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(54) HEAT PIPE AND METHOD OF MANUFACTURING IT

(57) It is an object of the invention to provide a heat pipe which can ensure the sealing effect under a high temperature condition, and has a further long life in comparison with the conventional ones, and a method for manufacturing the same. Another object of the invention is to provide a heat pipe which has an improved productivity and reduces the cost, and, has a further long life in comparison with the conventional ones.

According to a heat pipe 1 of the invention, an upper plate reinforcement member 50, an intermediate plate reinforcement member 52, a slit-provided reinforcement member 55 and a lower plate reinforcement member 60 adhere tightly to one another to form a support structure in vapor diffusion flow paths 44 facing the peripheral regions of a refrigerant charging hole 4 and an air outlet port 5. Therefore, the heat pipe 1 can receive external force from a press 75 by the support structure constituted by the upper plate reinforcement member 50, the intermediate reinforcement member 52, the slit-provided reinforcement member 55, and the lower plate reinforcement member 60, thus preventing an upper plate 2 or a lower plate 3 from being damaged by that external force and an interior space 10a from being crushed.

FIG.2A

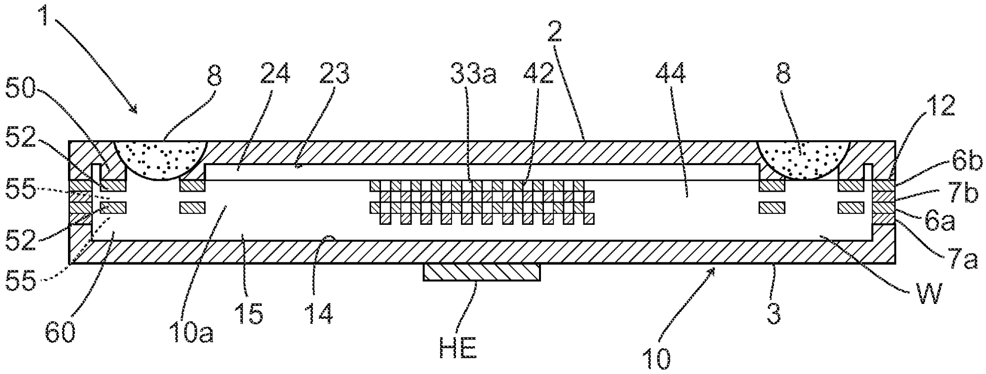

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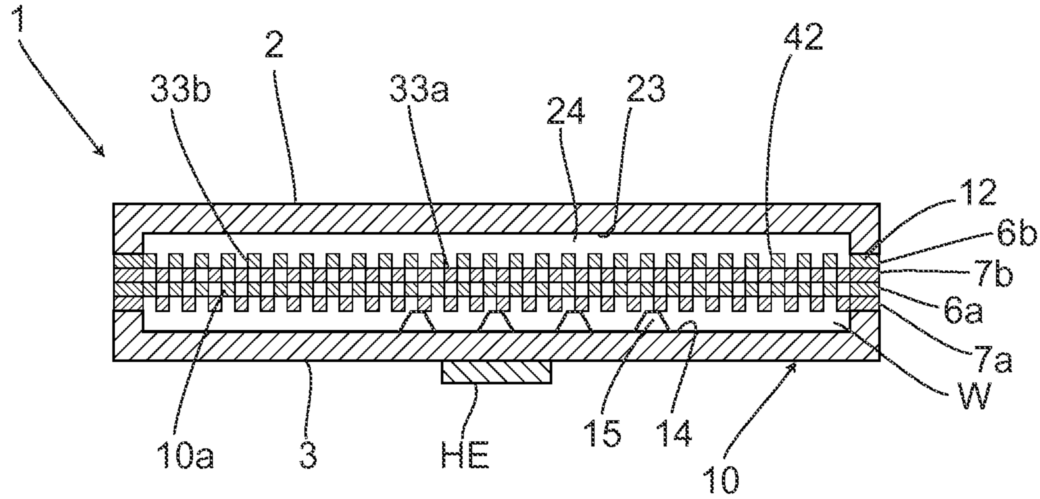
FIG.2B



Description

TECHNICAL FIELD

[0001] The present invention relates to a heat pipe and a method for manufacturing the same, and more particularly, a thin and tabular heat pipe.

BACKGROUND ART

[0002] Japanese Unexamined Patent Publications No. 2002-039693 and No. 2004-077120 disclose conventional heat pipes. Such heat pipes have a cooling unit main body that comprises a plurality of superimposed partition plates like thin plates with holes for circulating a refrigerant and outer wall members superimposed on the top and bottom of the superimposed partition plates, and has an interior space for circulating the refrigerant. The refrigerant like water is sealed in the refrigerant circulation space of the cooling unit main body.

[0003] Sealing of the refrigerant in the cooling unit main body is performed by a scheme of, for example, providing a hole in the side face, the top face, or the bottom face of a heat pipe, charging the refrigerant therein through that hole, and then plugging the hole by caulking or the like.

[0004] Because the heat pipes comprise thin tabular members, there is an advantage such that a thin and flat heat pipe can be provided, and further, there are some advantages such that portions of the refrigerant circulation holes overlapped one another serve as flow paths through which the refrigerant passes, the refrigerant moves in displaced portions of the refrigerant circulation holes by capillary phenomenon, and the thermal conductivity is good.

[0005] Such heat pipes have a heat spread effect several times to several ten times in comparison with a metallic body which is made of a similar metal and has similar contour and volume, and are appropriate for heat radiation of a device where heat dissipation is important, such as a CPU (Central Processing Unit) and an LED (Light Emitting Diode).

Patent Literature 1: Japanese Unexamined Patent Publication No. 2002-039693

Patent Literature 2: Japanese Unexamined Patent Publication No. 2004-077120

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] According to the conventional technique, after the refrigerant like water is charged in the cooling unit main body through a refrigerant charging hole, the refrigerant charging hole is plugged by a sealing member. A possible material of the sealing member is a solder, but in this case, the material of the cooling unit main body (e.g., copper, copper-based material, aluminum, or aluminum-based material) differs from that of the sealing member. This may causes a local battery effect due to the refrigerant which is charged in the cooling unit main body contacts both cooling unit main body and sealing member.

[0007] That is, even if pure water is carefully used as the refrigerant so as not to contain ions (charged impurities), a tiny amount of ions are to be contained. Accordingly, a local battery is inevitably formed inside the cooling unit main body and a local battery effect is caused, so that corrosion is likely to occur. The conventional heat pipes are of course designed as to have a long life, but it is desirable that corrosion originating from a local battery effect should be prevented to make the heat pipes further long-lived.

[0008] When a solder is used as the sealing member, because the melting point thereof is low, the sealing effect may be reduced or dissolved at a high temperature of, for example, 180 to 220 °C or so, and it is desirable to ensure the sealing effect under a high temperature condition.

[0009] According to Japanese Unexamined Patent Publications No. 2002-039693 and No. 2004-07712, to achieve miniaturization and thinning of the foregoing heat pipes, the mechanical strength becomes weak by what corresponds to the miniaturization and thinning, and a part of the cooling unit main body in which the refrigerant charging hole is formed may be broken in plugging the refrigerant charging hole with the sealing member.

[0010] That is, when the refrigerant charging hole is formed in a portion of the cooling unit main body corresponding to the refrigerant circulation hole of the partition plate, a damage such that a peripheral portion around the refrigerant charging hole is crushed by force applied to the sealing member when the sealing member is pressed against the refrigerant charging hole to plug it, so that it is difficult to improve the productivity. Moreover, that portion where the refrigerant charging hole is formed may be damaged when the heat pipe is in use.

[0011] The present invention has been made to overcome such problems, and it is an object of the invention to provide a heat pipe which can ensure the sealing effect under a high temperature condition, and has a further long life in comparison with the conventional ones, and a method for manufacturing the same. Another object of the invention is to provide a heat pipe which has an improved productivity and reduces the production cost, and, has a further long life in comparison with the conventional ones.

MEANS FOR SOLVING THE PROBLEMS

[0012] A heat pipe according to the first aspect of the invention comprises:

a cooling unit main body that is formed of a metal and has a circulation path for a refrigerant formed in an interior space thereof;

a refrigerant charging hole that is formed in the cooling unit main body and is for charging the refrigerant in the interior space; and
a sealing member that plugs the refrigerant charging hole to seal the refrigerant in the interior space, wherein
the sealing member is formed of a same or similar plastic metal to that of the cooling unit main body.

[0013] A heat pipe according to the second aspect of the invention comprises:

a cooling unit main body having a circulation path for a refrigerant formed in an interior space thereof by one or a plurality of intermediate plates provided between an upper plate and a lower plate; and
a refrigerant charging hole that is formed in the cooling unit main body and plugged by a sealing member when the refrigerant is charged in the interior space of the cooling unit main body, wherein
the intermediate plate has a reinforcement member formed at a portion corresponding to a peripheral region of the refrigerant charging hole and having a predetermined thickness, and a hole for the refrigerant formed in a portion corresponding to the refrigerant charging hole.

[0014] A heat pipe according to the third aspect of the invention comprises:

a cooling unit main body having a circulation path for a refrigerant formed in an interior space thereof; and
a refrigerant charging hole that is formed in the cooling unit main body and plugged by a sealing member when the refrigerant is charged in the interior space of the cooling unit main body, wherein
the refrigerant is made into minute particles and charged in the interior space through said refrigerant charging hole.

[0015] A heat pipe according to the fourth aspect of the invention comprises:

a cooling unit main body that is made of a metal and has a circulation path for a refrigerant formed in an interior space thereof by one or a plurality of intermediate plates provided between an upper plate and a lower plate;
a refrigerant charging hole that is formed in the cooling unit main body and is for charging the refrigerant in the interior space; and
a sealing member that plugs the refrigerant charging hole to seal the refrigerant in the interior space, wherein:

the sealing member is formed of a same or similar plastic metal to that of the cooling unit main body;
the intermediate plate has a reinforcement member formed at a portion corresponding to a peripheral region of the refrigerant charging hole and having a predetermined thickness, and a hole for the refrigerant formed in a portion corresponding to the refrigerant charging hole; and
the refrigerant is made into minute particles and charged in the interior space through the refrigerant charging hole.

[0016] The sealing member plugging the refrigerant charging hole does not protrude from a surface of the cooling unit main body.
[0017] The refrigerant charging hole may have a gas venting groove which is formed around an inner periphery surface thereof, causes the interior space to keep communicating with an exterior space until the refrigerant charging hole is completely plugged by the sealing member, and is plugged by the sealing member when the refrigerant charging hole is completely plugged.
[0018] The circulation path may have a vapor diffusion flow path where the refrigerant vaporizes and diffuses, and the portion corresponding to the refrigerant charging hole is disposed in the vapor diffusion flow path, and the reinforcement member may have a slit formed along a diffusion direction in which the refrigerant vaporizes and diffuses in the vapor diffusion flow path.
[0019] A heat pipe manufacturing method according to the fifth aspect of the invention comprises:

a charging step of charging a refrigerant in a cooling unit main body formed of a metal and having a circulation path for the refrigerant formed in an interior space thereof through a refrigerant charging hole formed in the cooling unit main body;
a mounting step of mounting a sealing member formed of a same or a similar metal to that of the cooling unit main body on the refrigerant charging hole; and
a sealing step of plugging the refrigerant charging hole with the sealing member by applying pressure on the sealing unit under a vacuum condition.

[0020] A heat pipe manufacturing method according to the sixth aspect of the invention comprises:

a charging step of charging a refrigerant in a cooling unit main body having a circulation path for the refrigerant formed in an interior space thereof through a refrigerant charging hole formed in the cooling unit main body;
a mounting step of mounting a sealing member on the refrigerant charging hole; and
a sealing step of plugging the refrigerant charging hole with the sealing member by applying pressure on the sealing member under a vacuum condition, wherein

the refrigerant is made into minute particles and charged in the interior space through the refrigerant charging hole in the charging step.

[0021] A heat pipe manufacturing method according to the seventh aspect of the invention comprises:

a preparation step of preparing a cooling unit main body having a circulation path for a refrigerant formed in an interior space thereof by one or a plurality of intermediate plates provided between an upper plate and a lower plate, the intermediate plate having a reinforcement member which is formed at a portion corresponding to a peripheral region of a refrigerant charging hole formed in the upper plate or the lower plate and has a predetermined thickness, and a hole for the refrigerant formed at a portion corresponding to the refrigerant charging hole;
a charging step of charging the refrigerant in the interior space of the cooling unit main body through the refrigerant charging hole;
a mounting step of mounting a sealing member on the refrigerant charging hole; and
a sealing step of plugging the refrigerant charging hole with the sealing member by applying pressure on the sealing member under a vacuum condition.

[0022] A heat pipe manufacturing method according to the eighth aspect of the invention comprises:

a preparation step of preparing a cooling unit main body that is formed of a metal and has a circulation path for a refrigerant formed in an interior space thereof by one or a plurality of intermediate plates provided between an upper plate and a lower plate, the intermediate plate having a reinforcement member which is formed at a portion corresponding to a peripheral region of a refrigerant charging hole formed in the upper plate or the lower plate and has a predetermined thickness, and a hole for the refrigerant formed at a portion corresponding to the refrigerant charging hole;
a charging step of charging the refrigerant in the interior space of the cooling unit main body through the refrigerant charging hole;
a mounting step of mounting a sealing member which is formed of a same or a similar metal to that of the cooling unit main body on the refrigerant charging hole; and
a sealing step of plugging the refrigerant charging hole with the sealing member by applying pressure on the sealing member under a vacuum condition, wherein
the refrigerant is made into minute particles and charged in the interior space through the refrigerant charging hole in the charging step.

[0023] In the sealing step, the interior space may keep communicating with an exterior space through a gas venting grove formed at an inner periphery surface of the refrigerant charging hole until the sealing member completely plugs the refrigerant charging hole.

[0024] In the sealing step, the refrigerant charging hole may be tentatively plugged with the sealing member by applying pressure on the sealing member under a vacuum condition, and be completely sealed with the sealing member by heating the sealing member while applying pressure thereon.

EFFECT OF THE INVENTION

[0025] According to the heat pipe and the heat pipe manufacturing method of the invention, it is possible to provide a heat pipe which can ensure the sealing effect under a high temperature condition, and has a further long life in comparison with the conventional ones.

