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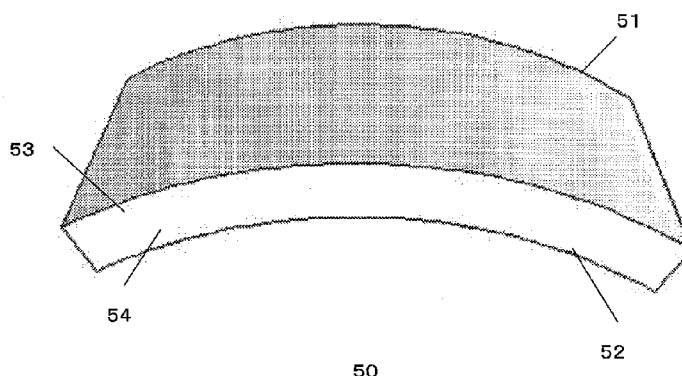
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[Continued on next page]

(54) Title: HEAT PIPE AND ELECTRONIC DEVICE

Figure 11



(57) Abstract: The Present Invention provides a heat pipe and an electronic device which can efficiently cool a light emitting element arranged in an end portion, so that it is possible to efficiently mount the heat pipe in a narrow space. The heat pipe is provided with an upper plate (3), a lower plate (4) opposing the upper plate (3), one intermediate plate or a plurality of intermediate plates (5) laminated between the upper plate (3) and the lower plate (4), a main body portion (2) formed by lamination of the upper plate (3), the lower plate (4) and the intermediate plate (5) and capable of sealing a cooling medium, a vapor diffusion path (6) capable of diffusing a vaporized cooling medium, and a capillary flow path (7) capable of reflowing a condensed cooling medium, and the vapor diffusion path (6) is formed from a first end portion (15) of the main body portion toward a second end portion (16) opposing the first end portion (15).



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HEAT PIPE AND ELECTRONIC DEVICE

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The Present Invention relates, generally, to a heat pipe, and more particularly, to a heat pipe for cooling a heating element.

DESCRIPTION OF THE RELATED ART

In electronic devices, the electronic parts are generally constructed as a heating element which generates heat by an electric current flowing through an internal portion. If the heat generation of the heating element comes to a fixed temperature or higher, there is a problem that an operation cannot be ensured, thereby adversely affecting the other parts of the electronic device and, potentially, the casing. As a result, performance deterioration of the electronic device may result.

Various proposals have been made to cool the heating element, such as, a heat pipe cooled by vaporization and condensation of a sealed cooling medium. In this example, the heat pipe transfers the heat away from the heating element towards the cooling medium, which, when in contact with the heat, vaporizes, thereby diffusing the heat. The vaporized cooling medium is then condensed by heat dissipation, which again reflows in a continuous closed cycle. Thus, the heat pipe can cool a heating element by repeated vaporization and condensation.

Typical examples of heat pipes have been disclosed in Japanese Patent No. 3233808 and Japanese Unexamined Patent Publication No. 11-101585. More specifically, the '808 Patent discloses a cooling system for transferring heat from a heating element to a heat dissipation member. That is, the '808 Patent describes, as a subject to be cooled, a heating element having a great calorific power – even as a simple substance such as the semiconductor integrated circuit, and conducts the heat from the heating element to a heat receiving portion, a heat conducting element and a heat dissipation portion to cool the heating element. In a different scope, the '585 Application discloses an electronic board having a cooling function.

In recent years, the various kinds of heating elements which require cooling make it necessary for the heat pipe to cool not only a central processing unit (CPU) and a large-scale

semiconductor integrated circuit, but also a light emitting element including a light emitting device (LED). In this case, the light emitting element is often very compact and is constructed by a set including a plurality of elements. In this case, a space in which the light emitting element and the heat pipe are mounted is often a narrow space.

The cooling system disclosed in the '808 Patent diffuses the heat from the heat receiving portion toward the heat conducting element. Accordingly, it is necessary for the cooling system disclosed in the '808 Patent to arrange the light emitting element in a back face of the heat receiving portion. Then, there is a problem that the light emitting element is hidden behind the member of the cooling system. If the cooling system is provided in an upright manner in an approximately vertical direction in order to avoid this, there is generated a problem that the cooling system occupies an extra volume. Since the heat is diffused radially from the light emitting element corresponding to a starting point, the member of the cooling system expands to up and down and right and left from the light emitting element corresponding to a starting point.

Accordingly, in order to cut down the mounting volume, it is necessary to arrange the light emitting element in an end portion of the member of the cooling system. However, in the cooling system disclosed in the '808 Patent, there is a problem that a heat diffusing capacity from the end portion to the heat conducting element is low, and a cooling capacity in the case where the light emitting element is arranged in the end portion is low. This is applied in the same manner to a heat pipe in which the heat receiving portion, a pipe passing the cooling medium vaporized by the heat receiving portion, and a cooling portion cooling the vaporized cooling medium received from the pipe are constructed by different members, regardless of the cooling system in the '808 Patent. In other words, even if it is intended to arrange the light emitting element in the end portion of the heat receiving portion in order to cut down the mounting volume, the cooling capacity is insufficient in the conventional heat pipe and cooling system.

Further, since the light emitting element is often compact and a plurality of light emitting elements are arranged, in comparison with the semiconductor integrated circuit, there is a problem that the light emitting element is hard to be arranged in the vicinity of the center of the heat receiving portion.

Further, in the electronic board in the '585 Application, although a plurality of narrow holes are aligned and the light emitting element is easily arranged in the end portion, it does not

have a structure suitable for diffusing the vaporized cooling medium and reflowing the condensed cooling medium, in addition to the fact that the narrow holes are independent. Therefore, the electronic board in the '585 Application is not suitable for cooling the light emitting element arranged in the end portion.

As mentioned above, the conventional heat pipe and cooling system cannot cool the heating element arranged in the end portion at a high efficiency by arranging the compact heating element in the end portion for cutting down the mounting volume. In particular, the conventional heat pipe and cooling system cannot cool the heating element arranged in the end portion efficiently, by making good use of the entire members (that is, the entire volume) of the heat pipe and the cooling system.

Further, in the light emitting element such as a high intensity LED or the like, taking Fourier law into consideration, (1) it is important to diffuse the heat efficiently so as to lower a heat flux. In other words, it is necessary to carry over the cooling function without any dry out (a state in which the vaporized cooling medium cannot be condensed) of the heat pipe, even if the high heat flux flows into the heat pipe. Further, (2) it is necessary that a combination with the heat dissipation member cooling the heat which is diffused by the heat pipe so as to be transferred is proper.

Taking this point into consideration, in the cooling system in the '808 Patent, since a heat exchanger plate element is constructed by a metal plate, a heat diffusing effect is insufficient and it is impossible to make the heat flux small. As a result, it is hard to keep a temperature of the heating element low. Further, in the heat exchanger plate element, the heat received from the heating element is transferred in a radial pattern in accordance with a temperature gradient, and a structure positively making the heat inflow with respect to the heat transfer path is not provided. Accordingly, the heat cannot efficiently flow into the heat transfer path.

The electronic board in the '585 Application can only transfer the heat one-dimensionally. In the case where the calorific power from the heating element reaches 100 W (the calorific power can reach 100 W in the high intensity LED), the cooling medium included in the electronic board dries out, and the cooling of the heating element cannot be carried over. Since the diffusing direction and the reflowing direction of the cooling medium included in the electronic board are one dimensional, the vaporized cooling medium is hard to be sufficiently cooled, and the dry out tends to be generated.

In other words, there is demanded a cooling apparatus which can efficiently diffuse and transfer the heat from the electronic part and the electronic element having a small size but a great calorific power so as to conduct the heat dissipation. At this time, it is important that there are few elements obstructing the inflow of the heat, at a time when the heat from the heating element is diffused and transferred. Further, the diffusion of the vaporized cooling medium is carried out by efficiently utilizing the casing of the heat pipe, whereby it is necessary to cool the vaporized cooling medium efficiently.

In other words, in the compact light emitting element in which the calorific power is very high, it is important that (1) the light emitting element serving as the heating element is easily mounted to the end portion, (2) the mounting volume as a whole is not made too large even if it is mounted to the end portion, (3) there are few obstructing elements in the diffusion and the transfer of the received heat, (4) the heat can be diffused and transferred by using the entire heat pipe, (5) the diffusion of the vaporized cooling medium and the reflow of the condensed cooling medium are carried out by using the entire heat pipe three-dimensionally.

The Present Invention has been made by taking these requirements into consideration, and an object of the invention is to provide a heat pipe and an electronic device which can efficiently cool a light emitting element arranged in an end portion, so that it is possible to efficiently mount the light emitting element in a narrow space.

SUMMARY OF THE INVENTION

Taking the object mentioned above into consideration, according to the Present Invention, there is provided a heat pipe including: an upper plate; a lower plate opposing the upper plate; one intermediate plate or a plurality of intermediate plates laminated between the upper plate and the lower plate; a main body portion formed by lamination of the upper plate, the lower plate and the intermediate plate and capable of sealing a cooling medium; a vapor diffusion path capable of diffusing the vaporized cooling medium; and a capillary flow path capable of reflowing the condensed cooling medium, wherein the vapor diffusion path is formed from a first end portion of the main body portion toward a second end portion opposing the first end portion.

The heat pipe according to the Present Invention easily mounts the heating element corresponding to the compact electronic part such as the high intensity LED to the end portion

thereof. Further, the heat pipe according to the Present Invention can efficiently diffuse the heat from the end portion in which the heating element is mounted, toward the end portion opposing the end portion. In particular, since it is possible to diffuse the vaporized cooling medium and reflow the condensed cooling medium by three-dimensionally making a good use of the entire heat pipe, the vaporized cooling medium can be effectively cooled.

As a result, even in the case where the high intensity LED or the like having a very high calorific power is mounted in the end portion, the heat pipe according to the Present Invention can maintain the cooling function without generating any dry out or the like.

BRIEF DESCRIPTION OF THE FIGURES

The organization and manner of the structure and operation of the Present Invention, together with further objects and advantages thereof, may best be understood by reference to the following Detailed Description, taken in connection with the accompanying Figures, wherein like reference numerals identify like elements, and in which:

- Fig. 1 is an inside view of a heat pipe according to the Present Invention;
- Fig. 2 is a cross sectional view of the heat pipe of FIG. 1;
- Fig. 3 is an exploded cross sectional view of the heat pipe of FIG. 1;
- Fig. 4 is an inside view of the heat pipe of FIG. 1;
- Fig. 5 is an inside view of a part of an electronic device according to the Present Invention;
- Fig. 6 is an inside view showing a modified example of the heat pipe of FIG. 1;
- Fig. 7 is a schematic view expressing three examples;
- Fig. 8 is a temperature distribution view of a heat pipe surface in Examples 1 to 3;
- Fig. 9 is a temperature distribution view of the heat pipe surface in Examples 1 to 3;
- Fig. 10 is an explanatory view showing a result of experiment;
- Fig. 11 is a perspective view of a heat pipe according to the Present Invention;
- Fig. 12 is a mounting view of a heat pipe of FIG. 1 having a curved shape;
- Fig. 13 is a mounting view of the heat pipe of FIG. 1;
- Fig. 14 is an exploded view of the heat pipe of FIG. 1; and
- Fig. 15 is a perspective view of an electronic device according to the Present Invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

While the Present Invention may be susceptible to embodiment in different forms, there is shown in the Figures, and will be described herein in detail, specific embodiments, with the understanding that the discussion herein is to be considered an exemplification of the principles of the Present Invention, and is not intended to limit the Present Invention merely to that as illustrated. Further, in the embodiments illustrated in the Figures, representations of directions such as up, down, left, right, front, rear and the like, used for explaining the structure and movement of the various elements of the Present Invention, are not absolute, but relative. These representations are appropriate when the elements are in the position shown in the Figures. If the description of the position of the elements changes, however, it is assumed that these representations are to be changed accordingly.

