described with reference to FIG. **7**.

[0086] In the ebullient cooling device **20** of the aforementioned first exemplary embodiment, the heat receiving member **26** is arranged on the heat receiving plate **22** that constitutes the chamber **24**, and the heat dissipating member **27** is arranged on the heat dissipating plate **23** that faces the heat receiving plate **22**. In this fifth exemplary embodiment, as shown in FIG. **7**, the heat receiving member **26** and the heat dissipating member **27** may be arranged on one heat conducting plate **32**.

[0087] By adopting this heat conducting plate **32**, it is possible to improve productivity by reducing the overall number of components due to member sharing. This heat conducting plate **32** is constituted with for example metal. The heat of the heat generating body **10**, by being transferred through that metal, migrates from the heat receiving member **26** to the heat dissipating member **27**, and it is possible to exhibit a synergistic effect combined with the heat transport via the coolant C.

[0088] This heat-receiving heat-dissipating member **32** may be fabricated by machining or forging. Alternatively, fins of the heat receiving member **26** and the heat dissipating member **27** that are separately manufactured may be attached by brazing. A sealing plate **33** that is arranged so as to face the heat conducting plate **32** may be made with aluminum or cooper with good thermal conductivity, and in consideration of productivity, may be made from a resin such as acrylic.

Sixth Exemplary Embodiment

[0089] Next, a sixth exemplary embodiment of the present invention shall be described with reference to FIG. **8** to FIG. **10**.

[0090] In the ebullient cooling device **20** of the aforementioned first exemplary embodiment, the chamber **24** is arranged to be horizontal, but it is not limited thereto. As shown in FIG. **8** to FIG. **10**, in the sixth exemplary embodiment, the ebullient cooling device **10** may be arranged in a vertical manner as shown in FIG. **9** and FIG. **10**, and a buffer tank **40** may be arranged at the upper position thereof.

[0091] That is to say, in the case of the heat generating body **10** being arranged in the vicinity of the upper end of the heat sink **28** in the vertical direction, it is necessary to immerse the heat receiving member **26** that is connected to the heat generating body **10** in the liquid coolant C**1**. Thereby, the liquid coolant C**1** comes to occupy the greater part of the interior of the chamber **24**. However, when the liquid coolant C**1** occupies the greater part of the interior space of the chamber **24**, due to the phase transition at the heat receiving member **26**, the liquid coolant C**1** is converted to the gas coolant C**2**, whereby its volume increases. Thereby, the space that can accommodate the coolant C disappears, and the pressure within the chamber **24** rises more than necessary. In this case, since the boiling point of the coolant C rises, there is the risk of no longer being able to cool the heat generating body **10** to a predetermined temperature.

[0092] In order to suppress this kind of increase in the internal pressure, that which becomes an evacuation space of the gas coolant C**2** is the buffer tank **40** that is shown in FIG. **8** to FIG. **10**. This buffer tank **40** is arranged at the upper portion of the heat dissipating plate **23** so as to project out. A buffer space for accommodating the gas coolant C**2** is formed within the buffer tank **40**. This buffer tank **40** is arranged at the upper portion of the heat dissipating plate **23** in the vertical direction, and above the heat sink **28**. On the other hand, the heat receiving member **26** that is connected to the heat generating body **10** is arranged at the opposing position of the buffer tank **40**.

[0093] FIG. **10** shows the sequence diagram of the coolant C at this time. At the heat receiving member **26** that is connected to the heat generating body **10**, the liquid coolant C**1** boils and gas bubbles are produced. When those gas bubbles separate from the heat receiving member **26**, the space that the gas bubbles (the gas coolant C**1**) occupies is released, and the liquid coolant C**2** flows into that space, whereby circulation occurs. Thereby, the heat of the heat generating body **10** is dispersed throughout the chamber **24**, and dissipated into the air by the heat sink **28** that is mounted on the heat dissipating member **27** at the lower portion in the vertical direction.