[0026] According to the invention, moreover, there is provided a heat pipe which has an improved productivity, reduces the production cost further, and has a further long life in comparison with the conventional ones.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027]

FIG. 1 is a perspective view showing the outline structure of a heat pipe according to the invention;
FIG. 2A is a cross-sectional view showing the side sectional structure of the heat pipe in FIG. 1 along a line A-A';
FIG. 2B is a cross-sectional view showing the side sectional structure of the heat pipe in FIG. 1 along a line B-B';
FIG. 3A is a schematic diagram showing the planer structure of a top outside surface of an upper plate;
FIG. 3B is a schematic diagram showing the planer structure of a bottom inside surface of the upper plate;
FIG. 4A is a schematic diagram showing the planer structure of a bottom outside surface of a lower plate;
FIG. 4B is a schematic diagram showing the planer structure of a top inside surface of the lower plate;
FIG. 5 is a schematic diagram showing the planer structure of a first intermediate plate;
FIG. 6 is a schematic diagram showing the planer structure of a second intermediate plate;
FIG. 7 is a schematic diagram showing the way how a through hole of the first intermediate plate and through holes of the second intermediate plate are arranged;
FIG. 8 is a schematic diagram showing the structures of vapor diffusion flow paths and capillary flow paths both formed by the first and second intermediate plates;
FIG. 9A is a detailed cross-sectional view showing a way (1) how refrigerant circulating phenomenon

occurs;

FIG. 9B is a detailed cross-sectional view showing a way (2) how refrigerant circulating phenomenon occurs;

FIG. 10 is a schematic diagram showing the way how the refrigerant spreads toward the peripheral portion from the center;

FIG. 11 is a schematic diagram showing the way how the refrigerant returns to the center from the peripheral portion;

FIG. 12A represents a front view showing the partial detailed structure of a region near a refrigerant charging hole formed in the bottom inside surface of the upper plate, and a cross-sectional view along a line C-C' in that front view;

FIG. 12B a front view showing the partial detailed structure (1) of a region near an intermediate plate reinforcement member formed at the first intermediate plate;

FIG. 12C is a front view showing the partial detailed structure (1) of a region near a slit-provided reinforcement member formed at the second intermediate plate;

FIG. 12D is a front view showing the partial detailed structure (2) of a region near the intermediate plate reinforcement member formed at the first intermediate plate;

FIG. 12E is a front view showing the partial detailed structure (2) of a region near the slit-provided reinforcement member formed at the second intermediate plate;

FIG. 12F is a front view showing the partial detailed structure of a region near a lower plate reinforcement member formed at the top inside surface of the lower plate;

FIG. 13 is a cross-sectional view showing the respective detailed structures of an upper plate reinforcement member, intermediate plate reinforcement member, slit-provided reinforcement member, and lower plate reinforcement member;

FIG. 14A is a cross-sectional view showing an example (1) of a heat pipe manufacturing method;

FIG. 14B is a cross-sectional view showing the example (2) of the heat pipe manufacturing method;

FIG. 14C is a cross-sectional view showing the example (3) of the heat pipe manufacturing method;

FIG. 14D is a cross-sectional view showing the example (4) of the heat pipe manufacturing method;

FIG. 14E is a cross-sectional view showing the example (5) of the heat pipe manufacturing method;

FIG. 15A is a schematic diagram showing the planer structure of the refrigerant charging hole;

FIG. 15B is a schematic diagram showing the way how a sealing member is disposed on the refrigerant charging hole;

FIG. 15C is a schematic diagram showing the way how the refrigerant charging hole is plugged by the sealing member;

FIG. 16A is a cross-sectional view showing the example (6) of the heat pipe manufacturing method;

FIG. 16B is a cross-sectional view showing the example (7) of the heat pipe manufacturing method;

FIG. 17 is a schematic diagram showing the way how the refrigerant is supplied into the cooling unit main body using an inkjet nozzle;

FIG. 18 is a schematic diagram showing the structure of a slit-provided reinforcement member according to another embodiment;

FIG. 19 is a schematic diagram showing the structure of a slit-provided reinforcement member according to another embodiment;

FIG. 20A is a schematic diagram showing a planer structure (1) of a refrigerant charging hole or an air outlet port according to the other embodiment of the invention;

FIG. 20B is a schematic diagram showing a side sectional structure (1) of the refrigerant charging hole or the air outlet port according to the other embodiment;

FIG. 20C is a cross-sectional view showing a way (1) how the refrigerant charging hole or the air outlet port according to the other embodiment are plugged by the sealing member;

FIG. 21A is a schematic diagram showing a planer structure (1) of a refrigerant charging hole or an air outlet port according to a further other embodiment of the invention;

FIG. 21B is a cross-sectional view showing a side sectional structure (2) of the refrigerant charging hole or the air outlet port according to the further other embodiment; and

FIG. 21C is a cross-sectional view showing a way (2) how the refrigerant charging hole or the air outlet port are plugged by the sealing member.

BEST MODE FOR CARRYING OUT THE INVENTION

[0028] According to the invention, a refrigerant is charged in the interior space of a cooling unit main body in which a refrigerant charging hole is formed, a sealing member made of the same or similar plastic metal to the cooling unit main body is disposed on the refrigerant charging hole, and then the refrigerant charging hole is sealed with the sealing member by pressurization under a vacuum condition. Further, to ensure the sealing effect by the sealing member, the sealing member is fixed by heating while applying pressure, thereby manufacturing a heat pipe having the refrigerant charging hole completed sealed.

[0029] As a result, because the heat pipe has the cooling unit main body formed of a metal and the sealing member formed of the same or similar plastic metal to the cooling unit main body, a local battery effect due to both of the cooling unit main body and the sealing member does not occur even if both cooling unit main body and sealing member contact the refrigerant or exposed thereto, and corrosion inherent to a local battery effect is prevented, thereby making the heat pipe further long-lived in comparison with the conventional ones.

[0030] When gold, silver, copper, copper-based material, aluminum, or aluminum-based metal is used as the materials of the cooling unit main body and sealing member, the melting point thereof is high, so that the sealing effect can be obtained under a high temperature condition of 200 to 300 °C or so in comparison with a solder. Therefore, the sealing effect is ensured under a high temperature condition.

[0031] Note that in embodiments to be discussed later, a heat pipe has a cooling unit formed by sandwiching one or a plurality of tabular intermediate plates between tabular upper and lower plates. In the cooling unit main body, one or the plurality of intermediate plates form a circulation path that is constituted by flow paths which cause a vapor to diffuse toward the peripheral portion of the cooling unit main body (hereinafter, these flow paths are called vapor diffusion flow path), and flow paths which cause the refrigerant to flow in a vertical and oblique directions by capillary phenomenon (hereinafter, those flow paths are called capillary flow paths) with a direction between the upper and lower plates taken as the vertical direction. Recessed grooves are formed in the bottom inside surface of the upper plate in a grid pattern, and recessed grooves are also formed in the upper inside surface of the lower plate in a grid pattern. The vapor diffusion flow paths are communicated with the capillary flow paths through the recessed grooves formed in the bottom inside surface of the upper plate (hereinafter called upper-plate-inside-surface groove portion) and the recessed grooves formed in the top inside surface of the lower plate (hereinafter called lower-plate-inside-surface groove portion).

[0032] Projecting poles each of which has a leading end formed in a planer shape are formed at individual regions partitioned by the upper-plate-inside-surface groove portion and the lower-plate-inside-surface groove portion. Because the leading end of each projecting pole is formed in a planer shape, the projecting poles can adhere tightly to an intermediate plate. The upper-plate-inside-surface groove portion and the lower-plate-inside-surface groove portion are formed in a grid pattern in the following embodiments, but may be formed in other patterns like a mesh pattern. In response to such patterns, the projecting pole is formed in such a manner as to have a transverse section formed in a square, circular, elliptical, polygonal, or a star shape.

[0033] When the heat pipe has the vapor diffusion flow paths formed radially toward the peripheral portion including, for example, all corners in the four corners, heat from a device to be cooled can efficiently diffuse and dissipate through the cooling unit main body entirely, and the heat conduction effect is enhanced, so that there is provided the most suitable heat pipe. The vapor diffusion flow path may be formed in a band-like shape, trapezoidal shape, or in such a shape that the width thereof becomes large or narrow from the center toward the peripheral portion. The vapor diffusion flow path may be formed in various other shapes.

[0034] When a plurality of intermediate plates are provided, overlapped holes for the vapor diffusion flow paths may be completely overlapped one another, or may be displaced in a width direction. When one intermediate plate is used, the through holes themselves serve as the vapor diffusion flow paths.

[0035] When the plurality of intermediate plates are used, by overlapping the plurality of intermediate plates one another, overlapped through holes form the capillary flow paths communicating with the vapor diffusion flow paths. The through holes of each intermediate plate may be formed in different patterns for each intermediate plate, and may be formed in the same pattern for all intermediate plates. When one intermediate plate is used, the through holes themselves serve as the capillary flow paths.

[0036] That is, the intermediate plates may be provided between the upper plate and lower plate in such a way that the positions, shapes and sizes of the through holes of the respective intermediate plates coincide to thereby constitute capillary flow paths having the same position, shape and size as the through hole of each intermediate plate. In this case, the through hole or the resultant capillary flow path may have a rectangular shape (e.g., square or oblong shape), of which the corners may be rounded. Although it is to be of a rectangular shape fundamentally, a part or whole sides thereof (peripheral inside surface of the capillary flow path) may be corrugated or wrinkled so as to enlarge a surface area thereof, because a cooling effect is enhanced if the peripheral inside surface area of the capillary flow path is large. Alternatively, the capillary flow path may take a hexagonal, circular or elliptical shape.

[0037] However, to form the capillary flow path with a smaller cross-sectional area in the horizontal direction orthogonal to the vertical direction with a direction between the upper plate and the lower plate taken as the vertical direction, the plural intermediate plates may be suitably displaced from the positions where the respective through holes are precisely aligned with one another so as to be only partially overlapped, thereby enabling the substantive cross-sectional area of the capillary flow path to be made small as compared with the cross-sectional area of the through hole of each intermediate plate.

[0038] Specifically, when the two intermediate plates are used, it is possible to reduce the substantive cross-sectional area of the capillary flow path to about 1/2 of that of the through hole of each intermediate plate, by displacing the respective intermediate plates by a half pitch of an arrangement pitch in a predetermined direction (e.g., lateral direction, (one side direction when the through hole is formed in a rectangular shape)), with the size, shape and arrangement pitch of each through hole being kept the same. Furthermore, if the positions of the through holes of the two intermediate plates are also displaced in a direction intersecting with the foregoing side direction (e.g., longitudinal direction. (another side direction orthogonal to one side direction)), the substantial cross-sectional area of the capillary flow path can be reduced to about 1/4 of that of the through hole of each intermediate plate. When the through holes are displaced in the respective intermediate plates, then the capillary flow paths are formed such that the refrigerant flows not only in the vertical direction but also in the oblique direction inclined from the vertical direction.

[0039] Suitable materials of the cooling unit main body, upper plate, lower plate and intermediate plates which constitute the cooling unit main body, and sealing member which plugs the refrigerant charging hole are copper, and copper-based metal like copper alloy, but the materials are not limited to those metals, and for example, aluminum and aluminum-based metal containing aluminum like aluminum alloy which have an advantage such that the material cost thereof is low, iron and iron-based metal like iron alloy, stainless steel, gold, silver may be used.

[0040] When the cooling unit main body is formed of copper or a copper-based metal like copper alloy, the outside surface of the cooling unit main body including the surface of the sealing member made of copper or a copper-based metal is normally undergone nickel plating.

[0041] Water (e.g., pure water, distilled water) having a large latent heat is suitable as the refrigerant, but the refrigerant is not limited to water, and, for example, ethanol, methanol, acetone, or the like is also suitable.

[0042] The refrigerant charging hole is constituted by an opening which is plugged by the disposed sealing member, and gas venting grooves, so that a gas in the cooling unit main body is taken out through the gas venting grooves in performing a plugging work with the sealing member.

[0043] That is, according to the heat pipe, when the refrigerant charging hole is sealed by the sealing member, vacuum deaeration can be performed through the gas venting grooves, and if a harmful component which causes the cooling unit main body to be corroded is present thereinside, air inside the cooling unit main body can be taken out through the gas venting grooves, so that the harmful component can be surely removed from the interior space of the cooling unit main body together with the air. By eliminating impurities attached to the interior surface of the cooling unit main body beforehand, it is possible to suppress generation of outgas from the interior surface after sealing, thereby providing a heat pipe which can prevent shortening of the lifetime thereof due to internal corrosion.

[0044] According to the heat pipe, the sealing member formed of a plastic metal performs plastic deformation, is fixed by pressure, and becomes a sealing plug by heating and pressurization. Therefore, according to the heat pipe, the gas venting grooves can be surely plugged by the sealing member, resulting in complete closing of the refrigerant charging hole, so that the refrigerant is sealed in the cooling unit main body, and it is possible to surely prevent the refrigerant from leaking.

[0045] In addition to the refrigerant charging hole for charging the refrigerant in the cooling unit main body using a nozzle, the cooling unit main body may be provided with an air outlet port which have, for example, the same size as that of the refrigerant charging hole, and in this case, when the refrigerant is charged through the refrigerant charging hole, air in the cooling unit main body is taken out through the air outlet port, thereby making the charging of the refrigerant more smooth.

[0046] The refrigerant may be supplied using a normal nozzle, but by using an inkjet nozzle, the refrigerant may be made into minute particles and charged in the cooling unit main body in a misty form.

[0047] This makes it possible to prevent a large droplet from putting around the refrigerant charging hole and the refrigerant charging hole from being covered by that droplet, thereby eliminating a depressurization work of depressurizing the interior space to prevent generation of such a droplet. At this time, the refrigerant may be supplied while keeping the nozzle away from the cooling unit main body so as not to contact the cooling unit main body.

[0048] Charging of the refrigerant through the refrigerant charging hole is possible without forming the air outlet port in the cooling unit main body, but formation of the air outlet port is preferable because the charging of the refrigerant becomes smooth. In a case where the air outlet port is formed in the cooling unit main body in addition to the refrigerant charging hole, plugging by the sealing member is performed not only on the refrigerant charging hole, but also on the air outlet port.

[0049] Possible nozzles which supply the refrigerant in a misty form are an inkjet nozzle, a micro dispenser which makes the refrigerant into tiny particles, and a nanoliter level dispenser which makes the refrigerant into ultrafine particles.

[0050] Meanwhile, miniaturization of a device to be cooled, thinning and miniaturization of the cooling unit main body associated with the thinning are requested for such a heat pipe, but the strength becomes week if such requests are merely satisfied, so that breakage may occur when the refrigerant charging hole of the cooling unit main body is plugged by a metallic body like copper, and when the heat pipes are in use.

[0051] In contrast, according to the heat pipe of the invention, an intermediate plate which is provided in the interior space of the cooling unit main body has a reinforcement member having a predetermined thickness and provided at a portion corresponding to the peripheral region of the refrigerant charging hole, the mechanical strength at the peripheral region of the refrigerant charging hole is improved, and occurrence of a breakage in manufacturing and in using the heat pipe can be prevented, thereby improving the productivity in comparison with the conventional ones, reducing the manufacturing cost, and making the heat pipe further long-lived.

[0052] In a case where a plurality of intermediate plates are used, by providing the reinforcement members to all intermediate plates, the reinforcement members are stacked one another, adhere tightly to form a support structure, thereby further improving the mechanical strength at the peripheral region of the refrigerant charging hole. Note that some of the intermediate plates may be provided with the reinforcement members.

[0053] When the reinforcement member is provided at a portion corresponding to the peripheral region of the refrigerant charging hole, it is preferable that the reinforcement member should have a hole for the refrigerant which is communicated with the refrigerant charging hole and is formed at a portion corresponding to the refrigerant charging hole. This makes it possible to cause the refrigerant to spread across the intermediate plate and the lower plate evenly through the refrigerant hole and slits when the refrigerant is charged in the interior space through the refrigerant charging hole.

[0054] Further, when a portion corresponding to the refrigerant charging hole is laid out over the hollow vapor diffusion flow paths formed by the intermediate plate, the slits may be formed along a diffusion direction in which the refrigerant vaporizes and passes through the vapor diffusion flow paths. This enables the refrigerant, which vaporizes and diffuse the vapor diffusion flow paths, to spread to the peripheral portion without being interrupted by the reinforcement member, thereby ensuring the heat dissipation effect. All reinforcement members of the intermediate plates may have slits, respectively, but some of the reinforcement members may have the slits.