According to a first aspect of the Present Invention, there is provided a heat pipe including: an upper plate; a lower plate opposing the upper plate; one intermediate plate or a plurality of intermediate plates laminated between the upper plate and the lower plate; a main body portion formed by lamination of the upper plate, the lower plate and the intermediate plate and capable of sealing a cooling medium; a vapor diffusion path capable of diffusing the vaporized cooling medium; and a capillary flow path capable of reflowing the condensed cooling medium, wherein the vapor diffusion path is formed from a first end portion of the main body portion toward a second end portion opposing the first end portion.

According to this structure, the heat pipe can efficiently diffuse the heat from the heating element arranged in the first end portion to the second end portion. Further, the heat pipe can diffuse the vaporized cooling medium and reflow the condensed cooling medium by using a whole thereof, and does not obstruct the diffusion and the reflow from each other. Accordingly, it is possible to diffuse the heat of the heating element arranged in the end portion by efficiently utilizing the entire heat pipe.

In a heat pipe according to a second aspect of the Present Invention, a width in the second end portion of the vapor diffusion path is wider than a width in the first end portion, in addition to the first aspect.

According to this structure, the cooling medium vaporized in the first end portion in which the heating element is arranged can be diffused toward the second end portion without

being obstructed. Therefore, the heat diffusion capacity from the first end portion toward the second end portion of the heat pipe is improved.

In a heat pipe according to a third aspect of the Present Invention, the vapor diffusion path broadens toward the end from the first end portion to the second end portion, in addition to the second aspect.

According to this structure, the cooling medium vaporized in the first end portion in which the heating element is arranged can be diffused toward the second end portion without being obstructed. Therefore, the heat diffusion capacity from the first end portion toward the second end portion of the heat pipe is improved.

In a heat pipe according to a fourth aspect of the Present Invention, a width in the second end portion of the vapor diffusion path is approximately identical to a width in the first end portion, in addition to the first aspect.

According to this structure, the cooling medium vaporized in the first end portion in which the heating element is arranged can be diffused toward the second end portion without being obstructed, and the condensed cooling medium can reflow without being obstructed. In other words, the diffusion of the vaporized cooling medium and the reflow of the condensed cooling medium can move with an appropriate balance. As a result, the heat pipe can efficiently diffuse the heat from the heating element arranged in the end portion.

In a heat pipe according to a fifth aspect of the Present Invention, the intermediate plate has a notch portion and an internal through hole, the notch portion forms the vapor diffusion path, and the internal through hole forms the capillary flow path, in addition to any one of the first to fourth aspects.

According to this structure, it is possible to easily form the vapor diffusion path which can diffuse the vaporized cooling medium in planar and thickness directions, and the capillary flow path which can reflow the condensed cooling medium in a vertical direction or vertical and planar directions, even in an inner portion of a thin heat pipe.

In a heat pipe according to a sixth aspect of the Present Invention, the number of the intermediate plates is plural, the internal through holes provided respectively in a plurality of intermediate plates overlap only partly, and a capillary flow path having a smaller cross sectional area than that in a horizontal direction of the internal through hole is formed, in addition to the fifth aspect.

According to this structure, the capillary flow path having a more minute flow path can be easily formed.

In a heat pipe according to a seventh aspect of the Present Invention, each of the upper plate and the lower plate is further provided with a concave portion communicating with at least a part of the capillary flow path and the vapor diffusion path, in addition to any one of the first to sixth aspects.

According to this structure, the vapor diffusion path can diffuse the vaporized cooling medium not only in a planar direction but also in a thickness direction. Further, a surface area with which the vaporized cooling medium comes into contact becomes large, and the cooling of the vaporized cooling medium is promoted. Further, the reflow of the condensed cooling medium to the capillary flow path is promoted.

In a heat pipe according to an eighth aspect of the Present Invention, the vapor diffusion path diffuses the vaporized cooling medium in a planar direction and a thickness direction, and the capillary flow path reflows the condensed cooling medium in a vertical direction or vertical and planar directions, in addition to any one of the first to seventh aspects.

According to this structure, the heat pipe can achieve the efficient heat diffusion from the first end portion toward the second end portion.

A description will be given of an embodiment according to the Present Invention with reference to the accompanying drawings.

Note that the heat pipe in the present specification means a member, a part, an apparatus and a device achieving a function of cooling the heating element by repeating the vaporization of the cooling medium sealed in the internal space due to the heat applied from the heating element, and the condensation of the vaporized cooling medium by being cooled.

Embodiment 1 – Description of concept of heat pipe

First, a description will be given of a concept of the heat pipe.

The heat pipe is structured such that the cooling medium is sealed in the internal portion, and the surface forming the heat receiving surface comes into contact with the heating element including the electronic part. The internal cooling medium is vaporized by receiving the heat from the heating element, and takes up the heat of the heating element at the time of vaporizing. The vaporized cooling medium moves (is diffused) in the heat pipe. The heat of the heating

element is transported due to this movement. The moving vaporized cooling medium is cooled in a heat dissipation surface or the like of the heat pipe (or by a secondary cooling member such as a heat sink, a cooling fan or the like) so as to be condensed. The cooling medium which is condensed so as to become the liquid reflows in the internal portion of the heat pipe so as to move again to the heat receiving surface. The cooling medium having moved to the heat receiving surface is again vaporized so as to take up the heat of the heating element.

The heat pipe cools the heating element by repeated vaporization and condensation of the cooling medium as mentioned above. Accordingly, it is necessary that the heat pipe has, in its internal portion, a vapor diffusion path diffusing the vaporized cooling medium and a capillary flow path reflowing the condensed cooling medium.

Examples of the heat pipe include a heat pipe having a structure reflowing a condensed cooling medium in a vertical direction as well as diffusing the vaporized cooling medium in the vertical direction while having a tubular shape, and a heat pipe having a structure in which a heat receiving portion coming into contact with the heating element and a cooling portion cooling the cooling medium are independent of each other and are connected by a pipe.

The heat pipes having these structures have a complicated shape for transporting the cooling medium vaporized due to the heat received by the heat receiving portion by the heat transfer element such as the pipe, and are hard to mount the heating element in the end portion. Accordingly, a tabular heat pipe is demanded. However, since the tabular heat pipe is structured so as to diffuse the heat from the center toward the periphery or diffuse the heat only linearly or one-dimensionally, the tabular heat pipe cannot achieve the heat diffusion from the end portion without dry out with respect to the heating element having the great calorific power.

The heat pipe according to the Present Invention can mount the heating element in the end portion, does not require the mounting volume, and can cool the heating element by three-dimensionally making a good use of the entire heat pipe so as to diffuse the heat.

Whole structure

First, a description will be given of a whole structure of the heat pipe with reference to Figs. 1 and 2.

Fig. 1 is an inside view of the heat pipe in the embodiment 1 according to the Present Invention, and Fig. 2 is a cross sectional view of the heat pipe in the embodiment 1 according to the Present Invention.

Fig. 1 shows a view obtained by seeing through the internal portion of the heat pipe from above, and Fig. 2 shows a cross sectional view as seen from the end portion of the heat pipe.

A heat pipe 1 is provided with an upper plate 3, a lower plate 4, one intermediate plate 5 or a plurality of intermediate plates 5, a vapor diffusion path 6, and a capillary flow path 7. The lower plate 4 opposes the upper plate 3, and one intermediate plate 5 or a plurality of intermediate plates 5 are laminated between the upper plate 3 and the lower plate 4. The main body portion 2 is formed by laminating and bonding the upper plate 3, the lower plate 4 and the intermediate plates 5, and has an internal space which can seal a cooling medium 11. The heat pipe 1 can cool the heating element by the vaporization and the condensation of the cooling medium sealed in the internal space.

The vapor diffusion path 6 is formed by a notch portion 8, and the capillary flow path 7 is formed by an internal through hole 9.

The vapor diffusion path 6 diffuses the vaporized cooling medium. The vaporized cooling medium is diffused to at least one of a planar direction and a thickness direction via the vapor diffusion path 6. In particular, since the vapor diffusion path 6 is formed from the upper plate 3 to the lower plate 4, and at least a part of the vapor diffusion path 6 is communicated with a concave portion 12 formed in at least a part of the upper plate 3 and the lower plate 4, the cooling medium vaporized by receiving the heat from the heating element is diffused three-dimensionally along the planar direction and the thickness direction.

As is apparent from Fig. 1, the vapor diffusion path 6 is formed from a first end portion 15 toward a second end portion 16. Accordingly, the vapor diffusion path 6 diffuses the vaporized cooling medium from the first end portion 15 toward the second end portion 16. In other words, the heat pipe 1 has a heat diffusion characteristic from the end portion 15 toward the end portion 16.

The capillary flow path 7 reflows the cooled and condensed cooling medium. The capillary flow path 7 reflows the condensed cooling medium in a vertical direction or vertical and planar directions. In other words, the capillary flow path 7 moves the condensed cooling medium three-dimensionally in the same manner as the vapor diffusion path 6. At this time,

since at least a part of the capillary flow path 7 is communicated with a part of the concave portion 12, the condensed cooling medium moves from the concave portion 12 of the upper plate 3 to the capillary flow path 7, or vice versa. Accordingly, the cooling medium can also move in the vertical direction. In the same manner, since the capillary flow path 7 is two-dimensionally formed in the internal space, the cooling medium can also move in a planar direction. As mentioned above, the capillary flow path 7 also reflows the condensed cooling medium three-dimensionally.

In addition, since the capillary flow path 7 is formed over the first end portion 15 and the second end portion 16 in conformity to the shape of the vapor diffusion path 6, the capillary flow path 7 reflows the condensed cooling medium from the second end portion 16 toward the first end portion 15.

Since the diffusion of the vaporized cooling medium and the reflow of the condensed cooling medium are carried out between the first end portion 15 and the second end portion 16, the heat from the heating element arranged in the first end portion 15 is efficiently cooled. The heat from the heating element received by the first end portion 15 is diffused from the first end portion 15 to the second end portion 16. Since the heat is diffused from the first end portion 15 to the second end portion 16, the diffusion is equivalent to the diffusion carried out by using the entire heat pipe 1. Further, since the diffusion is carried out three-dimensionally in the entire heat pipe 1, the vaporized cooling medium tends to be cooled. This is because the vaporized cooling medium moves by using the entire heat pipe 1, and a contact area with a member (the upper plate 3, the lower plate 4 and the side surface) connecting to the outside becomes wider.

In the same manner, since the capillary flow path 7 moves the condensed cooling medium from the second end portion 16 to the first end portion 15, the condensed cooling medium is supplied to the first end portion 15. Since the capillary flow path 7 is in a state of being separated from the vapor diffusion path 6, the capillary flow path 7 can reflow the condensed cooling medium without being obstructed by the diffusing vapor. Accordingly, the reflow of the condensed cooling medium can be carried out at a high speed. As a result, the condensed cooling medium is repeatedly supplied to the first end portion 15 in which the heating element is arranged.