[0094] At this time, gas that is produced by the heat receiving member **26** is accommodated in the internal space of the buffer tank **40** that is installed at the upper portion of the heat dissipating plate **23**. As a result, it is possible to inhibit a rise in the internal pressure of the chamber **24**, and derive a cooling effect for the heat generating body **10** that is installed on the upper portion of the chamber **24**. Also, in the case of the amount of heat of the heat generating body **10** being large, since more of the liquid coolant C**2** boils more liquid coolant C**2** needs to be present in the vicinity of the heat receiving member **26**. In that case, by compensating for the coolant C that is lacking by storing coolant C in a portion of the buffer tank **40**, it can be compatible also with the heat generating body **10** having a large amount of heat generation.

[0095] The exemplary embodiments of the present invention have been described in detail hereinabove with reference to the drawings, but specific constitutions are not limited to these exemplary embodiments, and design modifications and the like that does not depart from the scope of the present invention are also included.

[0096] This application is based upon and claims the benefit of priority from Japanese patent application No. 2010-115539, filed May 19, 2010, the disclosure of which is incorporated herein in its entirety by reference.

INDUSTRIAL APPLICABILITY

[0097] The present invention can be applied to an ebullient cooling device. With this ebullient cooling device, it is possible to suppress the heat generation of LSIs and ICs by utilizing the phase change phenomenon of a coolant that boils and liquefies.

DESCRIPTION OF REFERENCE SYMBOLS

[0098] **10** Heat generating body
[0099] **20** Ebullient cooling device
[0100] **21** Side plate portion
[0101] **22** Heat receiving plate
[0102] **23** Heat dissipating plate
[0103] **24** Chamber
[0104] **26** Heat receiving member
[0105] **27** Heat dissipating member
[0106] **28** Heat sink
[0107] **32** Heat conducting plate
[0108] C**1** (C) Liquid coolant
[0109] C**2** (C) Gas coolant

1. An ebullient cooling device comprising:
a chamber that includes a heat conducting plate with a heat generating body provided on an outer side surface thereof, and an airtight space provided on an inner side of the heat conducting plate, the airtight space filled with a coolant that undergoes a phase change between liquid and gas;
a heat sink that is provided on the outer side surface of the heat conducting plate;
a heat receiving member that is provided on an inner side surface of the heat conducting plate so as to oppose the heat generating body with the heat conducting plate sandwiched therebetween, the heat receiving member transferring heat generated at the heat generating body to the coolant; and
a heat dissipating member that is provided on the inner side surface of the heat conducting plate, the heat dissipating member receiving the heat transferred by the coolant, and dissipating the heat to the heat sink,
the heat receiving member and the heat dissipating member arranged spaced apart from each other in a surface direction of the heat conducting plate, and
the heat receiving member immersed in the coolant in a liquid state.

2. The ebullient cooling device according to claim **1**, wherein:
the heat conducting plate is a heat receiving plate and a heat dissipating plate that are arranged facing each other with the airtight space sandwiched therebetween;
the heat generating body and the heat receiving member are provided on the heat receiving plate; and
the heat sink and the heat dissipating member are provided on the heat dissipating plate.

3. The ebullient cooling device according to claim **2**, wherein a height of the heat receiving member from the heat receiving plate and a height of the heat dissipating member from the heat dissipating plate are respectively set to a dimension of approximately one-half a distance between the heat receiving plate and the heat dissipating plate.

4. The ebullient cooling device according to claim **2**, wherein:
the heat receiving member is spaced at least 1 mm or more from an inner side surface of the heat dissipating plate; and
the heat dissipating member is spaced at least 1 mm or more from an inner side surface of the heat receiving plate.

5. The ebullient cooling device according to claim **1**, wherein the heat receiving member and the heat dissipating member include a plurality of fins that are installed in a standing manner on the inner side surface of the heat conducting plate.

6. The ebullient cooling device according to claim **1**, wherein the heat receiving member and the heat dissipating member are cuboid blocks fixed to the inner side surface of the heat conducting plate.

7. The ebullient cooling device according to claim **1**, wherein surface roughening of a surface roughness range of 1 μm to 100 μm is carried out on a surface of the heat receiving member and the heat dissipating member.

8. The ebullient cooling device according to claim **1**, wherein the chamber includes a buffer tank in which the coolant in a gas state flows in.

9. The ebullient cooling device according to claim **1** wherein the heat receiving member and the heat dissipating member are immersed in the coolant of the liquid state.

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