Embodiments

[0055] Embodiments of the invention will be explained in detail with reference to the accompanying drawings.

[0056] FIG. 1 shows the outline structure of a top outside surface of a heat pipe 1 according to an embodiment. The heat pipe 1 has an upper plate 2 and a lower plate 3 both made of a copper-based metal having a high thermal conductivity, such as copper, or copper alloy, and a refrigerant charging hole 4 and an air outlet port 5 are formed in a top outside surface 2a of the upper plate 2. In the case of this embodiment, the refrigerant charging hole 4 is formed near one corner portion in a pair of diagonal corner portions, while the air outlet port 5 is formed near the other corner portion diagonally opposite to the one corner portion. After a refrigerant like water is charged in an interior space (to be discussed later) through the refrigerant charging hole 4 with the interior space being communicated with the exterior space through the air outlet port 5, the refrigerant charging hole 4 and the air outlet port 5 are plugged by sealing members 8 each of which is formed of the same copper-based metal as those of the upper plate 2 and the lower plate 3.

[0057] As shown in FIG. 2A which shows the side sectional structure of the heat pipe 1 along a line A-A' and FIG. 2B which shows the side sectional structure thereof along a line B-B', the heat pipe 1 has a cooling target device HE which is a heat generating body, such as an IC (semiconductor Integrated Circuit), an LSI (Large Scale Integrated circuit), or a CPU and is attached to the bottom outside surface of the lower plate 3.

[0058] In practice, according to the heat pipe 1, a second intermediate plate 7a, a first intermediate plate 6a, a second intermediate plate 7b and a first intermediate plate 6b are stacked on the lower plate 3 in this order, the upper plate 2 is stacked on the first intermediate plate 6b, those plates are positioned by non-illustrated positioning holes, directly joined and integrated together, thereby forming a cooling unit main body 10.

[0059] Note that the words "directly joined" mean applying pressure and performing a heat treatment with first and second surfaces to be joined being adhered tightly to each other, thereby causing atoms to rigidly join one another by atomic force applied between the first and second surfaces, and this enables integration of the first and second surfaces without using an adhesive or the like.

[0060] The first intermediate plates 6a, 6b and the second intermediate plates 7a, 7b are stacked alternately, thereby forming vapor diffusion flow paths 44 which extend radially from a region opposite to that portion where the cooling target device HE is provided and the peripheral region 33a thereof (hereinafter, those regions are collectively called cooling-target-device peripheral region) toward a peripheral portion 12 as shown in FIG. 2A, and minute capillary flow paths 42 shown in FIG. 2B in an interior space 10a of the cooling unit main body 10. FIG. 2A is a cross-sectional view of that region where the interior of the cooling unit main body 10 is partitioned into the capillary flow paths 42 and the vapor diffusion flow paths 44, and FIG. 2B is a cross-sectional view of that region where the interior space of the cooling unit main body 10 is filled with the capillary flow paths 42.

[0061] A predetermined amount of refrigerant W comprising water is sealed in the interior space 10a of the cooling unit main body 10 under a depressurized condition, so that the boiling point of the refrigerant W is dropped, and the refrigerant W is vaporized by a slight amount of heat from the cooling target device HE and circulates the vapor diffusion flow paths 44 and the capillary flow paths 42.

[0062] Next, the detailed structures of the respective upper plate 2, first intermediate plates 6a, 6b, second intermediate plates 7a, 7b, and lower plate 3 will be explained, and the vapor diffusion flow paths 44 and the capillary flow paths 42 will be explained briefly. FIG. 3A shows the structure of the top outside surface 2a of the upper plate 2, and FIG. 3B shows the structure of a bottom inside surface 2b of the upper plate 2. FIG. 4A shows the structure of a bottom outside surface 3a of the lower plate 3, and FIG. 4B shows the structure of a top inside surface 3b of the lower plate 3. FIG. 5 shows the structure of the first plate 6a, 6b, sandwiched between the upper plate 2 and the lower plate 3, and FIG. 6 shows the structure of the second intermediate plate 7a, 7b sandwiched between the upper plate 2 and the lower plate 3 like the first intermediate plate 6a, 6b.

[0063] As shown in FIG. 3B, the upper plate 2 has a main body 21 having a thickness of, for example, 500 μm, and formed in an almost square shape. The main body 21 has an upper-plate-inside-surface groove portion 23 recessed and formed in a grid pattern and formed at the bottom inside surface 2b other than the peripheral portion 12 formed in a frame-like shape. The upper plate 2 has projecting poles 24 each having a planer leading end are provided at individual regions partitioned in a grid pattern by the upper-plate-inside-surface groove portion 23.

[0064] As shown in FIG. 4B, the lower plate 3 has a tabular main body 11 having a thickness of, for example, 500 μm and formed in an almost square shape like the upper plate 2. The main body 11 has a lower-plate-inside-surface groove portion 14 recessed and formed in a grid pattern and formed at the top inside surface 3b other than the peripheral portion 12 formed in a frame-like shape. The lower plate 3 has projecting poles 15 each having a planer leading end are formed at individual regions partitioned in a grid pattern by the lower-plate-inside-surface groove portion 14.

[0065] A main body 31 of the first intermediate plate 6a, 6b shown in FIG. 5 and a main body 32 of the second intermediate plate 7a, 7b shown in FIG. 6 are made of the same copper-based metals as those of the upper plate 2 and the lower plate 3, have a thickness of, for example, 70 to 200 μm, and are formed in an almost square shape like the main body 11 of the lower plate 3.

[0066] Because the first intermediate plates 6a, 6b have the same size and are formed in the same shape, an explanation will be give of only the first intermediate plate 6a in the first intermediate plates 6a, 6b. As shown in FIG. 5, the first intermediate plate 6a has holes 34 for vapor diffusion flow paths and a capillary formation region 36 formed in the main body 31. The capillary formation region 36 comprises a cooling-target-device peripheral region 33a and regions 33b which are regions between the adjoining vapor diffusion flow path holes 34 and are regions other than the cooling-target-device peripheral region 33a. The cooling-target-device peripheral region 33a faces the cooling target device IE provided on the lower plate 3 when the main body 31 is stacked on the main body 11 of the lower plate 3. The vapor diffusion flow path holes 34 each formed in a band-like shape extend radially from the cooling-target-device peripheral region 33a including the four corners.

[0067] A plurality of through holes 37 for forming the capillary flow paths 42 (FIGS. 2A and 2B) are formed in the capillary formation region 36 in a first pattern (to be discussed later). The capillary formation region 36 has grid-like partition walls 38, and the individual region partitioned by the partition walls 38 serve as the through holes 37.

[0068] As shown in FIG. 7, the through holes 37 each formed in a rectangular shape are arranged regularly at predetermined intervals as the first pattern, and have four sides parallel to the respective sides of the peripheral portion 12 of the main body 32 (FIG. 5). In the embodiment, the width of a through hole 52 is selected to 280 μm or so, and the width of a partition wall 38 is selected to 70 μm or so.

[0069] The second intermediate plate 7a, 7b shown in FIG. 6 is formed to have the same size as that of the first intermediate plate 6a, 6b. An explanation will be given of only the second intermediate plate 7a in the second intermediate plates 7a, 7b. As shown in FIG. 6, the second intermediate plate 7a is provided with a capillary formation region 36 and holes 34 for vapor diffusion flow paths like the first intermediate plates 6a, 6b, but a plurality of through holes 40 formed in the capillary formation region 36 are formed in a second pattern (to be discussed later) which is different from the first pattern. The capillary formation region 36 of the second intermediate plate 7a has grid-like partition walls 41, and the individual regions partitioned by the partition walls 41 serve as the through holes 40. As shown in FIG. 7, the through holes 40 each formed in a rectangular shape are arranged regularly at predetermined intervals as the second pattern like the first pattern, and have four sides parallel to the respective sides of the peripheral portion 12 of the main body 32, and are displaced from the individual through holes 37 of the first intermediate plate 6a at predetermined distances.

[0070] In the embodiment, for example, when the first intermediate plate 6a and the second intermediate plate 7a are positioned and stacked, a through hole 37 of the first intermediate plate 6a is displaced in an X direction of one side of a through hole 40 of the second intermediate plate 7a by half of that side, and in a Y direction of the other side orthogonal to the X direction by half of the other side. This allows a through hole 37 of the first intermediate plate 6a to overlap four adjoining through holes 40 of the second intermediate plate 7a, thereby forming the four capillary flow paths 42. Accordingly, this enables lots of capillary flow paths 42, which are much smaller than the through holes 37, 40, partitioned minutely and have small surface areas, to be formed in one through hole 37.

[0071] Therefore, according to the heat pipe 1, as shown in FIG. 8, by stacking the second intermediate plates 7a, 7b and the first intermediate plates 6a, 6b alternately, the through holes 37, 40 are displaced one another, the capillary flow paths 42 are formed, the vapor diffusion flow path holes 34 are overlapped, and the vapor diffusion flow paths 44 are formed. The vapor diffusion flow paths 44 and the capillary flow paths 42 are communicated with one anther through the upper-plate-inside-surface groove portion 23 and the lower-plate-inside-surface groove portion 14 (FIGS. 2A, 2B).

[0072] As a result, according to the heat pipe, as shown in FIG. 9A which shows the side sectional structure of that portion where the vapor diffusion flow paths 44 and the capillary flow paths 42 are formed, along a line A-A' in FIG. 1, because the refrigerant W is always present in the individual capillary flow paths 42 in the cooling-target-device peripheral region 33a, the refrigerant W in the individual capillary flow paths 42 rapidly and surely absorbs heat conducted from the projecting portions of the cooling-target-device peripheral region 33a and starts vaporizing, and diffuses the vapor diffusion flow paths 44 which extend to the peripheral portion 12, the upper-plate-inside-surface groove portion 23 and the lower-plate-inside-surface groove portion 14.

[0073] That is, as shown in FIG. 10 which shows the planer structure of the first intermediate plate 6a, the refrigerant W diffuses radially and uniformly around the cooling target device HE provided on the lower plate 3 along the vapor diffusion flow paths 44, the upper-plate-inside-surface groove portion 23, and the lower-plate-inside-surface groove portion 14, and moves to the peripheral portion 12.

[0074] According to the heat pipe 1, as shown in FIG. 9B which shows the side sectional structure of a portion which is filled with the capillary flow paths 42 along a line B-B' in FIG. 1, the refrigerant W which is undergone heat dissipation condensation and is liquefied at the upper-plate-inside-surface groove portion 23, the lower-plate-inside-surface groove portion 14, the peripheral portion 12, and the like enters into the capillary flow paths 42 from upper-plate-inside-surface groove portion 23, the lower-plate-inside-surface groove portion 14, passes through the capillary flow paths 42, and returns to the cooling-target-device peripheral region 33a. Therefore, as shown in FIG. 11 which shows the planer structure of the first intermediate plate 6a, the refrigerant W passes through the capillary flow paths 42 radially arranged in the regions 33b, and evenly cools the cooling target device HE from the periphery thereof.

[0075] Next, an explanation will be given of the structure of a region of the cooling unit main body 10 around the refrigerant charging hole 4 or the air outlet port 5. Because the refrigerant charging hole 4 and the air outlet port 5 has the same structure, the explanation will be given of only the refrigerant charging hole 4 to omit redundant explanation.

[0076] FIG. 12A represents a front view showing the partial detailed structure of the vicinity region of the refrigerant charging hole 4 formed in the bottom inside surface 2b of the upper plate 2, and a cross-sectional view along a line C-C' in the front view. The bottom inside surface 2b of the upper plate 2 is provided with a circular upper plate reinforcement member 50 formed at the peripheral region of the refrigerant charging hole 4 in such a manner as to surround the refrigerant charging hole 4. The upper plate reinforcement member 50 is thicker than the upper-plate-inside-surface groove portion 23, and is set to the same thickness as that of the projecting pole 24 provided between the grooves of the upper-plate-inside-surface groove portion 23 and the peripheral portion 12.

[0077] In the case of this embodiment, the refrigerant charging hole 4 is a minute hole whose circular opening 4a at the center has a diameter of 500 to 1000 μm or so, has gas venting grooves 4b formed around the inner periphery surface thereof, and a recessed portion 4c which enables stable disposition of the spherical sealing member 8 on the opening 4a and the gas venting grooves 4b.

[0078] In the case of this embodiment, as shown in FIG. 15A which shows a planer structure of the refrigerant charging hole 4, each gas venting groove 4b is formed in a semi-spherical shape having a smaller diameter than that of the opening 4a, and the four gas venting grooves 4b are provided around the inner periphery surface of the opening 4a at equal intervals.

[0079] FIGS. 12B and 12D are front views showing the partial detailed structures of a region in the vicinity of an intermediate plate reinforcement member 52 formed at the first intermediate plate 6a, 6b. The intermediate plate reinforcement member 52 of the first intermediate plate 6a is formed in a circular shape which is the same shape as that of the upper plate reinforcement member 50, and is formed at a location corresponding to the upper plate reinforcement member 50. In the case of this embodiment, the intermediate plate reinforcement member 52 is formed in the vapor diffusion flow path hole 34, formed integral with the partition walls 38, and partitions the corner portion of the vapor diffusion flow path hole 34. The intermediate plate reinforcement member 52 is set to the same thickness as those of the partition wall 38 and the peripheral portion 12, and a hole 53 for the refrigerant is formed in a location corresponding to the opening 4a of the refrigerant charging hole 4 of the upper plate 2.

[0080] FIGS. 12C and 12E are front views showing the partial detailed structure of a region in the vicinity of a slit-provided reinforcement member 55 formed at the second intermediate plate 7a, 7b. The slit-provided reinforcement member 55 of the second intermediate plate 7a, 7b is formed integral with the partition walls 41, and has the same structure as that of the intermediate plate reinforcement member 52 of the first intermediate plate 6a, 6b, but has slits 56 each formed in such a manner as to communicate with the vapor diffusion flow path hole 34. A hole 57 for the refrigerant is formed in a location corresponding to the opening 4a of the refrigerant charging hole 4 of the upper plate 2, and is communicated with the slits 56.

[0081] In practice, the slit-provided reinforcement member 55 has the slits 56 formed along a diffusion direction D in which a vapor in the vapor diffusion flow path hole 34 diffuses (i.e., direction from the center of the second intermediate plate 7a, 7b toward the corner portion thereof), and is communicated with the vapor diffusion flow path hole 34 so that the vapor can diffuses and reaches the corner portion. Each slit 56 is formed linearly, and has a width of 0.3 mm or so.

[0082] FIG. 12F is a front view showing the partial detailed structure of a region in the vicinity of a lower plate reinforcement member 60 formed at the top inside surface 3b of the lower plate 3. The top inside surface 3b of the lower plate 3 has the circular lower plate reinforcement member 60 formed at a region corresponding to the intermediate plate reinforcement member 52 and the slit-provided reinforcement member 55. The lower plate reinforcement member 60 has a thicker thickness than that of the lower-plate-inside-surface groove portion 14 and the same thickness as those of the projecting pole 15 provided between the grooves of the lower-plate-inside-surface groove portion 14 and the peripheral portion 12. The lower plate reinforcement member 60 has slit-opposing grooves 61 which are communicated with the lower-plate-inside-surface groove portion 14 and a central recess portion 62. The slit-opposing groove 61 has a width of 300 μm or so, and is formed linearly at the lower plate reinforcement member 60 in such a manner as to oppose the slits 56. The central recess portion 62 is formed circularly at a portion corresponding to the opening 4a of the refrigerant charging hole 4 of the upper plate 2.