Particularly at this time, not only is the vapor diffusion path 6 formed from the first end portion 15 toward the second end portion 16, but also the capillary flow path 7 is formed from

the second end portion 16 toward the first end portion 15 in such a manner as to correspond to the position of the vapor diffusion path 6, so that a plurality of vapor diffusion paths 6 and capillary flow paths 7 which may form a plurality of passages are formed between the first end portion 15 and the second end portion 16. Further, as shown in Fig. 1, since the vapor diffusion path 6 and the capillary flow path 7 are lined up alternately while being positioned between the first end portion 15 and the second end portion 16 in such a manner that one vapor diffusion path 6 and one capillary flow path 7 are adjacent to each other, it is possible to achieve a balance between the diffusion of the vaporized cooling medium from the first end portion 15 to the second end portion 16 and the reflow of the condensed cooling medium from the second end portion 16 to the first end portion 15. In the cooling of the heating element by the heat pipe, not only the diffusion of the vaporized cooling medium but also the efficient reflow of the condensed cooling medium is demanded.

From this matter, since the vapor diffusion path 6 and the capillary flow path 7 are formed over the first end portion 15 and the second end portion 16 (particularly, a plurality of vapor diffusion paths 6 and a plurality of capillary flow paths 7 are respectively formed so as to be alternately lined up), the heat pipe 1 in the embodiment 1 can cool the heating element arranged in the end portion at a high efficiency. Of course, since it is possible to cool by using the entire heat pipe 1, there is no useless portion, and any extra mounting space is not demanded.

In this case, as is apparent from Fig. 1, the heat pipe 1 is of a thin type and has a tabular shape; however, it may have various shapes such as a circular shape, an oval shape and a polygonal shape. Of course, it may be curved.

Further, a size of the heat pipe 1 is not particularly limited; however, there is a case where a certain size range is proper in an actual use.

As one example, the heat pipe 1 has a rectangular shape of 20 mm $\times$ 20 mm square or more and 200 mm $\times$ 200 mm square or more, and further has a thickness of 1 mm or more and 5 mm or less. The size defined as mentioned above is introduced from a size of the electronic part corresponding to the heating element to be cooled, easiness on mounting to the circuit board, and the like. Since the heat pipe 1 has a size mentioned as an example in this case, the balance between the mounting and the cooling can be suitably achieved.

Of course, the size of the heat pipe 1 is not limited to this size, but may be defined in accordance with various demands such as a demand on manufacturing, a demand on use, a demand on mounting and the like.

Next, a description will be given of details of each of the portions with reference to Figs. 2 and 3. Fig. 3 is an exploded cross sectional view of the heat pipe in the embodiment 1 according to the Present Invention.

In this case, the first end portion 15 and the second end portion 16 are properly used as “first” and “second” as a matter of convenience, and are not specially differentiated. The side in which the heating element is arranged is merely defined as the first.

Upper plate

The upper plate 3 is formed as a tabular shape, and has predetermined shape and area.

The upper plate 3 is formed from a metal, a resin or the like, and is preferably formed from a metal having a high coefficient of thermal conductivity or a high rust proofing characteristic (durability) such as copper, aluminum, silver, aluminum alloy, iron, iron alloy, or stainless steel. Further, the upper plate 3 may have various shapes such as a rectangular shape, a rhombic shape, a circular shape, an oval shape, or a polygonal shape.

It is preferable that the upper plate 3 has a concave portion 12 which is communicated with at least one of the vapor diffusion path 6 and the capillary flow path 7, in one surface opposing the intermediate plate 5. Since the concave portion 12 is communicated with the capillary flow path 7, the condensed cooling medium tends to be transmitted from the upper plate 3 to the capillary flow path 7. Alternatively, since the concave portion 12 is communicated with the vapor diffusion path 6, the vaporized cooling medium tends to come into contact at a wide area with the surface of the upper plate 3, and the heat dissipation of the vaporized cooling medium is promoted. In addition, since the concave portion 12 is communicated with the vapor diffusion path 6, the vaporized cooling medium is diffused not only in the planar direction but also in the thickness direction (the vertical direction), and the vaporized cooling medium is diffused three-dimensionally.

It is preferable that the upper plate 3 is provided with a projection portion or an adhesion portion bonded to the intermediate plate 5. The upper plate 3 is called “upper” as a matter of convenience; however, it neither necessarily exists at an upper position physically, nor is

specially differentiated from the lower plate 4. Further, the upper plate 3 may be a surface coming into contact with the heating element or may be a surface opposing the heating element.

Further, the upper plate 3 may be provided with an injection port 10 for the cooling medium. If the upper plate 3, the intermediate plate 5, and the lower plate 4 are laminated and bonded, an internal space is formed. Since it is necessary to seal the cooling medium in this internal space, the cooling medium is filled from the injection port 10 after bonding the upper plate 3 and the like. The injection port 10 is sealed after the cooling medium is filled, and the internal space is sealed.

In this case, the cooling medium may be filled from the injection port 10 after the lamination, or may be filled when the upper plate 3, the lower plate 4 and the intermediate plate 5 are laminated.

Lower plate

The lower plate 4 sandwiches one or a plurality of intermediate plates 5 while opposing the upper plate 3.

The lower plate 4 is formed from a metal, a resin or the like, and is preferably formed from a metal having a high coefficient of thermal conductivity or a high rust proofing characteristic (durability) such as copper, aluminum, silver, aluminum alloy, iron, iron alloy, or stainless steel. Further, it may have various shapes such as a rectangular shape, a rhombic shape, a circular shape, an oval shape, or a polygonal shape; however, since the lower plate 4 forms the main body portion 2 while opposing the upper plate 3, it is preferable that the lower plate 4 has the same shape and area as those of the upper plate 3.

It is preferable that the lower plate 34 has a concave portion 12 which is communicated with the vapor diffusion path 6 and the capillary flow path 7, in one surface thereof opposing the intermediate plate 5. Since the concave portion 12 is communicated with the capillary flow path 7, the condensed cooling medium tends to be transmitted from the upper plate 3 to the capillary flow path 7. Alternatively, since the concave portion 12 is communicated with the vapor diffusion path 6, the vaporized cooling medium tends to come into contact at a wide area with the surface of the upper plate 3, and the heat dissipation of the vaporized cooling medium is promoted. In addition, since the concave portion 12 is communicated with the vapor diffusion path 6, the vaporized cooling medium is diffused not only in the planar direction but also in the

thickness direction (the vertical direction), and the vaporized cooling medium is diffused three-dimensionally. This has the same signification as the provision of the concave portion 12 in the upper plate 3.

The lower plate 4 is called “lower” as a matter of convenience; however, it neither necessarily exists at a lower position physically, nor is specially differentiated from the upper plate 3.

It is preferable that the lower plate 4 is provided with a projection portion or an adhesion portion bonded to the intermediate plate 5.

Further, the lower plate 4 may or may not come into contact with the heating element.

Intermediate plate

The intermediate plate 5 is constructed by one or a plurality of plate members. In Fig. 3, the heat pipe 1 has four intermediate plates 5. The intermediate plates 5 are laminated between the upper plate 3 and the lower plate 4.

The intermediate plate 5 is formed from a metal, a resin or the like, and is preferably formed from a metal having a high coefficient of thermal conductivity or a high rust proofing characteristic (durability) such as copper, aluminum, silver, aluminum alloy, iron, iron alloy, or stainless steel. Further, the intermediate plates 5 may have various shapes such as a rectangular shape, a rhombic shape, a circular shape, an oval shape, or a polygonal shape; however, since they are sandwiched by the upper plate 3 and the lower plate 4 so as to form the main body portion 2, it is preferable that they have the same shape as the upper plate 3 and the lower plate 4. In this case, since they are sandwiched by the upper plate 3 and the lower plate 4, the area of the intermediate plate 5 may be identical to those of the upper plate 3 and the lower plate 4, or may be somewhat smaller.

Further, the intermediate plate 5 may have a projection or an adhesion portion which is used at the time of being bonded to the upper plate 3 and the lower plate 4. In addition, the intermediate plate 4 has an internal through hole 9 having a small cross sectional area. The internal through hole 9 forms the capillary flow path 7.

Finally, the intermediate plates 5 are laminated between the upper plate 3 and the lower plate 4 so as to be bonded, whereby the main body portion 2 is formed. The number of the intermediate plates 5 may be one or plural number. In this case, as mentioned below, in order to

form the capillary flow path 7 having a more minute cross sectional area, it is preferable that the number of the intermediate plates 5 is plural.

Main body portion and end portion

The main body portion 2 is formed by laminating and bonding the upper plate 3, the lower plate 4 and the intermediate plates 5 which are sandwiched by the upper plate 3 and the lower plate 4. The main body portion 2 is a portion to be a base body of the heat pipe 1. The main body portion 2 has the internal space, in which the cooling medium is filled. Further, the internal space is provided with the vapor diffusion path 6 and the capillary flow path 7.

In other words, the main body portion 2 serves as the heat pipe in the heat pipe 1.

The first end portion 15 is one end portion of the main body portion 2, and the second end portion 16 is an end portion at a position opposing the first end portion 15 (that is, an end portion in an opposite side to the first end portion 15). The vapor diffusion path 6 is formed from the first end portion 15 toward the second end portion 16.

In this case, “end portion” in the first end portion 15 and the second end portion 16 not only indicates an accurate end surface of the main body portion 2, but indicates a position in the end of the surface of the main body portion 2. In other words, a position in the vicinity of the end in the main body portion 2 is called the end portion.

In this case, a combination of the opposed state between the first end portion 15 and the second end portion 16 may be other than that shown in Fig. 1. Even in the case where the metal plate or the like extends or protrudes from the first end portion 15 or the second end portion 16 in the main body portion 2, an end in the internal space provided in the main body portion 2 may be assumed as the end portion even if it is not the end portion of the protruding extension plate.

Intermediate plate, vapor diffusion path and capillary flow path

Next, a description will be given of the vapor diffusion path 6 and the capillary flow path 7. The intermediate plate 5 forms the vapor diffusion path 6 which diffuses the vaporized cooling medium at least in one of the planar direction and the thickness direction, and the capillary flow path 7 which reflows the condensed cooling medium in the vertical direction or the vertical and planar directions.

First, a description will be given of the vapor diffusion path 6.

The intermediate plate 5 has the notch portion 8 and the internal through hole 9.

The notch portion 8 forms the vapor diffusion path 6. In the case where the intermediate plate 5 is laminated between the upper plate 3 and the lower plate 4, the notch portion 8 forms a gap. The gap becomes the vapor diffusion path 6.

In this case, since the notch portion 8 forms the gap from the lower plate 4 to the upper plate 3, the vapor diffusion path 6 is formed from the lower plate 4 to the upper plate 3. In addition, since the vapor diffusion path 6 is communicated with the concave portion 12 formed in the upper plate 3 and the lower plate 4, the vaporized cooling medium can move from the vapor diffusion path 6 to the concave portion 12. The vaporized cooling medium reaching the concave portion 12 can move again to the vapor diffusion path 6. As mentioned above, the vaporized cooling medium is diffused from the first end portion 15 toward the second end portion 16 while diffusing not only in the planar direction but also in the thickness direction.

As mentioned above, the vapor diffusion path 6 is formed from the first end portion 15 to the second end portion 16. Since the capillary flow path 7 is formed in the other portions than the vapor diffusion path 6, the vapor diffusion path 6 and the capillary flow path 7 are lined up alternately like lateral stripes in the inner portion of the main body portion 2.

The heat pipe 1 has the vapor diffusion path 6 broadening toward the end from the first end portion 15 to the second end portion 16 as shown in Fig. 1, as one example. In other words, a cross sectional area of the vapor diffusion path 6 in the planar direction close to the second end portion 16 is wider than a cross sectional area of the vapor diffusion path 6 in the planar direction close to the first end portion 15. The shape and the structure of the vapor diffusion path 6 as mentioned above are defined by the notch portion 8 of the intermediate plate 5.

As mentioned above, because of the vapor diffusion path 6 having such a shape that the cross sectional area expands from the first end portion 15 toward the second end portion 16, the heat pipe 1 has a heat diffusing characteristic from the first end portion 15 toward the second end portion 16. In this case, the vapor diffusion path 6 has the shape broadening toward the end in Fig. 1; however, a bending and an inflection may exist from the first end portion 15 to the second end portion 16, and a fluctuation in increase and decrease of the cross sectional area may exist.

Next, a description will be given of the capillary flow path 7.

The intermediate plate 12 has the internal through hole 9. The internal through hole 9 is a minute through hole, and forms the capillary flow path 7 through which the condensed cooling

medium reflows. In the case where the intermediate plate 5 has the notch portion 8 as shown in Fig. 3, the internal through hole 9 is formed in the other portions than the notch portion 8.

In this case, the number of the intermediate plate 5 is singular, the internal through hole 9 provided in the intermediate plate 5 becomes the capillary flow path 7 as it is.

On the contrary, in the case where the number of the intermediate plate 5 is plural, only a part of the internal through holes 9 provided respectively in a plurality of intermediate plates 5 overlaps, whereby the capillary flow path 7 having a smaller cross sectional area than the cross sectional area in the planar direction of the internal through hole 9 is formed. Since the capillary flow path 7 having the smaller cross sectional area than the cross sectional area of the internal through hole 9 itself is formed in the case where the number of the internal plate 5 is plural, as mentioned above, it is possible to more effectively reflow the condensed cooling medium in the capillary flow path 7. Since the cross sectional area of the capillary pipe is small, the movement of the liquid is promoted due to a capillary phenomenon.

In this case, a plurality of internal through holes 9 are provided in the intermediate plates 5. A plurality of internal through holes 9 can form the capillary flow path 7 having a plurality of flow paths.

The internal through hole 9 passes through from a front face to a back face of the intermediate plate 5, and its shape may be formed as a circular shape, an oval shape or a rectangular shape. Alternatively, it may be a slit shape.

The internal through hole 9 may be formed in accordance with digging, press molding, wet etching, dry etching or the like.

In the case where the number of the intermediate plate 5 is plural, the intermediate through holes 9 are provided respectively in a plurality of intermediate plates 5. In this case, since a plurality of intermediate plates 5 are laminated in such a manner that the internal through holes 9 overlap only partly, the positions of the internal through holes 9 should be properly shifted per adjacent intermediate plates 5. For example, the position of the internal through hole 9 in a certain intermediate plate 5 and the position of the internal through hole 9 in another intermediate plate 5 which is adjacent to the former intermediate plate 5 are shifted in such a manner that the internal through holes 9 overlap only in a part of the cross section. Since the positions of the internal through holes 9 are shifted per adjacent intermediate plates 5 as mentioned above, it is possible to form the capillary flow path 7 having the smaller cross

sectional area than the cross sectional area in the planar direction of the internal through hole 9, when a plurality of intermediate plates 5 are laminated.

The capillary flow path 7 is structured such that the internal through holes 9 partly overlap when a plurality of intermediate plates 5 are laminated, and the capillary flow path 7 has the smaller cross sectional area than the cross sectional area in the planar direction of the internal through hole 9. Since the holes having the smaller cross sectional area than the cross sectional area of the internal through hole 9 are laminated in the vertical direction of the heat pipe 1, and the holes in the vertical direction are connected to each other, the flow path in the vertical direction is formed. Further, since a step-like hole is formed in the vertical direction, it is possible to form the flow path which can flow also in the planar direction as well as in the vertical direction. The flow path formed in the vertical and planar directions has a very small cross sectional area, and reflows the condensed cooling medium in the vertical direction or the vertical and planar directions. In addition, since the capillary flow path 7 is communicated with the concave portion 12, the cooling medium cooled and condensed in the concave portion 12 is transferred to the capillary flow path 7 from the concave portion 12 and reflows through the capillary flow path 7 as it is. Since the concave portion 12 is communicated with the capillary flow path 12 as mentioned above, the reflow of the condensed cooling medium is promoted.

In the case where the capillary flow path 7 having the smaller cross sectional area than the internal through hole 9 is formed in such a manner that only a part of the internal through holes 9 overlaps, there is an advantage that the capillary flow path 7 can be manufactured more easily than the case where it is directly processed.

Note that the capillary flow path 7 reflows the condensed cooling medium, but can also pass the vaporized cooling medium.

Further, it is preferable that the capillary flow path 7, a corner portion of the concave portion 12 or a corner portion of the notch portion 8 may be chamfered or may be rounded. The cross section of the capillary flow path 7 may have various cross sectional shapes such as a hexagonal shape, a circular shape, an oval shape, a rectangular shape, or a polygonal shape. The cross sectional shape of the capillary flow path 7 is defined in accordance with the shape of the internal through hole 9, and an overlapping manner between the internal through holes 9. Further, the cross sectional area may be defined in the same manner.

Manufacturing step

Next, a description will be given of a manufacturing step of the heat pipe 1.

The upper plate 3, the lower plate 4 and the intermediate plate 5 are laminated and bonded, whereby the heat pipe 1 is manufactured.

A description will be given of the manufacturing step with reference to Fig. 3.

The upper plate 3, the lower plate 4 and a plurality of intermediate plates 5 (four intermediate plates 12 in Fig. 3) are aligned in accordance with such a positional relationship that they overlap at the same position. In addition, a plurality of intermediate plates 5 are aligned in accordance with such a positional relationship that the internal through holes 9 respectively provided in a plurality of intermediate plates 5 overlap only partly.

At least one of the upper plate 3, the lower plate 4 and a plurality of intermediate plates 5 has a bonding projection.

The upper plate 3, the lower plate 4, and a plurality of intermediate plates 5 are laminated after being positioned, and are directly bonded by a heat press so as to be integrated. At this time, each of the members is directly bonded by the bonding projection.

In this case, the direct bonding is applying a heat treatment while pressurizing in a state in which surfaces of two members to be bonded are closely attached, that is, bonding firmly between atoms on the basis of an atomic force applied between the surface portions, and can integrate the surfaces of two members with each other without using any adhesive agent. At this time, the bonding projection achieves a firm bonding.

As a condition of the direct bonding in the heat press, it is preferable that a press pressure is in the range of 40 kg/cm² and 150 kg/cm², and a temperature is in the range of 250 and 400°C.

Next, the cooling medium is injected through the injection port 10 provided in a part of the upper plate 3 and the lower plate 4. Thereafter, the injection port 10 is sealed, and the heat pipe 1 is completed. In this case, the filling of the cooling medium is carried out under vacuum or decompression. Under the vacuum or the decompression, the internal space of the heat pipe 1 comes to a vacuum state or a decompressed state, and the cooling medium is filled. Under the decompression, the vaporization and condensation temperatures of the cooling medium become low, so that there is an advantage that the repeated vaporization and condensation of the cooling medium become active.

Description of operation

Next, a description will be given of an operation of the heat pipe 1.

Fig. 4 is an inside view of the heat pipe in the embodiment 1 according to the Present Invention. The heat pipe 1 in Fig. 4 is provided with the vapor diffusion path 6 and the capillary flow path 7 which have the same shapes as those in Fig. 1. A plurality of heating elements 20 are arranged in the first end portion 15 of the main body portion 2.

In this case, the heating element 20 is constructed by a high intensity LED or the like which is compact and has a great calorific power. The high intensity LED often employs a plurality of elements such as electric spectaculars and a head lamp of a vehicle, and a plurality of heating elements 20 are often arranged in the first end portion 15, as shown in Fig. 4.

Each of the heating elements 20 arranged in the first end portion 15 generates heat. The heat pipe 1 receives the heat from the heating element 20 via the upper plate 3 or the lower plate 4 in the first end portion 15. The cooling medium vaporizes in the first end portion 15 by the received heat. The cooling medium takes up the heat of the heating element 20 at the time of vaporizing. The vaporized cooling medium is diffused through the vapor diffusion path 6 in the planar and thickness directions. Since the vapor diffusion path 6 is formed as the shape broadening toward the end from the first end portion 15 to the second end portion 16 as shown in Fig. 4, the vaporized cooling medium is diffused at a high speed toward the second end portion 16.

The vaporized cooling medium is diffused in the vapor diffusion path 6, and comes into contact with the upper plate 3 and the lower plate 4 at a wide area including the concave portion 12 and the like, due to the diffusion. Although not shown in Fig. 4, the vaporized cooling medium is cooled by a fin, a cooling fan, a liquid cooled jacket or the like provided in the vicinity of the surface or the second end portion 16 of the heat pipe 1. When cooled, the vaporized cooling medium is condensed. The condensed cooling medium reflows in the vertical direction or the vertical and planar directions from the second end portion 16 via the capillary flow path 7. If it reflows, the cooling medium which is condensed to become the liquid again reaches the first end portion 15. The cooling medium reaching the first end portion 15 again takes up the heat from the heating element 20 so as to vaporize, and the vaporized cooling

medium is diffused from the first end portion 15 to the second end portion 16 via the vapor diffusion path 6.

As mentioned above, in the heat pipe 1 in the embodiment 1, a plurality of vapor diffusion paths 6 and capillary flow paths 7 are alternately lined up from the first end portion 15 to the second end portion 16 of the main body portion 2. Further, according to such a shape that the cross sectional area of the vapor diffusion path 6 in the second end portion 16 is wider than the cross sectional area of the vapor diffusion path 6 in the first end portion 15 being the arranged position of the heating element, the diffusion speed of the vaporized cooling medium becomes higher. One example of the vapor diffusion path 6 mentioned above is the vapor diffusion path 6 having the shape broadening toward the end from the first end portion 15 to the second end portion 16, as shown in Figs. 1 and 4.

The capillary flow path 7 is formed in the other regions than the region in which the vapor diffusion path 6 is formed. According to the study of the inventors, in the heat diffusion from the end portion to the end portion and the cooling of the heating element as the result of the heat diffusion, it is proper to balance them while giving priority to the diffusing speed of the vaporized cooling medium over the reflow of the condensed cooling medium. Accordingly, the heat pipe 1 gives priority to the diffusion of the vaporized cooling medium over the reflow of the condensed cooling medium, by means of the vapor diffusion path 6 and the capillary flow path 7 having the shapes shown in Figs. 1 and 4. In the vapor diffusion path 6 having the shape broadening toward the end from the first end portion 15 to the second end portion 16 corresponding to the arranged position of the heating element, since the moving space of the vaporized cooling medium broadens little by little from the first end portion 15 to the second end portion 16, the vapor diffusion path 6 easily diffuses the vaporized cooling medium. As a result, the diffusing speed of the vaporized cooling medium becomes high, and the heat pipe 1 is excellent in the heat diffusion and the cooling of the heating element arranged in the first end portion 15.