[0083] FIG. 13 is a cross-sectional view showing the detailed structures of the upper plate reinforcement member 50, intermediate plate reinforcement member 52, slit-provided reinforcement member 55 and lower plate reinforcement member 60 when the second intermediate plate 7a, the first intermediate plate 6a, the second intermediate plate 7b and the first intermediate plate 6b are stacked together on the lower plate 3 in this order and the upper plate 2 is staked on the first intermediate plate 6b.

[0084] The upper plate reinforcement member 50, the intermediate plate reinforcement member 52, the slit-provided reinforcement member 55 and the lower plate reinforcement member 60 adhere together to form a support structure below the peripheral region of the refrigerant charging hole 4 of the upper plate 2, resulting in improvement of the mechanical strength.

[0085] Refrigerant particles W1 which are successively delivered into the refrigerant charging hole 4 in a droplet form one by one from a nozzle 70 at a high speed (e.g., 1000 droplets per second) pass through the opening 4a of the upper plate 2, the hole 53 of the first intermediate plate 6b, the hole 57 of the second intermediate plate 7b, and the like, reach the slit-opposing grooves 61 and the central recessed portion 62 of the lower plate 3, and spread across the entire interior space 10a (FIG. 2A) of the cooling unit main body 10 through the slits 56.

[0086] Next, an explanation will be given of a method of manufacturing the heat pipe 1. FIGS. 14A to 14E and FIGS. 16A and 16B shows an example of the manufacturing method of the heat pipe 1, and as shown in FIG. 14A, first, the second intermediate plate 7a, the first intermediate plate 6a, the second intermediate plate 7b, the first intermediate plate 6, and the upper plate 2 are stacked on the lower plate 3 in this order.

[0087] The first intermediate plate 6a, 6b and the second intermediate plate 7a, 7b have joining projections 72 which protrude from the respective top face thereof and are formed in a frame-like pattern along the respective peripheral portion 12. The lower plate 3 has a joining projection 73 which protrudes from the top inside surface 3b of the main body 11 and is formed in a frame-like pattern along the peripheral portion 12.

[0088] Subsequently, the second intermediate plate 7a, the first intermediate plate 6a, the second intermediate plate 7b, the first intermediate plate 6b and the upper plate 2 are overlapped at the most appropriate position, stacked on the lower plate 3, heated at a temperature lower than or equal to the melting point, and pressurized to directly join those plates together through the joining projections 72, 73.

[0089] As shown in FIG. 14B, the upper plate 2, the lower plate 3, the first intermediate plates 6a, 6b, and the second intermediate plates 7a, 7b are directly joined together, thereby forming the integrated cooling unit main body 10. At this time, the cooling unit main body 10 has the interior space 10a which is communicated with the exterior space through the refrigerant charging hole 4 and the air outlet port 5 both formed in the upper plate 2.

[0090] Each of the first intermediate plates 6a, 6b, second intermediate plates 7a, 7b, and lower plate 3 has a projection 74 provided at the four-side contour position of the central portion facing the cooling target device HE, and direct joining for integration is obtained not only at the peripheral portions 12 but also at the contour position of the cooling-target-device peripheral region 33a through the projections 74. The cooling unit main body 10 also has a support structure at the cooling-target-device peripheral region 33a to improve the mechanical strength, and this prevents the cooling unit main body 10 from being damaged due to phenomenon such that the refrigerant thermally expands due to heat generated from the cooling target device HE and causes the central portion of the cooling unit main body 10 to expand outwardly (hereinafter, this phenomenon is called Popcorn phenomenon).

[0091] In the interior space 10a of the cooling unit main body 10, the overlapped vapor diffusion flow path holes 34 of the respective first intermediate plates 6a, 6b, and second intermediate plates 7a, 7b form the vapor diffusion flow paths 44, and the overlapped capillary formation regions 36 form the plurality of capillary flow paths 42, thereby forming a circulation path constituted by the vapor diffusion flow paths 44 and the capillary flow paths 42 (FIGS. 9A and 9B).

[0092] At this time, the upper plate reinforcement member 50, the intermediate plate reinforcement member 52, the slit-provided reinforcement member 55 and the lower plate reinforcement member 60 adhere tightly, thereby forming a support structure below the regions around the refrigerant charging hole 4 and the air outlet port 5.

[0093] Next, as shown in FIG. 14C which shows the manufacturing method of the heat pipe 1 in sequence, the predetermined amount of refrigerant W1 (e.g., water) is charged in the interior space 10a of the cooling unit main body 10 through the refrigerant charging hole 4 using the nozzle 70 under an atmospheric pressure. At this time, the air outlet port 5 serves as the exhaust port of air, thereby making the charging of the refrigerant into the interior space 10a smooth. When the refrigerant is water, it is preferable that the charging amount thereof should be almost equal to the total volume of the through holes 37, 40, and ultrapure water having no ion contamination is preferable for the longer life of the heat pipe 1. When vacuuming is performed through the air outlet port 5 in charging the refrigerant, the charging of the refrigerant becomes further smooth.

[0094] Subsequently, the plurality of sealing members 8 formed in, for example, a spherical shape are prepared, and as shown in FIG. 14D which shows the manufacturing method of the heat pipe 1 in sequence, the sealing members 8 are disposed on the refrigerant charging hole 4 and the air outlet port 5. As shown in FIG. 15A, the refrigerant charging hole 4 and the air outlet port 5 have the plurality of gas venting grooves 4b formed around the inner periphery surface of the opening 4a, so that even if the spherical sealing member 8 is disposed, the interior space 10a of the cooling unit main body 10 is still communicated with the exterior space through the gas venting grooves 4b as shown in FIG. 15B, thereby enabling gas venting from the interior space 10a of the cooling unit main body 10.

[0095] As shown in FIG. 14E which shows the manufacturing method of the heat pipe 1 in sequence, vacuum deaeration by pressure reduction is performed for, for example, 10 minutes through the gas venting grooves 4b in this state under a normal temperature condition. In this step, by performing the vacuum deaeration through the gas venting grooves 4b, air in the interior space 10a is removed through the gas venting grooves 4b, harmful components are removed together with the air from the interior space 10a, thereby reducing an outgas. Note that arrows in FIG. 14E represent the directions of the deaeration (gas venting).

[0096] Thereafter, as shown in FIG. 16A which shows the manufacturing method of the heat pipe 1 in sequence, a press 75 presses the sealing members 8 from the above for a couple of minutes in a normal temperature condition, and the sealing members 8 are subjected to low-temperature pressurization deformation. By performing low-temperature vacuum pressurization in this manner, the refrigerant charging hole 4 and the air outlet port 5 are tentatively sealed by the sealing members 8. At this time, the refrigerant charging hole 4 and the air outlet port 5 are plugged by the sealing members 8.

[0097] Because the support structure is formed at portions opposite to the peripheral regions of the refrigerant charging hole 4 and the air outlet port 5 by causing the upper plate reinforcement member 50, the intermediate plate reinforcement member 52, the slit-provided reinforcement member 55 and the lower plate reinforcement member 60 to adhere tightly, the support structure receives external force from the press 75 when the sealing members 8 are pressed by the press 75, so that the sealing members 8 can be surely pressurized by the external force from the press 75 without crushing the interior space 10a.

[0098] When the sealing members 8 are pressurized at a temperature higher than a normal temperature, the vapor of the refrigerant, e.g., a moisture vapor becomes likely to leak out, so that it is not preferable. Therefore, it is preferable that the temperature at which vacuum deaeration is performed should be 25 °C or so.

[0099] Next, when the low-temperature vacuum pressurization has been completed, the vacuum degree under a high temperature condition is set to, for example, 0.5 KPa for 10 minutes or so, and the press 75 presses the sealing members 8 from the above. Accordingly, the sealing members 8 are subjected to high-temperature pressurization deformation, deeply enter into the refrigerant charging hole 4 and the air outlet port 5, so that the sealing members 8 are attached by pressure and further firmly plug the refrigerant charging hole 4 and the air outlet port 5.

[0100] That is, the sealing member 8 mainly performs plastic deformation by pressurization, and auxiliary performs plastic deformation by heating, and plugs the refrigerant charging hole 4 or the air outlet port 5 including the gas venting grooves 4b. Therefore, as shown in FIGS. 15C and 16B, the sealing members 8 which have been in a spherical shape are formed in the shapes of the refrigerant charging hole and the air outlet port 5 by plastic deformation, attached to the refrigerant charging hole 4 and the air outlet port 5 by pressure, substantially become the sealing plugs, and seal the interior space 10a of the cooling unit main body 10. After the refrigerant charging hole 4 and the air outlet port 5 are plugged by the sealing members 8, heating, vacuuming, and pressurization by the press 75 are terminated, thereby terminating pressurization, heating and vacuuming.

[0101] It is preferable that the outside surface of the sealing member 8 should form a flat plane with the outside surface of the cooling unit main body 10. This is because that if the outside surface of the heat pipe 1 is flat, adherence of the heat pipe 1 to a radiator attached thereto like a fin becomes good, so that thermal conductivity therebetween is improved well.

[0102] Thereafter, the outside surface of the cooling unit main body 10 is subjected to nickel plating for antirusting. If the refrigerant charging hole 4 and the air outlet port 5 are plugged by the sealing members which are formed of solders, it is difficult to perform nickel plating well on the solders, and this raises a problem such that nickel plating is not performed well on those portions where the refrigerant charging hole 4 and the air outlet port 5 are plugged.

[0103] In contrast, according to the invention, the refrigerant charging hole 4 and the air outlet port 5 are plugged by the sealing members 8 which are formed of the same copper-based metal as that of the cooling unit main body 10, so that such a problem does not occur, and nickel plating can be performed well on those portions where the refrigerant charging hole 4 and the air outlet port 5 are plugged.

[0104] According to such a manufacturing method (refrigerant filling method) of the heat pipe 1, the plurality of heat pipes 1 may be laid out under a vacuum condition, the sealing members 8 may be disposed on the refrigerant charging hole 4 and the air outlet port 5 of each heat pipe 1, gas venting, pressurization and heating of the sealing members 8 are performed on the plurality of heat pipes 1 at the same time, all of the sealing members 8 are undergone plastic deformation, thereby performing sealing on the plurality of heat pipes 1 at the same time. As a result, the productivity of the heat pipe 1 can be improved in comparison with conventional sealing schemes that require time-consuming works, such as caulking, welding, and bonding which are separately performed for each refrigerant charging hole 4, and such improvement of the productivity reduces the cost of the heat pipe 1.

[0105] According to the heat pipe 1, the interior space 10a is set in a reduced pressure condition (e.g., 0.5 KPa or so when the refrigerant is water), the boiling point of the refrigerant drops, and the refrigerant becomes not likely to vaporize at a temperature (e.g., 30 to 35 °C) slightly higher than a normal temperature less than or equal to, for example, 50 °C. Accordingly, the heat pipe 1 can cause the refrigerant to circulate successively and easily by slight heat from the cooling target device HE.

[0106] According to the foregoing structure, the heat pipe 1 has the refrigerant charging hole 4 and the cooling unit main body 10 sealed by the sealing members 8 which are formed of the same plastic copper-based metal as that of the cooling unit main body 10. Therefore, even if the refrigerant contacts both cooling unit main body 10 and sealing member 8, or the cooling unit main body 10 and the sealing member 8 are exposed thereto, a local battery effect due to both cooling unit main body 10 and sealing member 8 does not occur, and as a result, it is possible to prevent corrosion inherent to the local battery effect, thereby making the heat pipe 1 further long-lived in comparison with the conventional ones by what corresponds to the prevention of corrosion.

[0107] When plastic metals are used as the materials of the cooling unit main body 10 and the sealing member 8, because the melting points thereof are high, the sealing effect can be enhanced under a high temperature condition of 200 to 300 °C or so.

[0108] When a solder is used as the sealing member 8, the solder contains lead which is a harmful substance, and sealing with lead requires a maintenance or the like thus taking a cost, but according to the invention, a copper-based metal is used as the material of the sealing member 8, the maintenance required for lead is unnecessary, thereby reducing the cost by what corresponds to it.

[0109] Because a copper-based metal has a high thermal conductivity, and enhances the thermal diffusibility, it is preferable that the cooling unit main body 10 should be formed of a copper-based metal, but when the cooling unit main body 10 is formed of a copper-based metal, the outside surface of the cooling unit main body 10 is normally subjected to nickel plating for anti-rusting. When the refrigerant charging hole 4 of the cooling unit main body 10 is plugged by a solder, the solder is eroded at the preparation for nickel plating, a plating film having weak adhesive force is formed on the surface of the solder, so that adhesion with the underlayer of a nickel plating film to be formed later becomes weak.

[0110] In contrast, according to the heat pipe 1 of the invention, the cooling unit main body 10 is formed of a copper-based metal, and the sealing member 8 for plugging the refrigerant charging hole 4 is also formed of a copper-based metal, so that it is possible to surely perform nickel plating well on the entire contour.

[0111] According to the heat pipe 1, the spherical sealing members 8 are undergone plastic deformation in accordance with the shapes of the refrigerant charging hole 4 and the air outlet port 5 and serve as the sealing plugs. Therefore, the sealing members 8 are not likely to protrude from the top outside surface of the heat pipe 1, and sealing does not detract the flatness of the outside surface of the heat pipe 1, resulting in improvement of the degree of freedom of mounting the heat pipe 1 on a portable device or a compact device.

[0112] That is, according to the heat pipe 1, when an electronic part, such as a CPU or an LED (Light Emitting Diode) which requires heat dissipation is mounted on one side and a radiator (heat dissipation device) like a fin is mounted on the other side, because the outside surface of the sealing member 8 does not protrude from the outside surface of the cooling unit main body 10, adherence to the electronic part and the radiator are improved, thermal conductivity therebetween becomes well, thereby effectively dissipating heat generated by the electronic part or the like.

[0113] According to the heat pipe 1, the refrigerant charging hole 4 and the air outlet port 5 have the gas venting grooves 4b provided around the inner periphery surface of the opening 4a. Accordingly, when the sealing members 8 which become sealing plugs are mounted on the refrigerant charging hole 4 and the air outlet port 5, and start melting so that sealing slightly progresses, the interior space 10a of the heat pipe 1 is not plugged by the sealing members 8 on the refrigerant charging hole 4 and the air outlet port 5, thereby ensuring gas venting.

[0114] According to the heat pipe 1, the sealing member 8 is pressurized under a vacuum condition, the refrigerant charging hole 4 is tentatively sealed by the sealing member 8, and the sealing member 8 is further pressurized and heated, so that the sealing member 8 formed of a plastic metal performs plastic deformation and deforms in accordance with the shape of the gas venting groove 4b. Therefore, the sealing member 8 can surely plug the gas venting grooves 4b, thereby preventing the refrigerant W charged in the interior space 10a from leaking.