Further, since the cooling capacity of the heating element arranged in the end portion is excellent, there is generated an advantage that no extra mounting space is needed in the electronic device incorporating the heat pipe. Fig. 5 is an inside view of a part of the electronic device in the embodiment 1 according to the Present Invention. Fig. 5 shows a part of a projected portion, for example, of a light projector or the like.

An electronic device 30 is provided with a casing 33, a control apparatus 31, and a projecting lens 32, and is further provided with the heating element 20 corresponding to a light emitting element projecting the light to the projecting lens 32, and the heat pipe 1 cooling the heating element 20. The heating element 20 is arranged in the first end portion 15 of the heat pipe 1.

Since it is necessary for the lens 32 to receive the light from the light emitting element corresponding to the heating element 20, it is preferable that the heating element 20 is arranged approximately on a center line of the lens 32. In addition, since it is necessary for the control apparatus 31 to carry out various controls on the basis of the light and an image received from the lens 32, the control apparatus 31 needs to oppose a part of the lens 32. Accordingly, as shown in Fig. 5, a mounting space for the heating element 20 and the control apparatus 31 is necessary in the region opposing the lens 32.

In this case, if the heat pipe cooling the heating element 20 is of a type heat diffusing from a center toward a periphery, or of a type having a mode that it is separated into a heat receiving portion and a heat transport portion, the heat pipe occupies a great mounting space, in the region opposing the lens 32. In this case, the mounting region of the control apparatus 31 runs short or the projection to the lens 32 is adversely affected.

On the contrary, since the heat pipe 1 in the embodiment 1 can diffuse the heat from the first end portion 15 to the second end portion 16, the heating element 20 can be arranged in the first end portion 15. As a result, in the case where the heating element 20 exists approximately on the center line of the lens 32, the first end portion 15 of the heat pipe 1 exists at a similar position. In other words, as shown in Fig. 5, only a space approximately below the center line of the lens 32 in the heat pipe 1 is necessary in the mounting.

As mentioned above, the heat pipe 1 in the embodiment 1 has an advantage that no extra mounting space is needed at the time of being mounted to the electronic device.

Modified example

Next, a description will be given of a modified example of the heat pipe 1. Fig. 6 is an inside view showing a modified example of the heat pipe in the embodiment 1 according to the Present Invention.

In the heat pipe 1 shown in Fig. 6, a width of the vapor diffusion path 6 in the first end portion 15 is approximately identical to a width of the vapor diffusion path 6 in the second end portion 16. Further, the vapor diffusion path 6 may have the same width from the first end portion 15 to the second end portion 16.

In this case, the heat pipe 1 has a heat diffusing characteristic from the first end portion 15 to the second end portion 16. Further, the capillary flow path 7 is formed in the other portions than the vapor diffusion path 6. In this case, the vapor diffusion path 6 may be formed as a curved line from the first end portion 15 to the second end portion 16, may have a bent portion, or may generate some difference in the width. As mentioned above, on the basis of the vapor diffusion path 6 having approximately the same width from the first end portion 15 to the second end portion 16, and the corresponding capillary flow path 7, the heat pipe 1 is excellent in the heat diffusing characteristic from the first end portion 15 toward the second end portion 16. As a result, it is possible to cool the heating element which is compact and has a high calorific power such as the high intensity LED, in a state of being arranged in the end portion.

As mentioned above, the heat pipe 1 (including the modified example) in the embodiment 1 satisfies the following points: (1) the light emitting element serving as the heating element is easily mounted in the end portion; (2) the mounting volume as a whole is not made too large even if it is mounted in the end portion; (3) the obstructing element is little in the diffusion and the transfer of the received heat (because the vaporized cooling medium is diffused and the condensed cooling medium is reflowed by using the entire heat pipe 1, and it is not necessary to conduct the heat to another member such as the pipe en route); (4) the heat can be diffused and transferred by using the entire heat pipe (because the entire inner portion of the heat pipe is constructed by the vapor diffusion path 6 and the capillary flow path 7, and the vapor diffusion path 6 and the capillary flow path 7 are arranged with good balance); and (5) the diffusion of the vaporized cooling medium and the reflow of the condensed cooling medium are carried out three-dimensionally by using the entire heat pipe (because the vapor diffusion path 6 diffuses the vaporized cooling medium in the planar and thickness directions, and the capillary flow path 7 reflows the condensed cooling medium in the vertical direction or the vertical and planar directions).

As a result, unlike the related art, it is possible to arrange and cool the heating element which is a compact heating element and is limited its arranged position, particularly such as the light emitting element.

Further, since the heat pipe 1 is provided with the vapor diffusion path 6 and the capillary flow path 7 which are alternately arranged in the main body portion 2, it is possible to cool each of a plurality of heating elements 20, even in the case where a plurality of heating elements 20 are arranged.

Embodiment 2

Next, a description will be given of an embodiment 2.

In the embodiment 2, a description will be given of a result of experiment about superiority of the heat pipe 1.

The inventors conducted experiments as to what shape is optimum for the vapor diffusion path 6 and the capillary flow path 7 provided in the heat pipe 1.

The inventors simulated heat pipes of three examples 1 to 3. On the basis of the result of simulation, the inventors made a study of what shape of heat pipe is optimum. Fig. 7 is a schematic view expressing three examples. In Fig. 7, the example 1, the example 2 and the example 3 are expressed from the left.

Example 1

A heat pipe 40 according to the example 1 is provided with a vapor diffusion path 6 in which a width is gradually narrowed from the first end portion 15 to the second end portion 16, and a corresponding capillary flow path 7 (the capillary flow path 7 in which a width is gradually narrowed from the first end portion 15 to the second end portion 16).

Example 2

In the same manner as shown in Fig. 1, a heat pipe 41 according to the example 2 is provided with a vapor diffusion path 6 in which a width is gradually broadened from the first end portion 15 to the second end portion 16, and a corresponding capillary flow path 7 (the capillary flow path 7 in which a width is gradually broadened from the first end portion 15 to the second

end portion 16). In other words, the heat pipe 41 is provided with the vapor diffusion path 6 in which the width in the second end portion 16 is wider than the width in the first end portion 15.

Example 3

In the same manner as shown in Fig. 6, a heat pipe 42 according to the example 3 is provided with a vapor diffusion path 6 having the same width from the first end portion 15 to the second end portion 16, and a corresponding capillary flow path 7 (the capillary flow path 7 having the same width from the first end portion 15 to the second end portion 16). In other words, the heat pipe 42 is provided with the vapor diffusion path 6 and the capillary flow path 7 in which the width in the first end portion 15 is approximately identical to the width in the second end portion 16.

In all of the heat pipes according to the examples 1 to 3, the vapor diffusion path 6 and the capillary flow path 7 are formed in such a manner that the heat diffusion can be carried out from the first end portion 15 toward the second end portion 16.

Experimental conditions

The experiment was executed under the following experimental conditions.

Heat source: arranging a heat source having a size of 2×7 mm approximately in the center of the first end portion 15

Thermal bonding agent: using a thermal grease (PA-080 manufactured by INEX Co., Ltd.)

Heat dissipation treatment: heat dissipation side is forcedly air cooled by a spot cooler (Crisp manufactured by Daikin Industries, Ltd.)

Upper surface temperature distribution measurement: measuring an upper surface temperature distribution by a thermography (TVS-200 manufactured by Nippon Avionics Co., Ltd.)

Heat output of heat source: executed by the following two cases

Case 1: 1 W ($= 1 \text{ MW/m}^2$), heat quantity equivalent to a calorific power of the mounted high intensity LED

Case 2: output in which $T_s = 90^\circ\text{C}$

Subject to be compared: in order to comprehend a temperature change state of the heat pipes according to the examples 1 to 3, a copper plate is set to a subject to be compared.

Under the above conditions, the heat source is arranged approximately in the center of the first end portion 15 of the heat pipe according to each of the examples 1 to 3, and the heat diffusion state is measured.

Fig. 8 is a temperature distribution view of the heat pipe surfaces according to the examples 1 to 3 of the embodiment 2 of the Present Invention in Case 1. Fig. 8 shows a temperature state of the heat pipe surface measured by the simulation in Case 1. Further, in order to check a temperature distribution of the heat pipes according to the examples 1 to 3, a copper plate is set to a subject to be compared.

As is apparent from Fig. 8, in comparison with the copper plate corresponding to the comparative example, the temperature difference between the vicinity of the center and the periphery is small in each of the examples 1 to 3, and it is found that the heat pipes according to the examples 1 to 3 have a high heat diffusion capacity.

Further, in the three examples, it seems that in the heat pipe 40 according to the example 1, the surface temperature is most fixed. However, on the basis of the following result of experiment of Case 2, it can be thought that this dries out and as a result the temperature only seems to be fixed or low.

Fig. 9 is a temperature distribution view of a heat pipe surface of the examples 1 to 3 of the embodiment 2 according to the Present Invention in Case 2.

As is apparent from Fig. 9, an upper surface temperature of the heat pipe according to the example 1 is low, and this can be thought to dry out. In other word, the cooling medium cannot be condensed while being vaporized, and does not reach the upper surface of the heat pipe 40 (in other words, it is thought that since the vaporized cooling medium including the heat stays in the internal space, and the heat cannot reach the upper surface, the temperature of the upper surface is kept abnormally low). This is thought to be a proper determination because the upper surface temperature is lower than the copper plate corresponding to the comparative example.

On the other hand, in each of the heat pipes 41 and 42 according to the example 2 and the example 3, the upper surface temperature difference is not so much as is apparent from Fig. 9. Further, since the temperature of the heat source portion is higher than the periphery in the copper plate corresponding to the comparative example, it does not sufficiently diffuse the heat.

On the contrary, it is known that since the temperature distribution is even in the heat pipes according to the examples 1 and 2, it sufficiently diffuses the heat.

Next, Fig. 10 shows a result about how much the temperature decrease in the center of the upper surface becomes in comparison with the copper plate, by manufacturing a plurality of samples by way of trial with regard to each of the examples 1 to 3. Fig. 10 is an explanatory view showing the result of experiment in the embodiment 2.

As is apparent from Fig. 10, the effect of the example 1 is low; however the effects of the examples 2 and 3 are high. Comparing the examples 2 and 3, the effect is somewhat higher in the example 3, and in the case of arranging the heating element in the first end portion 15, it can be thought that the heat pipe 42 shown in the example 3 is optimum. In this case, the difference between the examples 2 and 3 is not extreme, and any of the heat pipe 41 according to the example 2 and the heat pipe 42 according to the example 3 may be used depending on the characteristic of the heating element to be cooled.

As mentioned above, in accordance with the experiments, in the cooling of the heating element arranged in the end portion, it is known that the heat pipe having the vapor diffusion path 6 having the shape in which the width is expanded little by little or is approximately the same from the first end portion 15 to the second end portion 16, and the capillary flow path 7 corresponding to the shape of the vapor diffusion path 6 is preferable.

Embodiment 3

Next, a description will be given of an embodiment 3.

Fig. 11 is a perspective view of a heat pipe in the embodiment 3 according to the Present Invention. The heat pipe in the embodiment 3 is curved.