[0115] According to the heat pipe 1, the upper plate reinforcement member 50, the intermediate plate reinforcement member 52, the slit-provided reinforcement member 55, and the lower plate reinforcement member 60 adhere tightly to form the support structure at portions corresponding to the peripheral regions of the refrigerant charging hole 4 and the air outlet port 5. Therefore, the mechanical strengths at the peripheral regions of the refrigerant charging hole 4 and the air outlet port 5 are improved, breakage such that the interior space 10a is crushed by external force from the press 75 which is applied to the sealing member 8 from the outside of the upper plate 2 is prevented in a manufacturing process, and the productivity is improved, resulting in reduction of a production cost. When the heat pipe 1 is in use after manufactured, it is possible to prevent the interior space 10a from being crushed at peripheral regions of the refrigerant charging hole 4 and the air outlet port 5 due to various external forces applied through the upper plate 2 and the lower plate 3, thereby making the heat pipe 1 long-lived.

[0116] In particular, according to this embodiment, for miniaturization and thinning of the heat pipe 1 and good heat dissipation, the vapor diffusion flow paths 44 and the capillary flow paths 42 are formed as the circulation path in the interior space 10a. The vapor diffusion flow paths 44 are formed in such a manner as to extend to the uttermost corners of the four sides from the center to cause heat to dissipate to the peripheral portion 12 of the cooing unit main body 10 and to perform heat dissipation efficiently.

[0117] To make charging of the refrigerant in the entire interior space of the heat pipe 1 smooth, the refrigerant charging hole 4 is disposed at one corner portion of the heat pipe 1, and the air outlet port 5 is disposed at the other diagonal corner portion thereof. Thus, the refrigerant charging hole 4 and the air outlet port 5 are disposed on the vapor diffusion flow paths 44 which employ a hollow structure. Therefore, when the sealing members 8 are disposed on the refrigerant charging hole 4 and the air outlet port 5 and a pressing process is performed, only the upper plate 2 receives external force from the press 75 if the regions opposite to the refrigerant charging hole 4 and the air outlet port 5, respectively, merely employ a hollow structure, so that the upper plate 2 may be damaged.

[0118] In contrast, according to the heat pipe 1 of the invention, the upper plate reinforcement member 50, the intermediate plate reinforcement member 52, the slit-provided reinforcement member 55 and the lower plate reinforcement member 60 adhere tightly to form the support structure in the vapor diffusion flow paths 44 which face the peripheral region of the refrigerant charging hole 4 or the air outlet port 5. Accordingly, the support structure can receive external force from the press 75, thereby preventing the upper plate 2 or the lower plate 3 from being damaged by the external force and the interior space 10a from being crushed.

[0119] The upper plate reinforcement member 50, the intermediate plate reinforcement member 52, the slit-provided reinforcement member 55 and the lower plate reinforcement member 60 have the holes 53, 57 for the refrigerant which are communicated with the refrigerant charging hole 4 and formed at a portion corresponding to the refrigerant charging hole 4 of the upper plate 2. Accordingly, when the refrigerant W is charged in the interior space 10a through the refrigerant charging hole 4, the refrigerant W can spread evenly to all corners in the cooling unit main body 10 through the holes 53, 57, the slits 56, and the like.

[0120] In this case, the slit-provided reinforcement member 55 has the slits 56 formed along the diffusion direction D of the refrigerant W which diffuse the vapor diffusion flow paths 44, the refrigerant W is guided to the corner portion of the cooling unit main body 10 through the slits 56, thereby enabling efficient heat dissipation.

[0121] Although the explanation has been given of the embodiment of the invention, the invention is not limited to the foregoing embodiment, and can be changed and modified in various forms. For example, a sealing member formed of a similar plastic metal to that of the cooling unit main body 10 may be used, and the same effects can be achieved in this case.

[0122] As shown in FIG. 17, when a refrigerant is charged in the cooling unit main body 10 using an inkjet nozzle 80 for example, the cooling unit main body 10 may have no air outlet port. In this embodiment, regarding the shape and structure of the circulation path in the interior space 10a, the explanation and illustration thereof will be omitted.

[0123] Specifically, the inkjet nozzle 80 makes a refrigerant (for example, pure water) into tiny refrigerant particles (water particle) W2 each of which has a diameter of, for example, 50 to 300 μm, and successively charged one droplet by one droplet at a speed of approximately 1000 droplets per second. The tiny refrigerant particles W2 are regularly arranged in a line and supplied into the interior space 10a of the cooling unit main body 10. In this case, although the amount of a droplet is tiny, the effectiveness of charging of the refrigerant is extremely high because, for example, approximately 1000 droplets are successively charged per second at a fast speed.

[0124] When the refrigerant is made into extremely tiny refrigerant particles W2 through the inkjet nozzle 80, the refrigerant particles are charged at a fast speed one droplet by one droplet, vacuum deaeration through the foregoing air outlet port can be omitted, thereby reducing the manufacturing cost by what corresponds to that omission. In this case, regarding controlling of the amount of the refrigerant to be charged, even if the amount of the refrigerant to be charged is a tiny amount like 1 to 5 mg, employing a mechanism which digitally controls the discharging numbers from the inkjet nozzle makes it possible to easily charge the refrigerant at a fast speed with an accuracy one droplet by one droplet.

[0125] FIGS. 18 and 19 are top plan views showing slit-provided reinforcement members 81, 85 according to the other embodiment, and the difference from the slit-provided reinforcement member 55 is that the shape of the slit 56 differs. As shown in FIG. 18, a slit-provided reinforcement member 81 has slits 83 each formed in such a way that the width thereof gradually becomes wide from the center of a circular refrigerant hole 82 toward the outer periphery of the slit-provided reinforcement member 81. Moreover, as shown in FIG. 19, a slit-provided reinforcement member 85 has slits 87 each formed in such a way that the width thereof gradually becomes narrow from the center of a refrigerant hole 86 toward the outer periphery of the slit-provided reinforcement member 85. The slit-provided reinforcement members 81, 85 can achieve the same effect as that of the slit-provided reinforcement member 55 in the foregoing embodiment. Note that the widths of the slits, 56, 81, 85 may be unequal for each intermediate plate.

[0126] The explanation has been given of the case where the refrigerant charging hole 4 or the air outlet port 5 has the four semi-spherical gas venting grooves 4b provided around the inner periphery surface of the circular opening 4a in the foregoing embodiment, but the invention is not limited to this case. As shown in FIG. 20A which shows the planer structure of a refrigerant charging hole or a air outlet port, and in FIG. 20B which shows the side sectional structure thereof, a refrigerant charging hole 90a or an air outlet port 90b may be formed in a reversed trapezoidal conic structure such that the diameter thereof is largest at the upper end, and becomes gradually small toward the bottom end, and is smallest at the bottom end. As shown in FIG. 20C which shows the way of sealing by the sealing member 8, the spherical sealing member 8 performs plastic deformation in accordance with the shape of the refrigerant charging hole 90a or the air outlet port 90b and becomes flat, thereby surely sealing the interior space.

[0127] As shown in FIG. 21A which shows the planer structure of a refrigerant charging hole or an air outlet port and in FIG. 21B which shows the side sectional structure thereof, a refrigerant charging hole 91 a or an air outlet port 91b in a further other embodiment may have an upper portion 92 having a large diameter and formed in a short cylindrical shape, and a lower portion 93 having a small diameter and formed in a short cylindrical shape, the upper plate 92 and the lower plate 93 being integrated together through a step 94.

[0128] In this case, as shown in FIG. 21C which shows the way of sealing by the sealing member 8, when the sealing member 8 performs plastic deformation and completely fills out the lower portion 93, the residue of the sealing member 8 is retained in the upper portion 92, so that it is possible to prevent the sealing member 8 from protruding from the top outside surface of the heat pipe 1, and the top outside surface can be flat. Note that the same effect as that of the foregoing embodiment can be achieved in any embodiments shown in FIGS 20A, 20B, and FIGS. 21A, 21B.

Claims

1. A heat pipe comprising:

a cooling unit main body that is formed of a metal and has a circulation path for a refrigerant formed in an interior space thereof;
a refrigerant charging hole that is formed in said cooling unit main body and is for charging said refrigerant in said interior space; and
a sealing member that plugs said refrigerant charging hole to seal said refrigerant in said interior space, wherein
said sealing member is formed of a same or similar plastic metal to that of said cooling unit main body.

2. A heat pipe comprising:

a cooling unit main body having a circulation path for a refrigerant formed in an interior space thereof by one or a plurality of intermediate plates provided between an upper plate and a lower plate; and
a refrigerant charging hole that is formed in said cooling unit main body and plugged by a sealing member when said refrigerant is charged in said interior space of said cooling unit main body, wherein
said intermediate plate has a reinforcement member formed at a portion corresponding to a peripheral region of said refrigerant charging hole and having a predetermined thickness, and a hole for said refrigerant formed in a portion corresponding to said refrigerant charging hole.

3. A heat pipe comprising:

a cooling unit main body having a circulation path for a refrigerant formed in an interior space thereof; and
a refrigerant charging hole that is formed in said cooling unit main body and plugged by a sealing member when said refrigerant is charged in said interior space of said cooling unit main body, wherein
said refrigerant is made into minute particles and charged in said interior space through said refrigerant charging hole.

4. A heat pipe comprising:

a cooling unit main body that is made of a metal and has a circulation path for a refrigerant formed in an interior space thereof by one or a

plurality of intermediate plates provided between an upper plate and a lower plate;
a refrigerant charging hole that is formed in said cooling unit main body and is for charging said refrigerant in said interior space; and
a sealing member that plugs said refrigerant charging hole to seal said refrigerant in said interior space, wherein:

said sealing member is formed of a same or similar plastic metal to that of said cooling unit main body;
said intermediate plate has a reinforcement member formed at a portion corresponding to a peripheral region of said refrigerant charging hole and having a predetermined thickness, and a hole for said refrigerant formed in a portion corresponding to said refrigerant charging hole; and
said refrigerant is made into minute particles and charged in said interior space through said refrigerant charging hole.

5. The heat pipe according to any one of claims 1 to 4, wherein said sealing member plugging said refrigerant charging hole does not protrude from a surface of said cooling unit main body.

6. The heat pipe according to any one of claims 1 to 5, wherein said refrigerant charging hole has a gas venting groove which is formed around an inner periphery surface thereof, causes said interior space to keep communicating with an exterior space until said refrigerant charging hole is completely plugged by said sealing member, and is plugged by said sealing member when said refrigerant charging hole is completely plugged.

7. The heat pipe according to claim 2 or 4, wherein
said circulation path has a vapor diffusion flow path where said refrigerant vaporizes and diffuses, and said portion corresponding to said refrigerant charging hole is disposed in said vapor diffusion flow path, and
said reinforcement member has a slit formed along a diffusion direction in which said refrigerant vaporizes and diffuses in said vapor diffusion flow path.

8. A heat pipe manufacturing method comprising:

a charging step of charging a refrigerant in a cooling unit main body formed of a metal and having a circulation path for said refrigerant formed in an interior space thereof through a refrigerant charging hole formed in said cooling unit main body;
a mounting step of mounting a sealing member formed of a same or a similar metal to that of said cooling unit main body on said refrigerant charging hole; and
a sealing step of plugging said refrigerant charging hole with said sealing member by applying pressure on said sealing unit under a vacuum condition.

9. A heat pipe manufacturing method comprising:

a charging step of charging a refrigerant in a cooling unit main body having a circulation path for said refrigerant formed in an interior space thereof through a refrigerant charging hole formed in said cooling unit main body;
a mounting step of mounting a sealing member on said refrigerant charging hole; and
a sealing step of plugging said refrigerant charging hole with said sealing member by applying pressure on said sealing member under a vacuum condition, wherein
said refrigerant is made into minute particles and charged in said interior space through said refrigerant charging hole in said charging step.

10. A heat pipe manufacturing method comprising:

a preparation step of preparing a cooling unit main body having a circulation path for a refrigerant formed in an interior space thereof by one or a plurality of intermediate plates provided between an upper plate and a lower plate, said intermediate plate having a reinforcement member which is formed at a portion corresponding to a peripheral region of a refrigerant charging hole formed in said upper plate or said lower plate and has a predetermined thickness, and a hole for said refrigerant formed at a portion corresponding to said refrigerant charging hole;
a charging step of charging said refrigerant in said interior space of said cooling unit main body through said refrigerant charging hole;
a mounting step of mounting a sealing member on said refrigerant charging hole; and
a sealing step of plugging said refrigerant charging hole with said sealing member by applying pressure on said sealing member under a vacuum condition.

11. A heat pipe manufacturing method comprising:

a preparation step of preparing a cooling unit main body that is formed of a metal and has a circulation path for a refrigerant formed in an interior space thereof by one or a plurality of intermediate plates provided between an upper plate and a lower plate, said intermediate plate having a reinforcement member which is formed at a portion corresponding to a peripheral region

of a refrigerant charging hole formed in said upper plate or said lower plate and has a predetermined thickness, and a hole for said refrigerant formed at a portion corresponding to said refrigerant charging hole;
a charging step of charging said refrigerant in said interior space of said cooling unit main body through said refrigerant charging hole;
a mounting step of mounting a sealing member which is formed of a same or a similar metal to that of said cooling unit main body on said refrigerant charging hole; and
a sealing step of plugging said refrigerant charging hole with said sealing member by applying pressure on said sealing member under a vacuum condition, wherein
said refrigerant is made into minute particles and charged in said interior space through said refrigerant charging hole in said charging step.

12. The heat pipe manufacturing method according to any one of claims 8 to 11, wherein in said sealing step, said interior space keeps communicating with an exterior space through a gas venting grove formed at an inner periphery surface of said refrigerant charging hole until said sealing member completely plugs said refrigerant charging hole.

13. The heat pipe manufacturing method according to any one of claims 8 to 12, wherein in said sealing step, said refrigerant charging hole is tentatively plugged with said sealing member by applying pressure on said sealing member under a vacuum condition, and is completely sealed with said sealing member by heating said sealing member while applying pressure thereon.