A heat pipe 50 having a curved shape is provided with a main body portion 54 having a curved upper plate 51, a curved lower plate 52 opposing the upper plate 51, and one curved intermediate plate 53 or a plurality of curved intermediate plates 53 laminated between the upper plate 51 and lower plate 52 and forming at least a part of a vapor diffusion path and a capillary flow path. Since Fig. 11 shows a perspective view from an outer appearance of the heat pipe 50, an internal portion is not visible. Accordingly, Fig. 11 cannot show the vapor diffusion path and the capillary flow path; however, the internal portion of the main body portion 54 is provided

with the vapor diffusion path and the capillary flow path formed as described in the embodiment 1.

As is apparent from Fig. 11, the main body portion 54 has a curved shape as a whole. As mentioned above, the heat pipe 50 having the curved shape can be easily mounted even in a narrow space or a complicated space.

For example, as shown in Fig. 12, the heat pipe 50 having the curved shape can cool a heating element 55 existing at a position where the heat pipe is hard to be arranged, by making a good use of the curved shape. Fig. 12 is a mounting view of the heat pipe having the curved shape in the embodiment 3 according to the Present Invention.

If the heating element 55 is arranged in the first end portion of the heat pipe 50, the heat pipe 50 diffuses the heat from the first end portion toward the second end portion (an arrow in the drawing). A fan 58 sends air to the second end portion, thereby cooling the second end portion. Since the second end portion is cooled, the vaporized cooling medium is condensed, and the condensed cooling medium reflows from the second end portion to the first end portion (an opposite direction to the arrow in the drawing).

As mentioned above, since the heat pipe 1 described in the embodiment 1 is replaced by the curved heat pipe 50, the heat pipe 50 can cool the heating element 55 arranged in the end portion, even in a mounting state in which the heating element 55 and the heat pipe are hard to be arranged.

In this case, the state in which the heat pipe 55 is hard to be mounted means the case where a mounting board or other apparatus 56 exists besides the heat pipe 55, for example, as shown in Fig. 13. Fig. 13 is a mounting view of the heat pipe having the curved shape in the embodiment 3 according to the Present Invention.

Next, a description will be given of details of the heat pipe 50 having the curved shape.

Fig. 14 is an exploded view of the heat pipe in the embodiment 3 according to the Present Invention. A description will be further given of the heat pipe 50 having the curved shape by using Fig. 14.

The curved intermediate plate 53 is sandwiched and laminated between the curved upper plate 51 and the curved lower plate 52. The intermediate plate 53 is provided with a notch portion 60 and an internal through hole 61, the notch portion 60 forms a vapor diffusion path 64,

and the internal through hole 61 forms a capillary flow path 65. Further, at least one of the upper plate 51 and the lower plate 52 has a concave portion 62.

At least one of the upper plate 51, the lower plate 52 and the intermediate plate 53 has a projection portion 63, which functions as an adhesive agent when the upper plate 51, the lower plate 52 and the intermediate plate 53 are bonded. If they are bonded by using the projection portion 63 as the adhesive agent, the main body portion 54 having the curved shape is formed, and the vapor diffusion path 64 and the capillary flow path 65 are formed in an inner portion thereof. As mentioned above, since the curved upper plate 51, lower plate 52 and intermediate plate 53 are bonded, the heat pipe 50 having the curved shape is formed. The heat pipe 50 fills a cooling medium in its internal portion, the vaporized cooling medium diffuses in the internal portion of the main body portion 54 via the vapor diffusion path 64, and the condensed cooling medium reflows via the capillary flow path 65. Due to the repeated vaporization and condensation of the cooling medium, the heat pipe 50 having the curved shape can cool the heating element.

As mentioned above, the heat pipe 50 having the curved shape can be obtained by laminating and bonding the curved upper plate 51, lower plate 52 and intermediate plate 53.

Except the curved shape, the upper plate 51, the lower plate 52 and the intermediate plate 53 have the similar structures and functions to those described in the embodiment 1.

As mentioned above, the heat pipe which is excellent in the heat diffusion from the first end portion to the second end portion may be curved, and has an advantage of being excellent in cooling the heating element arranged in the end portion while making a good used of an advantage of a high flexibility on mounting caused by the curved shape.

Embodiment 4

Next, a description will be given of an embodiment 4.

In the embodiment 4, a description will be given of an electronic device mounting the heat pipes described in the embodiments 1 to 3.

An example of the electronic device is shown in Fig. 15. Fig. 15 is a perspective view of the electronic device in the embodiment 4 according to the Present Invention. An electronic device 82 is an electronic device which is required to be thin and compact, such as a car television set, a personal monitor or the like.

The electronic device 82 is provided with a display 83, a light emitting element 84, and a speaker 85. The heat pipe 1 is stored in an internal portion of the electronic device 82, and achieves the cooling of the heating element.

Since the heat pipe 1 as mentioned above is used, it is possible to achieve the cooling of the heating element without obstructing the downsizing and the thinned structure of the electronic device. In particular, the heat pipe 1 can cool the heating element, mounted in the end portion, such as LED which is necessary in the display 83. Accordingly, to say nothing of the cooling performance, the heat pipe 1 can be mounted without necessity of the extra mounting space.

In view of this, the heat pipe 1 can be replaced by a heat dissipation fin, a liquid cooling apparatus or the like which is mounted on a notebook personal computer, a portable terminal, a computer terminal or the like, or can be preferably replaced by a heat dissipation frame, a cooling apparatus or the like which is mounted on a light, an engine, or a control computer portion of a motor vehicle or an industrial equipment. Since the heat pipe 1 has a higher cooling capacity than the conventionally used heat dissipation fin or heat dissipation frame, it can be of course downsized. Further, it can be flexibly applied to the heating element, and can set various electronic parts to the cooled subject. As a result, the heat pipe 1 has a wide scope of application.

Note that the heat pipe and the electronic device described in the embodiments 1 to 4 are only one example which describes the scope of the Present Invention, and includes a modification and a conversion within the range of the Present Invention.

While a preferred embodiment of the Present Invention is shown and described, it is envisioned that those skilled in the art may devise various modifications without departing from the spirit and scope of the foregoing Description and the appended Claims.

CLAIMS**WHAT IS CLAIMED IS:**

1. A heat pipe comprising:
an upper plate;
a lower plate opposing the upper plate;
one intermediate plate or a plurality of intermediate plates laminated between the upper plate and the lower plate;
a main body portion formed by lamination of the upper plate, the lower plate and the intermediate plate and capable of sealing a cooling medium;
a vapor diffusion path capable of diffusing a vaporized cooling medium; and
a capillary flow path capable of reflowing a condensed cooling medium;
wherein the vapor diffusion path is formed from a first end portion of the main body portion toward a second end portion opposing the first end portion.
2. The heat pipe of Claim 1, wherein a width in the second end portion of the vapor diffusion path is wider than a width in the first end portion.
3. The heat pipe of Claim 2, wherein the vapor diffusion path broadens toward the end from the first end portion to the second end portion.
4. The heat pipe of Claim 3, wherein the intermediate plate has a notch portion and an internal through hole, the notch portion forms the vapor diffusion path, and the internal through hole forms the capillary flow path.
5. The heat pipe of Claim 4, wherein the number of the intermediate plates is plural, the internal through holes provided respectively in the plurality of intermediate plates overlap only partly, and a capillary flow path having a smaller cross sectional area than a cross sectional area in a horizontal direction of the internal through hole is formed.

6. The heat pipe of Claims 5, wherein each of the upper plate and the lower plate is further provided with a concave portion communicating with at least a part of the capillary flow path and the vapor diffusion path.

7. The heat pipe of Claim 6, wherein the vapor diffusion path diffuses the vaporized cooling medium in a planar direction and a thickness direction, and the capillary flow path reflows the condensed cooling medium in a vertical direction or vertical and planar directions.

8. The heat pipe of Claims 7, wherein the heating element is mountable on the first end portion, and the heat of the heating element is diffusible from the first end portion toward the second end portion.

9. The heat pipe of Claim 1, wherein a width in the second end portion of the vapor diffusion path is approximately identical to a width in the first end portion.

10. The heat pipe of Claims 9, wherein the intermediate plate has a notch portion and an internal through hole, the notch portion forms the vapor diffusion path, and the internal through hole forms the capillary flow path.

11. The heat pipe of Claim 10, wherein the number of the intermediate plates is plural, the internal through holes provided respectively in the plurality of intermediate plates overlap only partly, and a capillary flow path having a smaller cross sectional area than a cross sectional area in a horizontal direction of the internal through hole is formed.

12. The heat pipe of Claim 11, wherein each of the upper plate and the lower plate is further provided with a concave portion communicating with at least a part of the capillary flow path and the vapor diffusion path.

13. The heat pipe of Claim 12, wherein the vapor diffusion path diffuses the vaporized cooling medium in a planar direction and a thickness direction, and the capillary flow

path reflows the condensed cooling medium in a vertical direction or vertical and planar directions.

14. The heat pipe of Claims 13, wherein the heating element is mountable on the first end portion, and the heat of the heating element is diffusible from the first end portion toward the second end portion.

15. The heat pipe of Claim 1, wherein the intermediate plate has a notch portion and an internal through hole, the notch portion forms the vapor diffusion path, and the internal through hole forms the capillary flow path.

16. The heat pipe of Claim 15, wherein the number of the intermediate plates is plural, the internal through holes provided respectively in the plurality of intermediate plates overlap only partly, and a capillary flow path having a smaller cross sectional area than a cross sectional area in a horizontal direction of the internal through hole is formed.

17. The heat pipe of Claim 16, wherein each of the upper plate and the lower plate is further provided with a concave portion communicating with at least a part of the capillary flow path and the vapor diffusion path.

18. The heat pipe of Claim 17, wherein the vapor diffusion path diffuses the vaporized cooling medium in a planar direction and a thickness direction, and the capillary flow path reflows the condensed cooling medium in a vertical direction or vertical and planar directions.

19. The heat pipe of Claims 18, wherein the heating element is mountable on the first end portion, and the heat of the heating element is diffusible from the first end portion toward the second end portion.