FIG.1

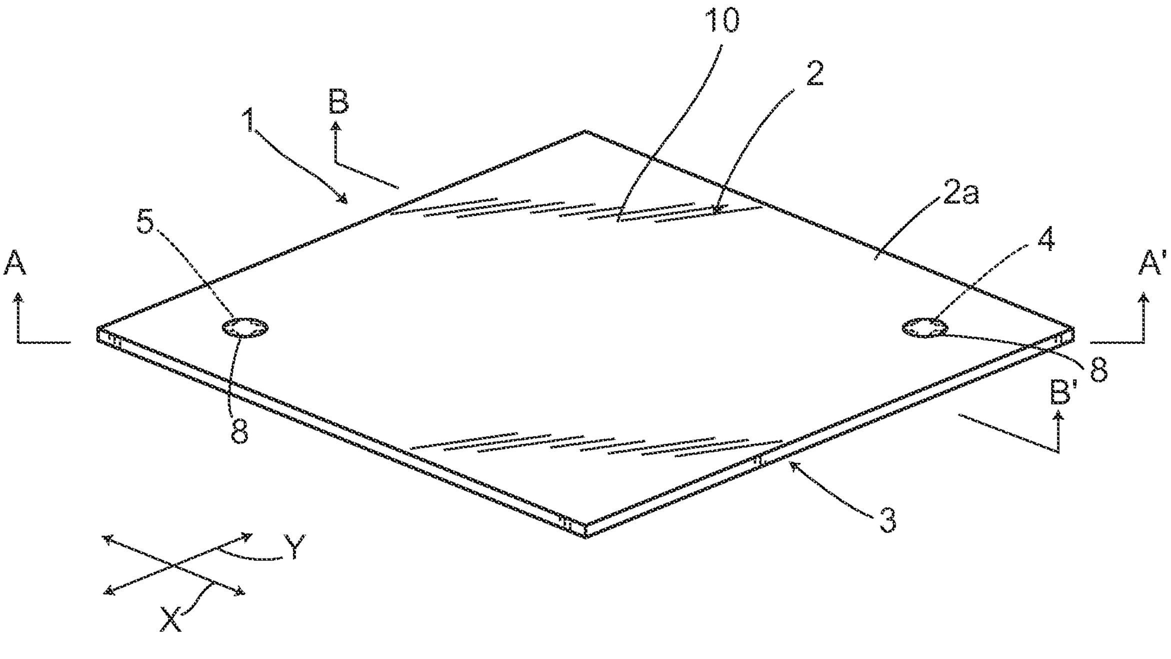
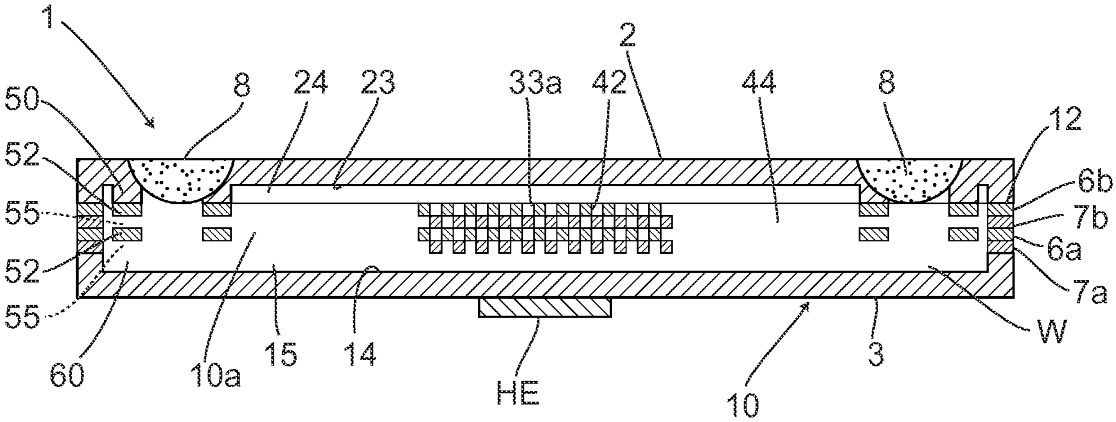


FIG.2A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8
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7b
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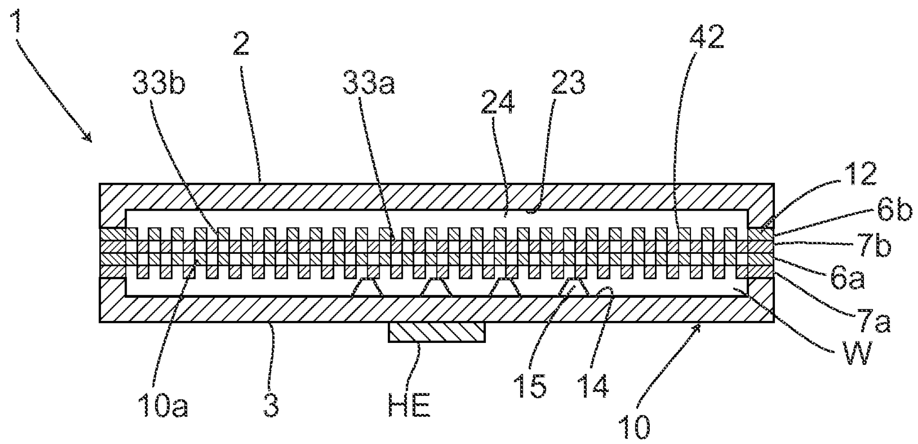
55
W
60
10a
15
14
HE
10
3

FIG.2B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14
10

FIG.3A

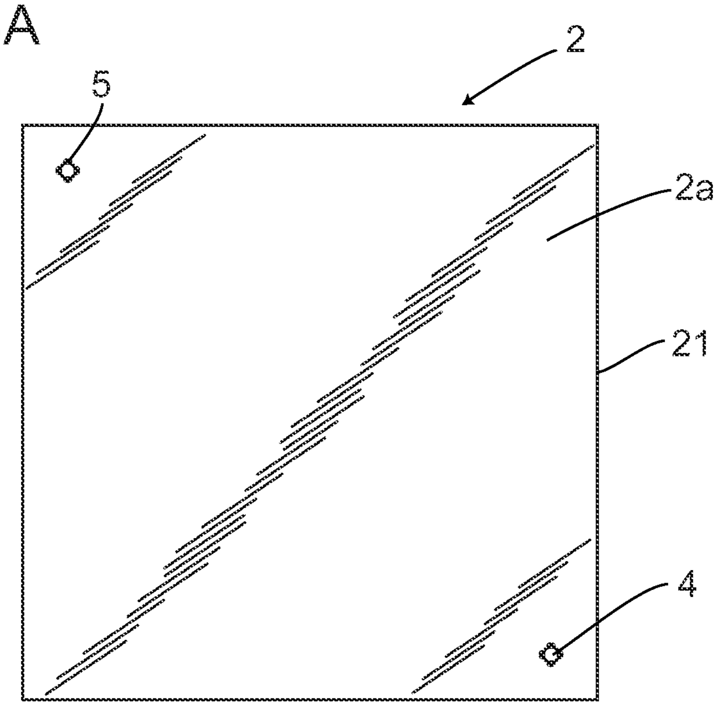


FIG.3B

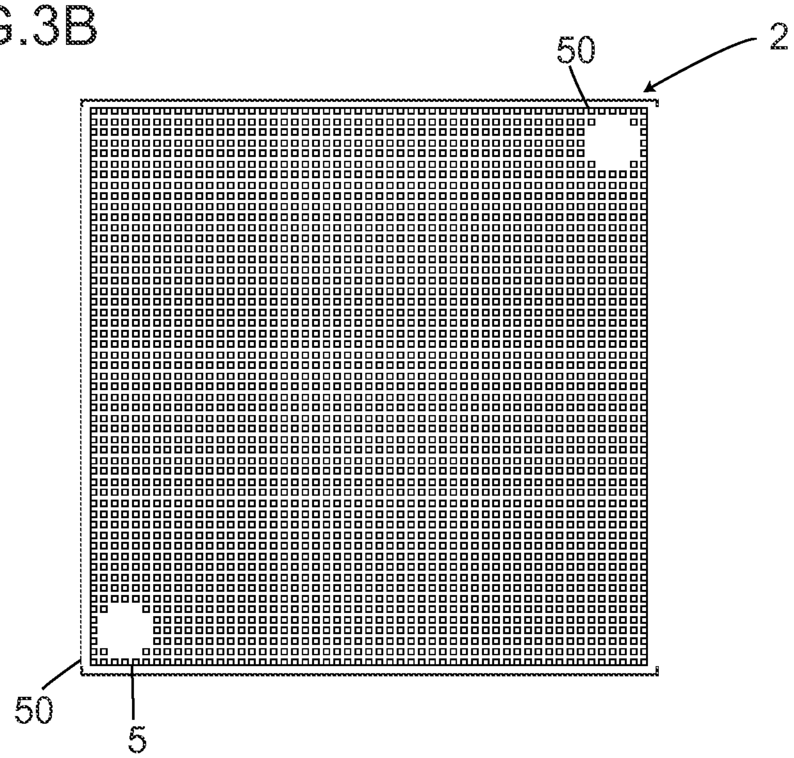


FIG.4A

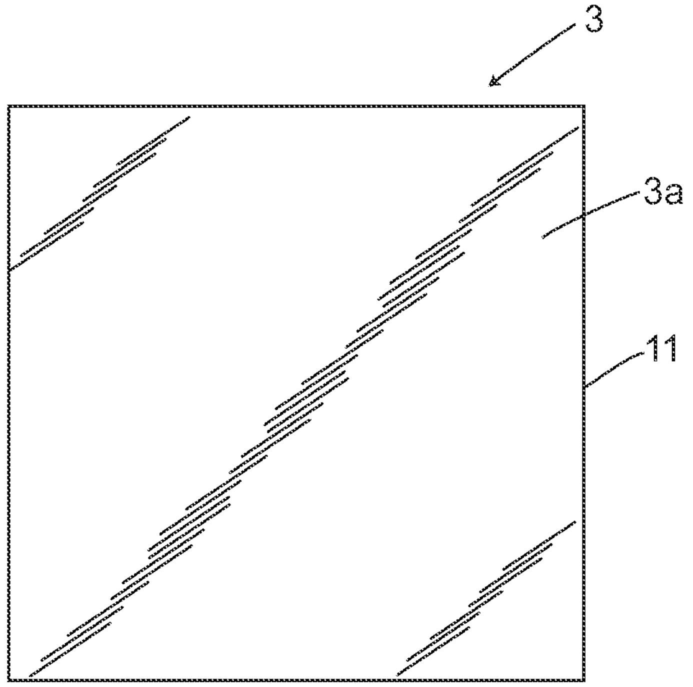


FIG.4B

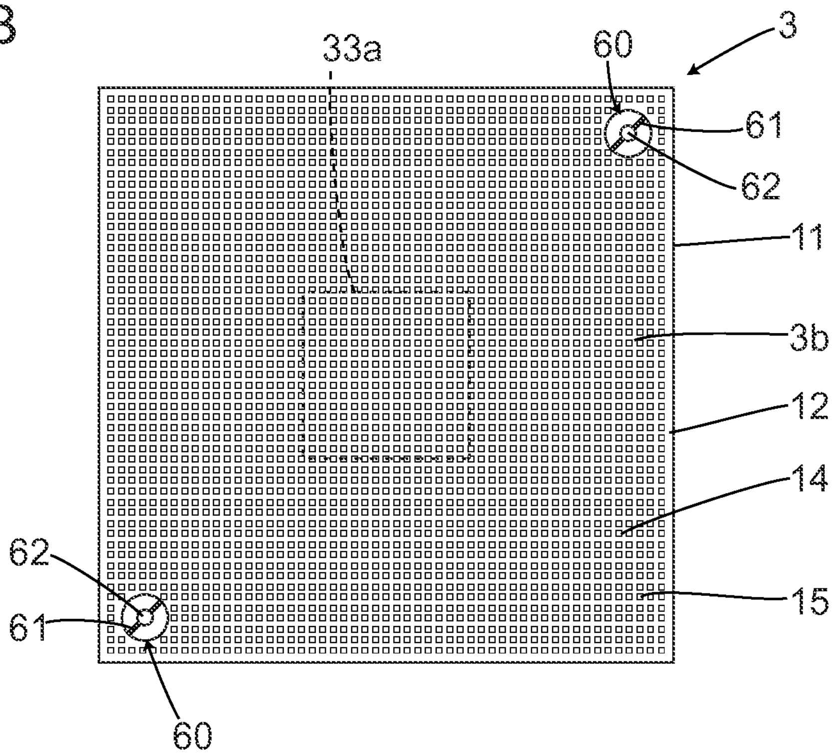


FIG.5

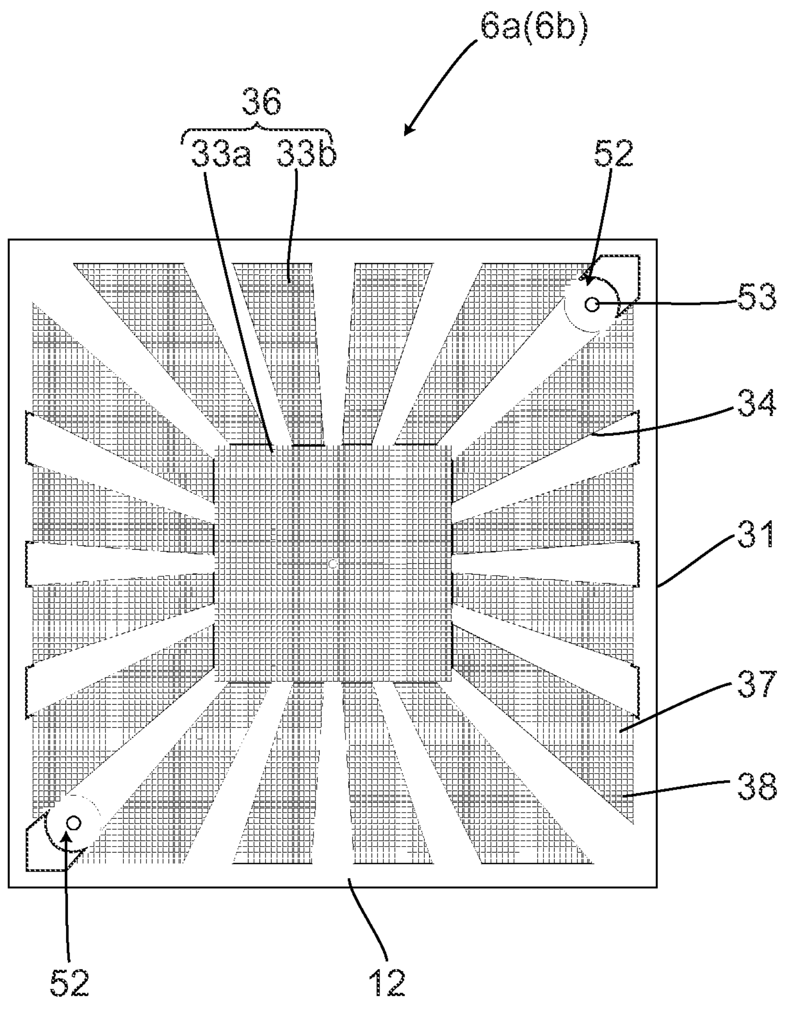


FIG.6

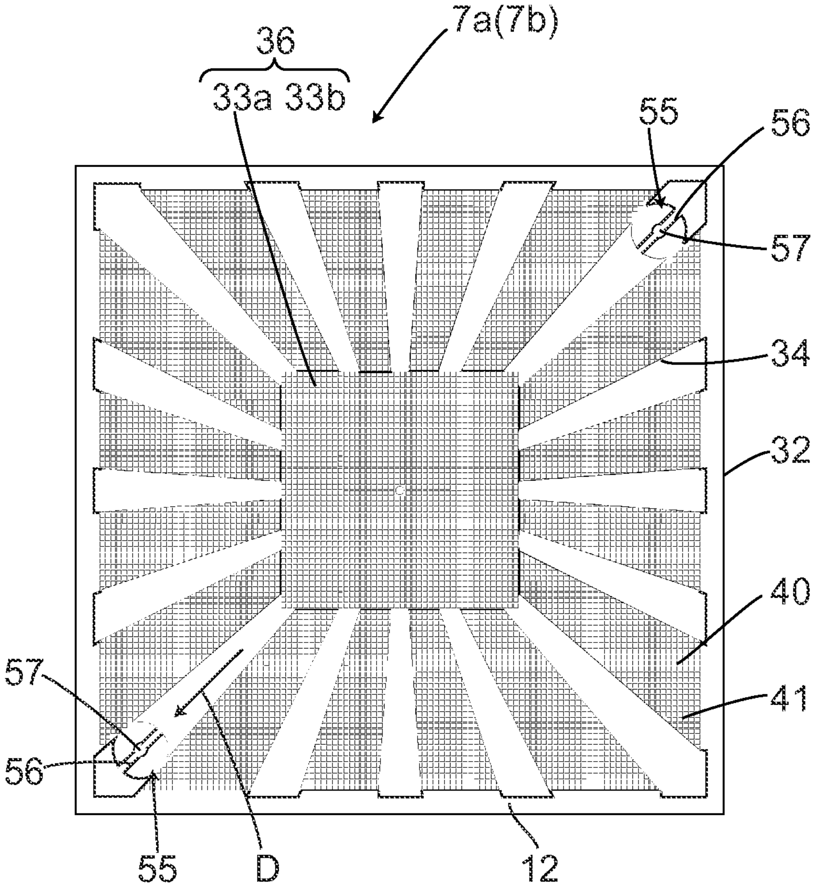


FIG.7

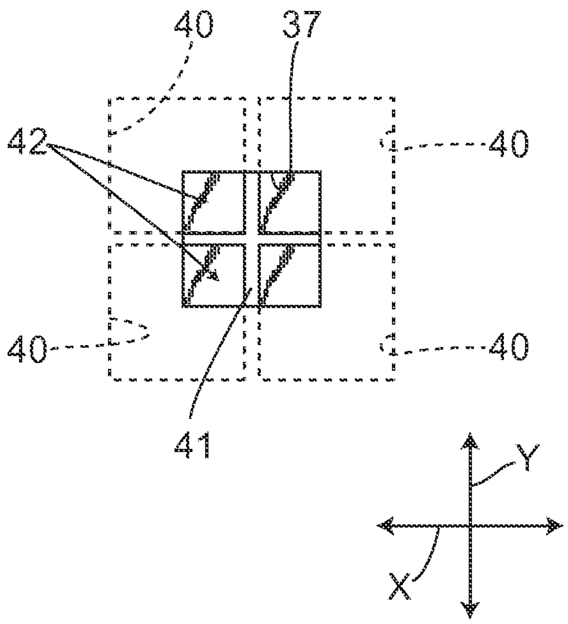


FIG.8

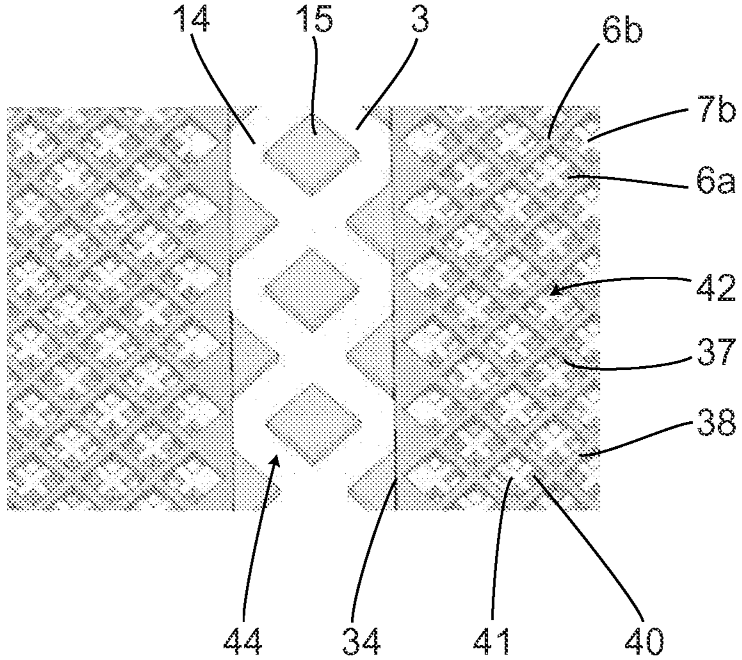
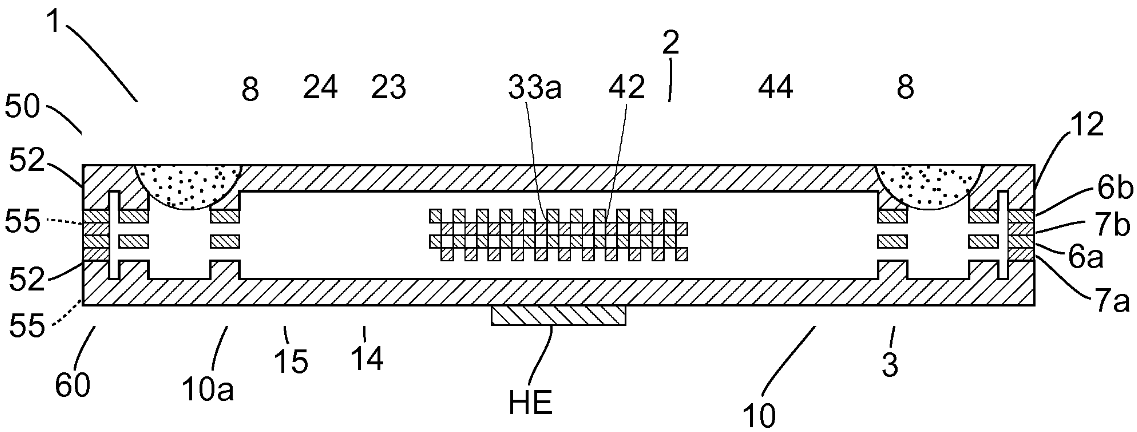


FIG.9A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14
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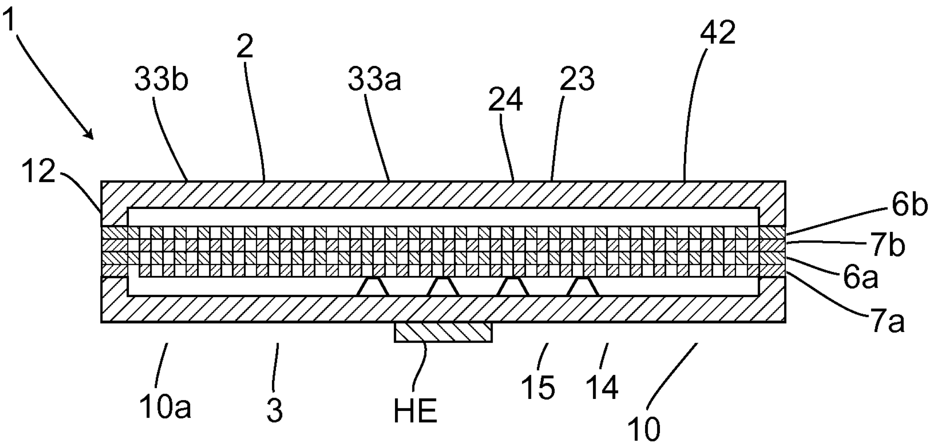
10
3

FIG.9B


1
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14
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FIG.10