Figure 1

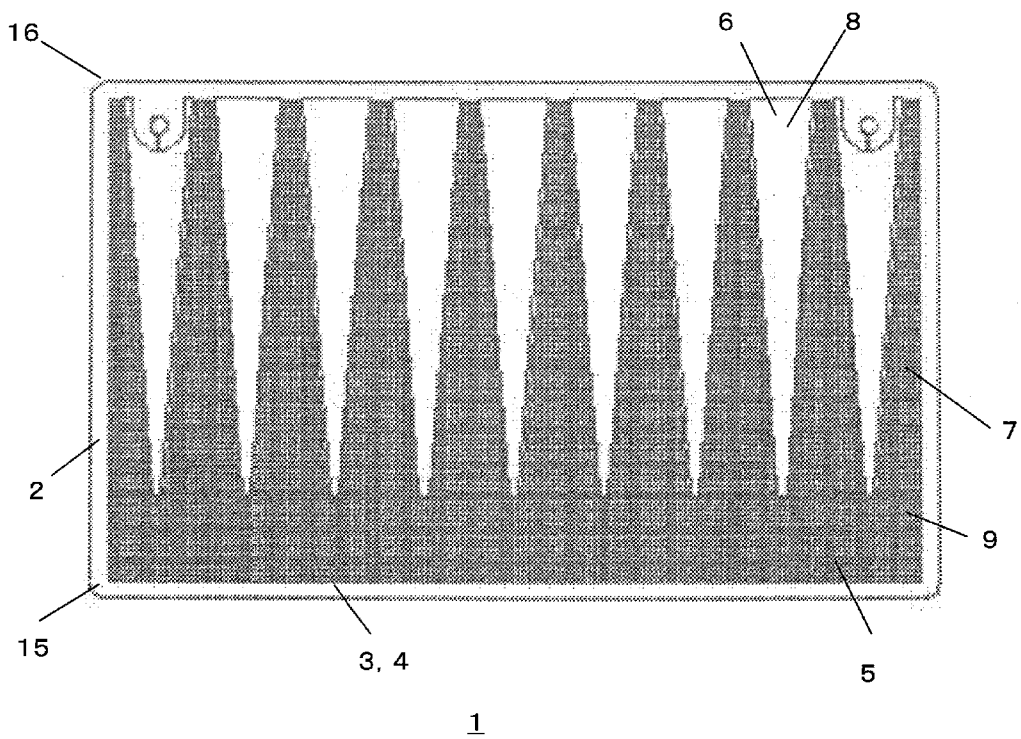


Figure 2

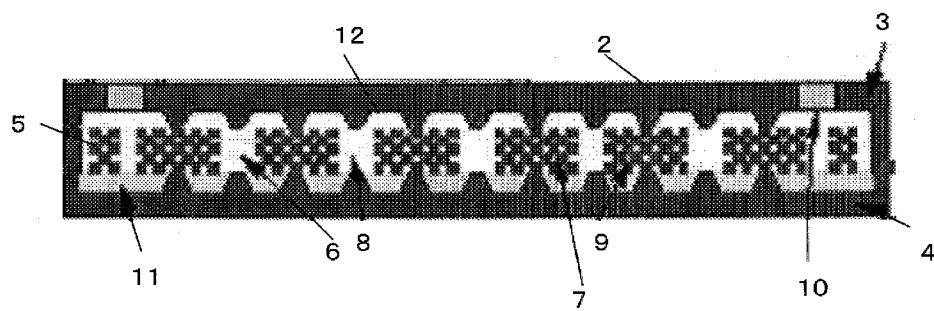


Figure 3

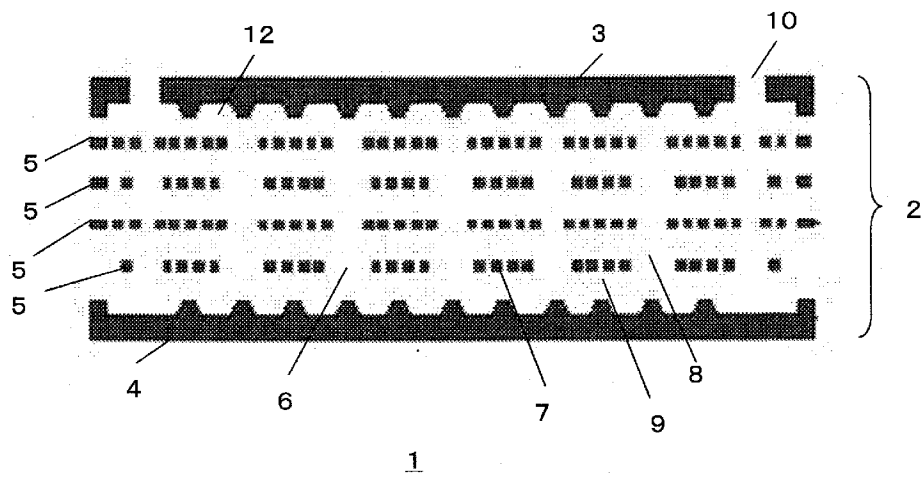


Figure 4

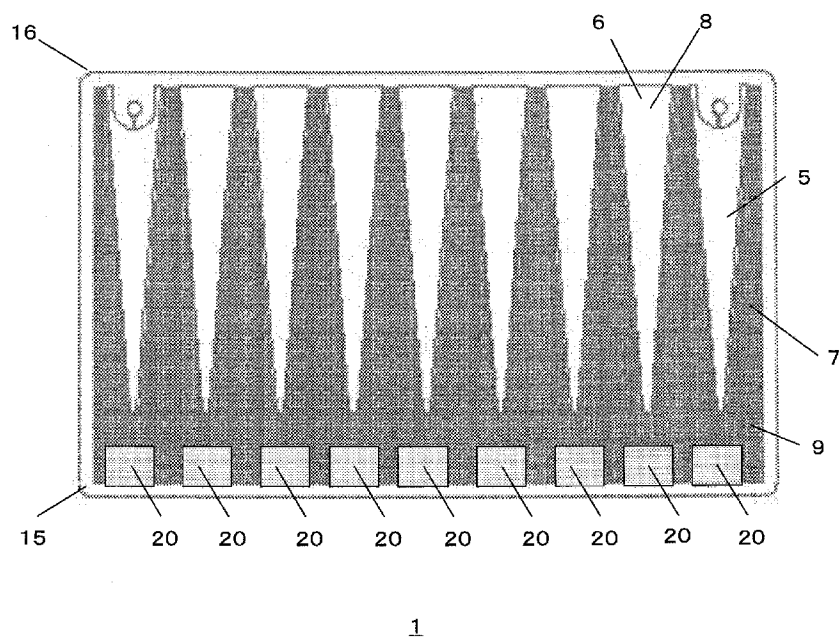


Figure 5

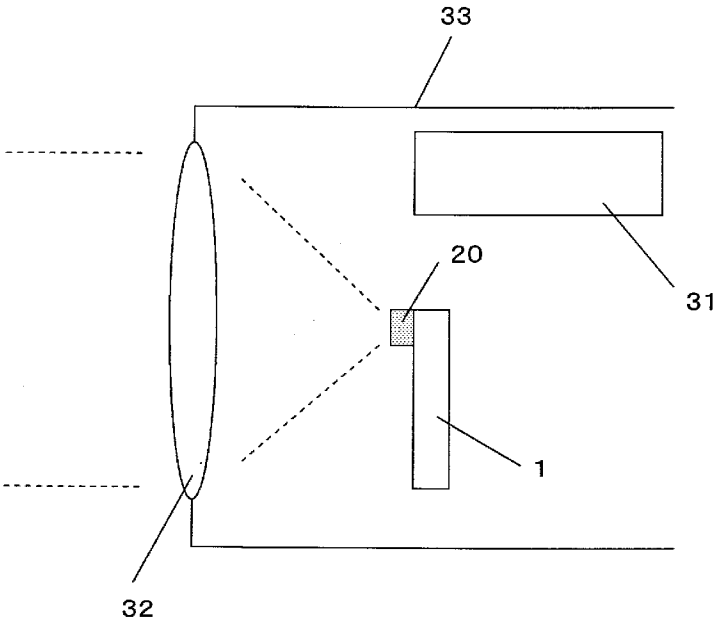


Figure 6

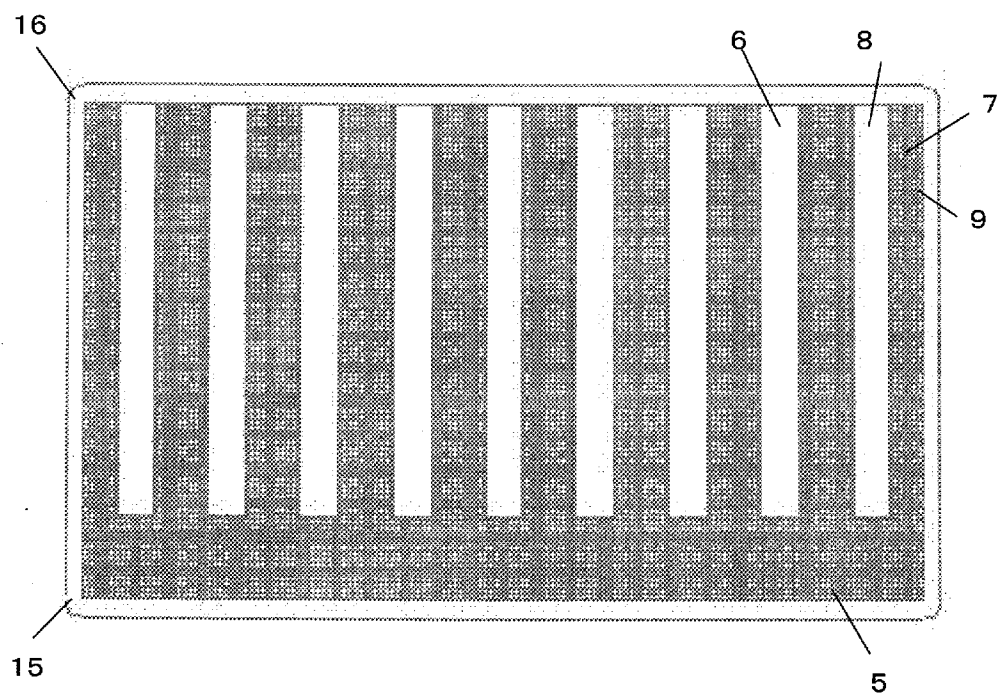


Figure 7

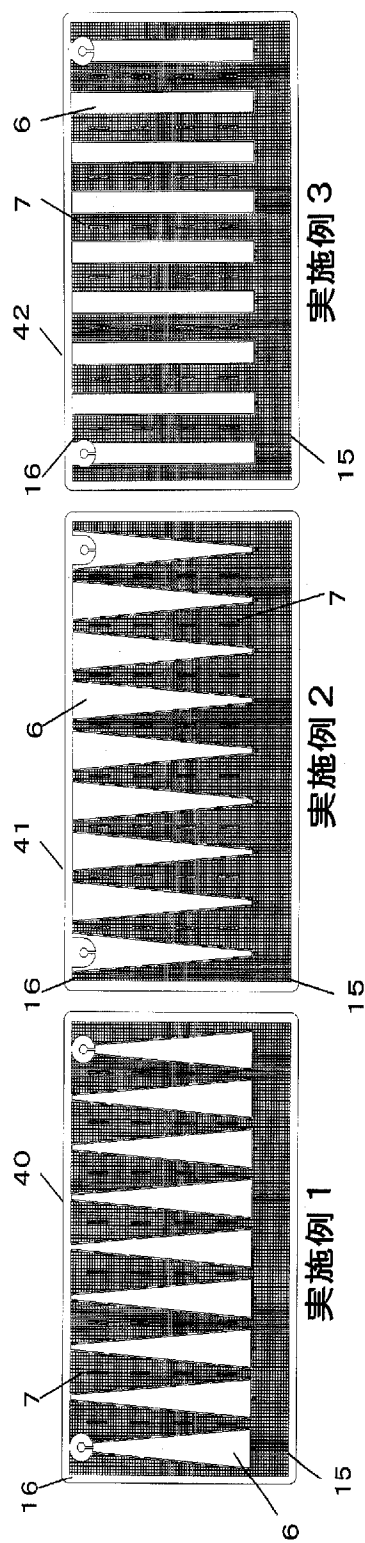
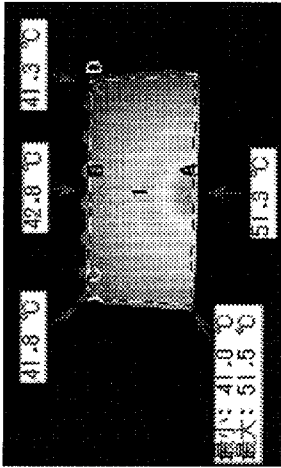
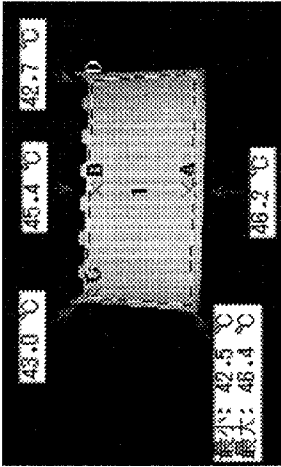