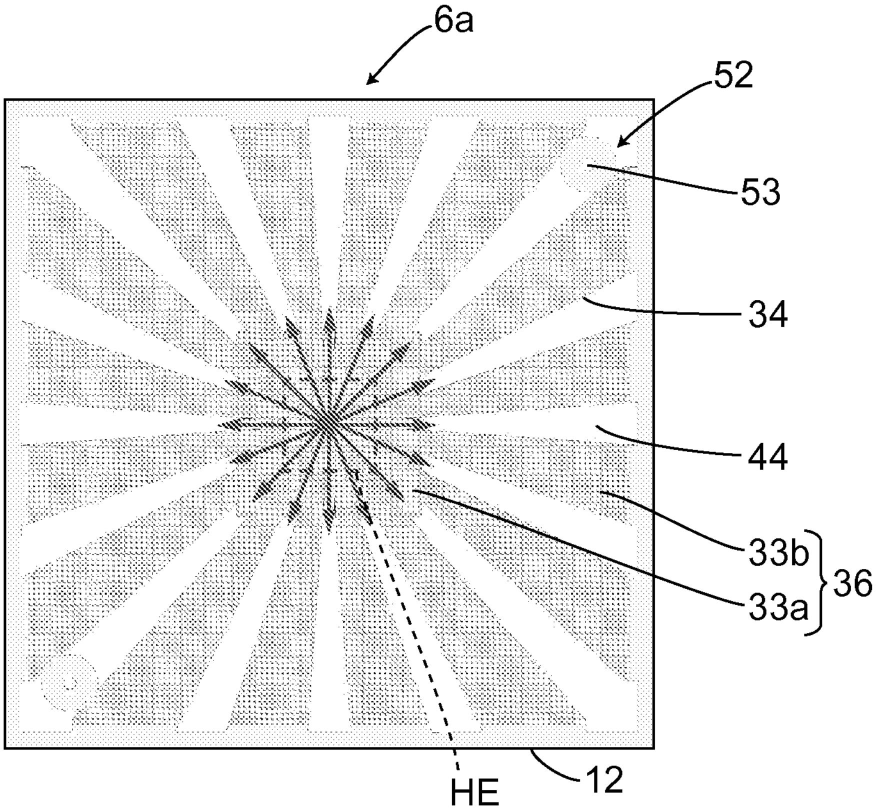


FIG.11

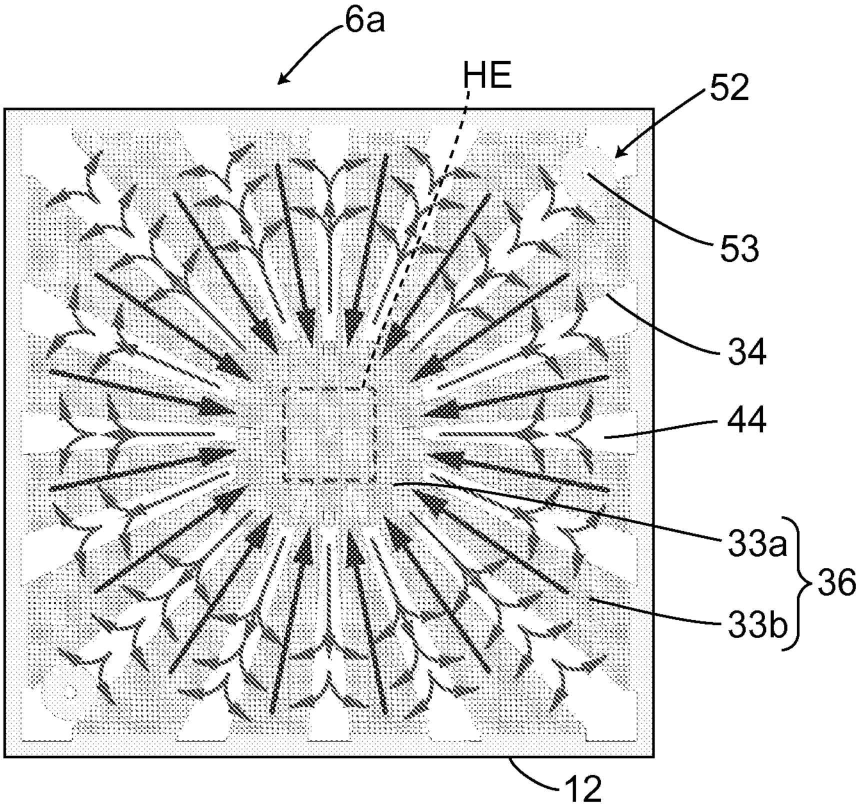


FIG.12A

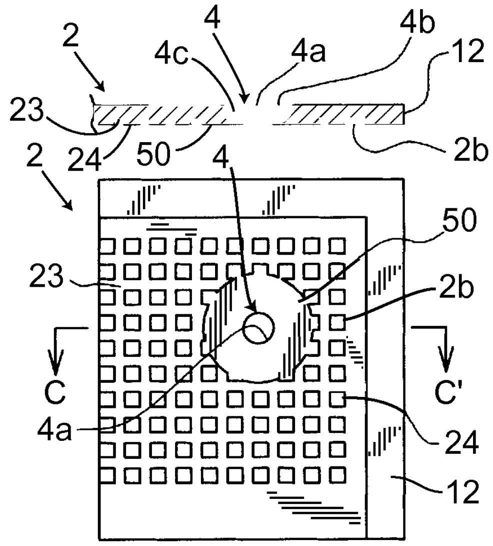


FIG.12B

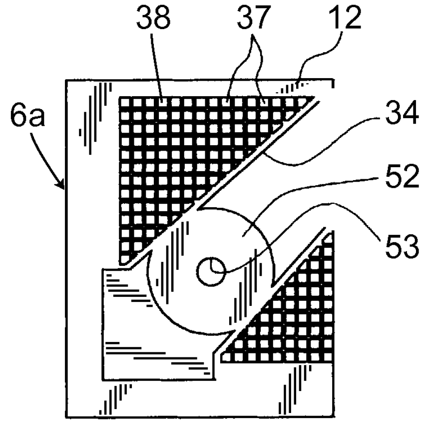


FIG.12C

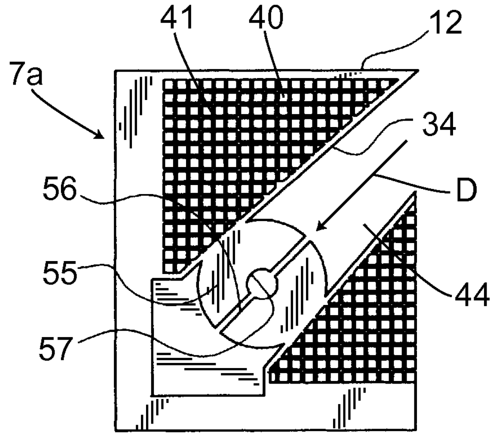


FIG.12D

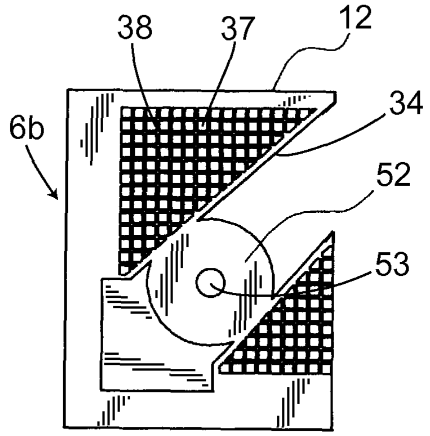


FIG.12E

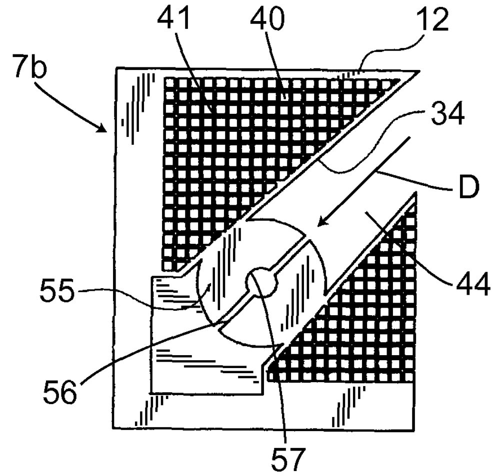


FIG.12F

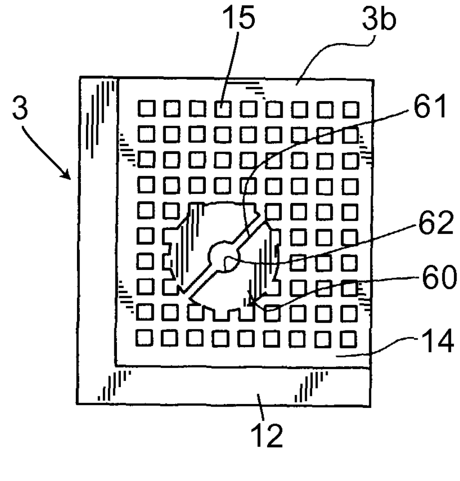


FIG.13

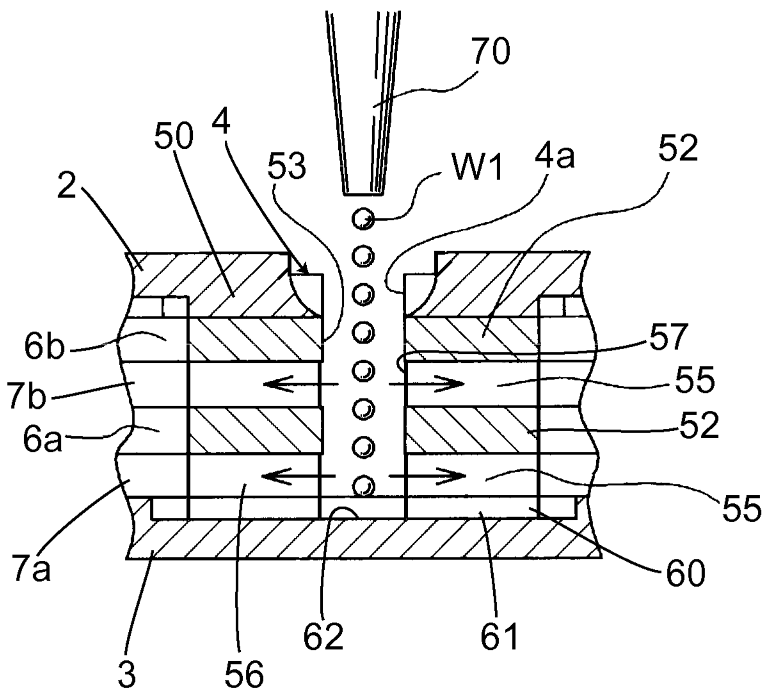


FIG.14A

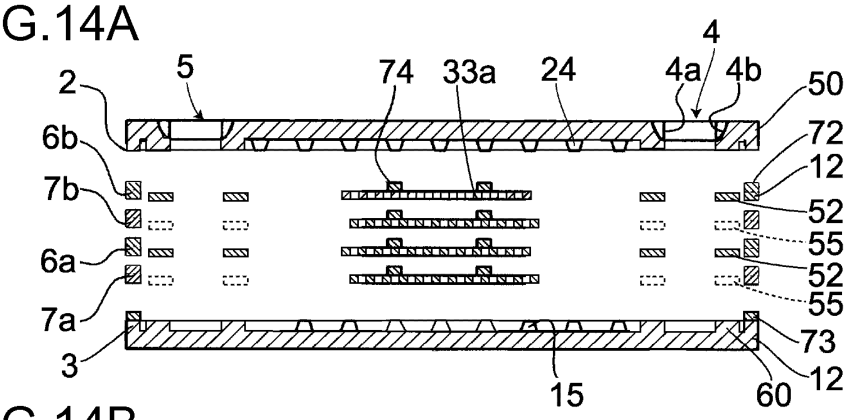


FIG.14B

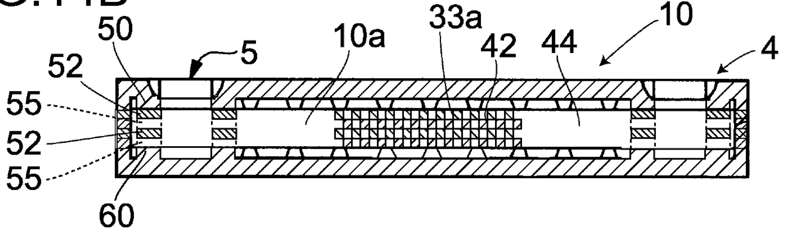


FIG.14C

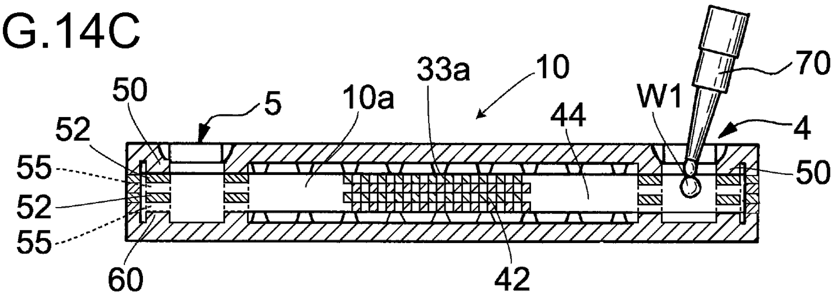


FIG.14D

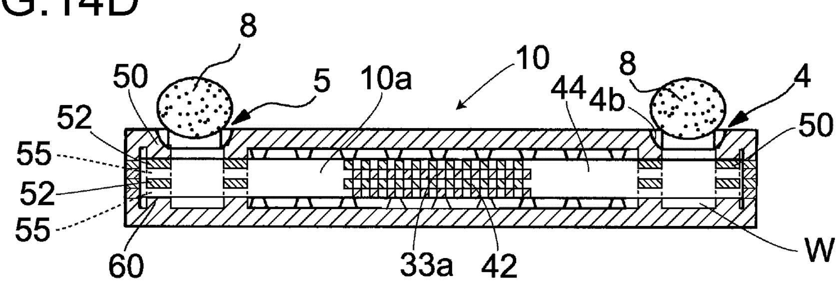


FIG.14E

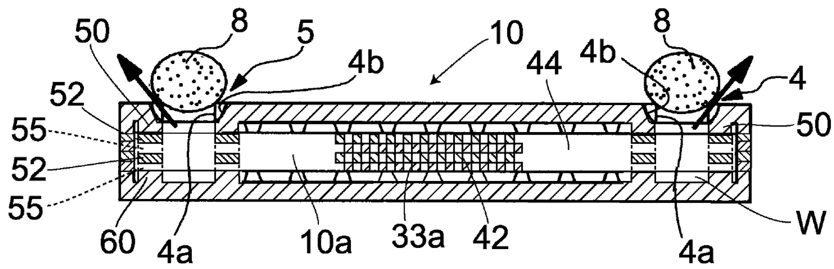


FIG.15A

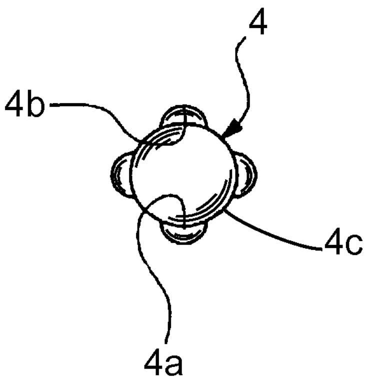


FIG.15B

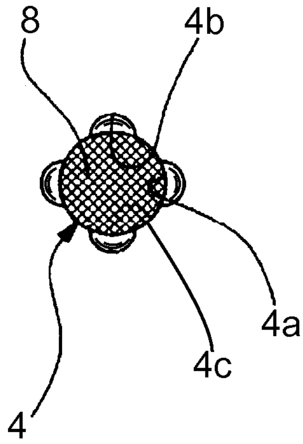


FIG.15C

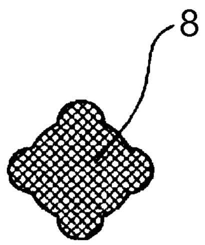


FIG.16A

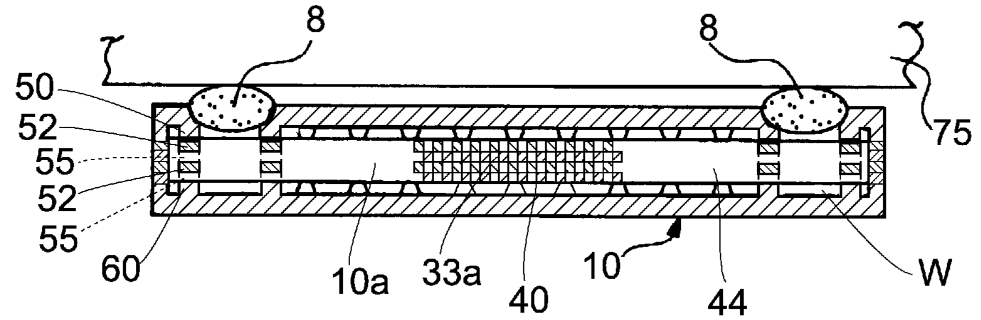


FIG.16B

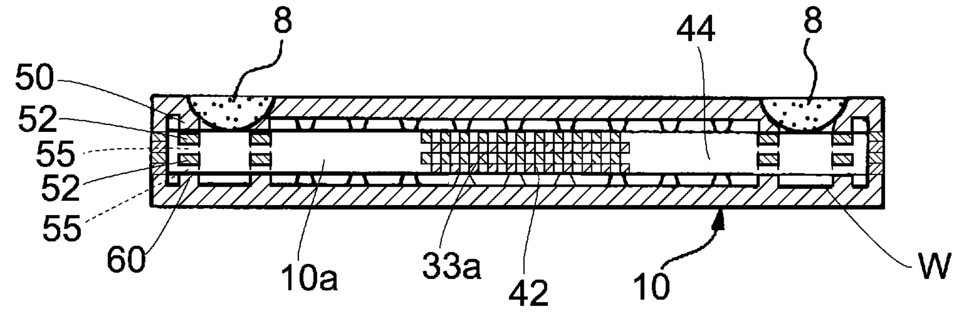


FIG.17

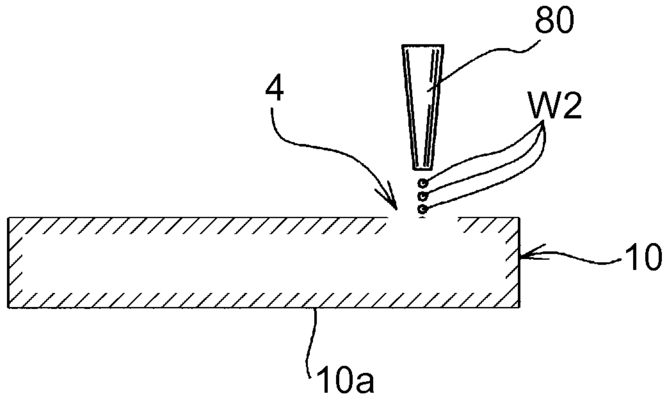


FIG.18

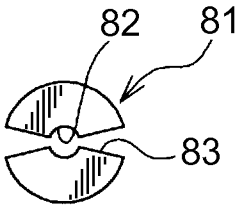


FIG.19

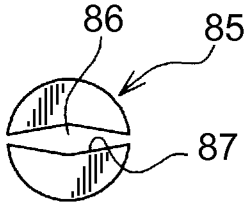


FIG.20A

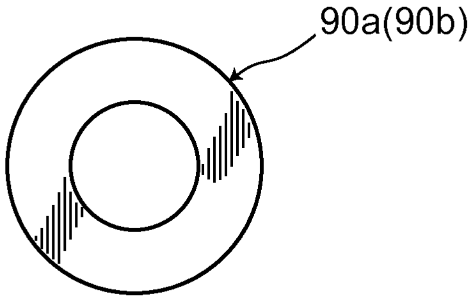


FIG.20B

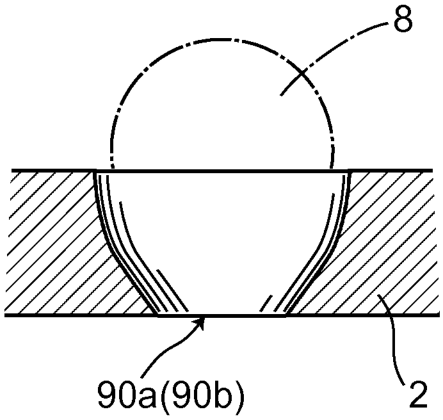


FIG.20C

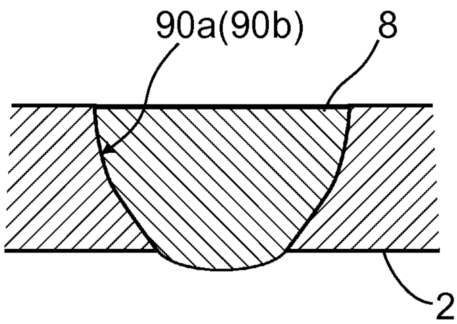


FIG.21A

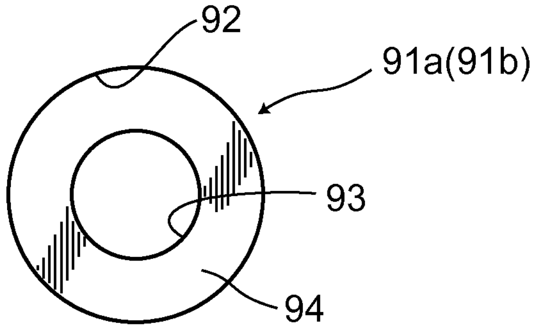


FIG.21B

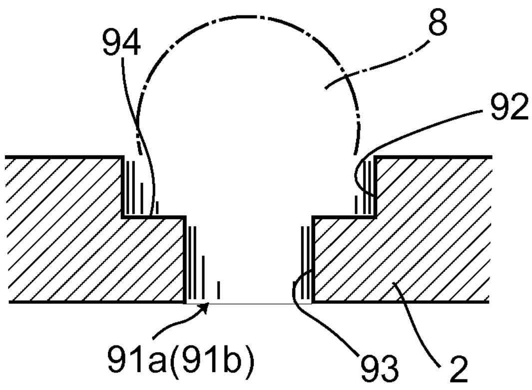
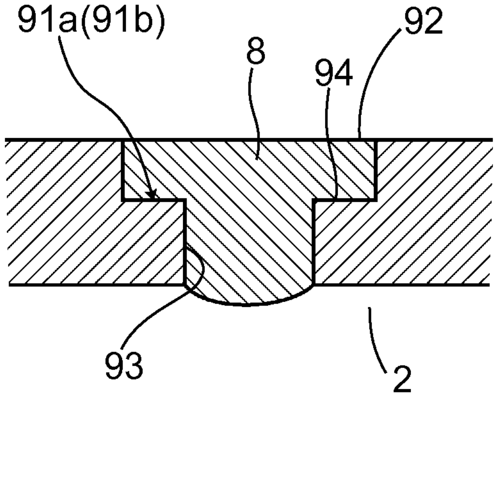


FIG.21C



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2007/053509

A. CLASSIFICATION OF SUBJECT MATTER
F28D15/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28D15/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 53-106135 A (Ricoh Co., Ltd.), 14 September, 1978 (14.09.78), Page 2, column 3, lines 7 to 14; column 5, lines 1 to 16 (Family: none)	1,5,8 4,9-11
Y A	JP 11-31768 A (Denso Corp.), 02 February, 1999 (02.02.99), Par. No. [0013]; Figs. 1 to 4, 8, 9 (Family: none)	2,4,10,11 6,7,12,13
Y A	JP 2000-156445 A (Denso Corp.), 06 June, 2000 (06.06.00), Par. No. [0014]; Fig. 3 & US 6341646 B1	2,4,10,11 6,7,12,13

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 May, 2007 (18.05.07)	29 May, 2007 (29.05.07)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/053509

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2000-249482 A (Hitachi Cable, Ltd.), 14 September, 2000 (14.09.00), Claim 3 (Family: none)	3 9-11

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2002039693 A **[0002] [0005] [0009]**
- JP 2004077120 A **[0002] [0005]**
- JP 2004007712 A **[0009]**