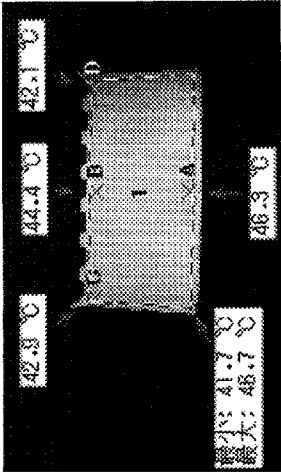
Figure 8



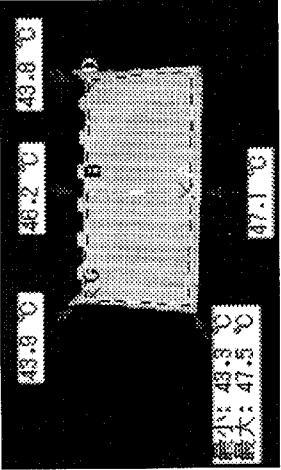
比較例: 銅板



実施例 1



実施例 2



実施例 3

Figure 9

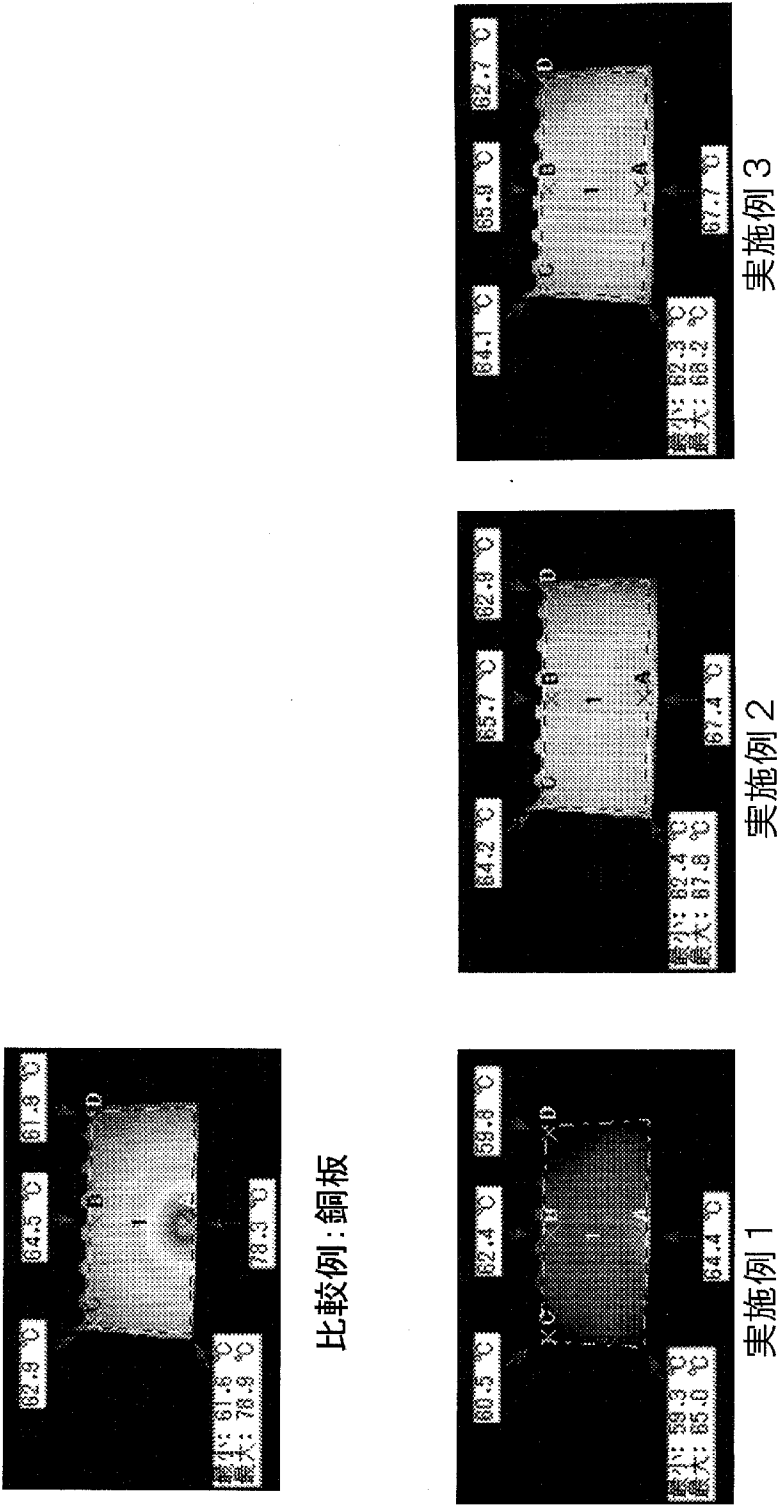


Figure 10

Case 1			Case 2		
实施例1	实施例2	实施例3	实施例1	实施例2	实施例3
	3.5%	8.0%		2.3%	4.9%
0.3%		1.0%	-2.4%		4.2%
3.0%	6.9%	5.0%	-5.4%	0.6%	2.8%
1.1%	4.2%	3.0%	-4.8%	0.5%	-1.3%
2.4%	0.9%	4.2%	-0.4%	-2.6%	0.4%
1.69%	3.86%	4.26%	-3.23%	0.20%	2.19%

Figure 11

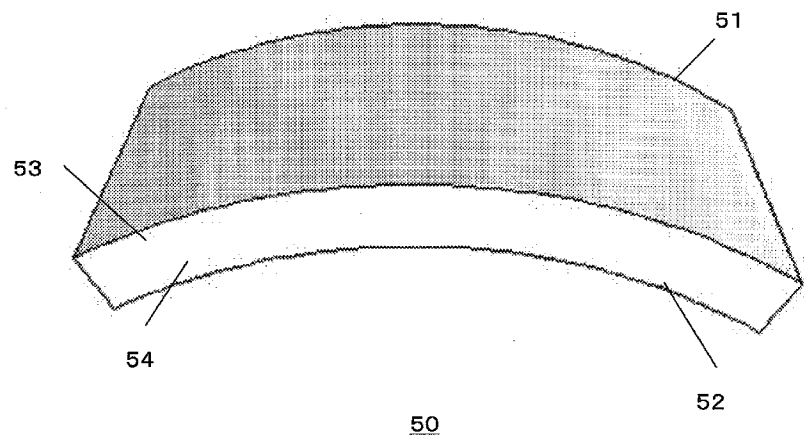


Figure 12

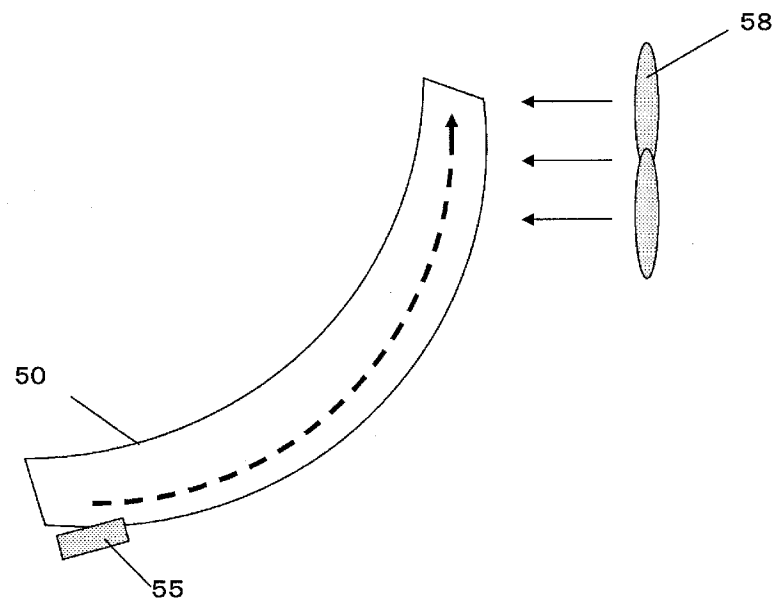


Figure 13

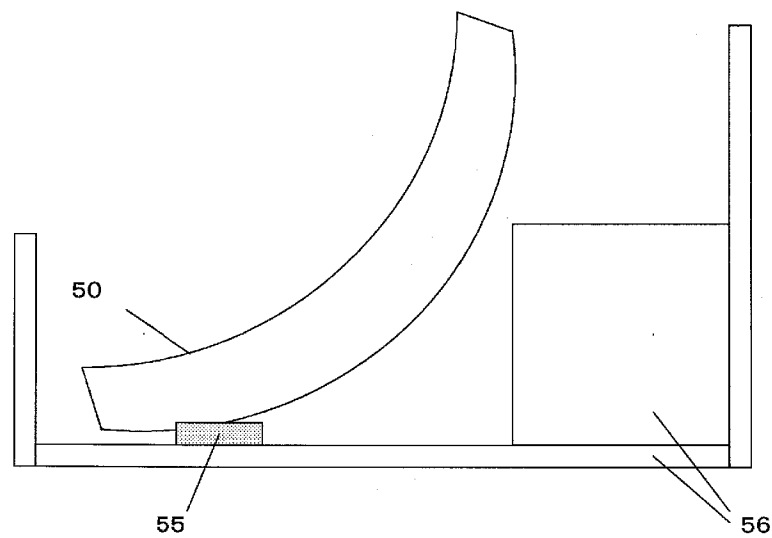


Figure 14

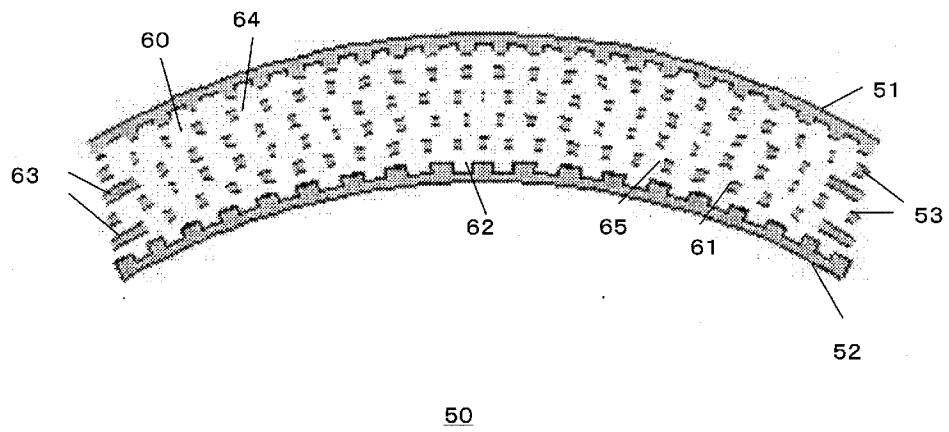


Figure 15

