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(71) Applicant (for all designated States except US):
MOLEX INCORPORATED [US/US]; 2222 Wellington Court, Lisle, Illinois 60532-1682 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **TSURUTA, Kat-suya** [JP/JP]; Molex Incorporated, 2222 Wellington Court, Lisle, Illinois 60532 1682 (US). **OHSAWA, Kenji** [JP/JP]; Molex Incorporated, 2222 Wellington Court, Lisle, Illinois 60532 1682 (US). **FUKUNAGA, Rinkou**

[JP/JP]; Molex Incorporated, 2222 Wellington Court, Lisle, Illinois 60532 1682 (US).

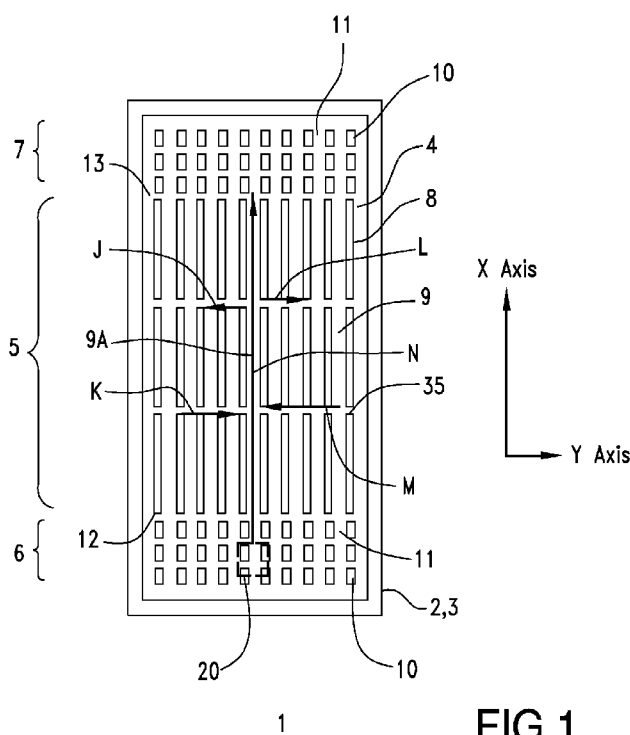
(74) Agents: **MORELLA, Timothy Michael** et al.; Molex Incorporated, 2222 Wellington Court, Lisle, Illinois 60532 1682 (US).

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[Continued on next page]

(54) Title: HEAT TRANSPORTING UNIT, ELECTRONIC CIRCUIT BOARD AND ELECTRONIC DEVICE



(57) Abstract: The heat transporting unit according to the Present Disclosure comprises: an upper plate; a lower plate that faces the upper plate; an interior space that is formed by the upper plate and the lower plate and wherein a refrigerant can be sealed; a first region, that is a region that is part of the interior space and that is provided with a first column portion that forms a plurality of first ducts that extend in the X-axis direction; and a second region that is provided with a second column portion that forms a plurality of second ducts that extend in the X-axis direction and the Y-axis direction, that is a region that is other than the first region within the interior space; wherein: the first ducts and second ducts connect at a boundary between the first region and the second region.



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**HEAT TRANSPORTING UNIT, ELECTRONIC CIRCUIT BOARD
AND ELECTRONIC DEVICE**

REFERENCE TO RELATED APPLICATIONS

5 [0001] The Present Application claims priority to prior-filed Japanese Patent Application No. 2010-095565, entitled "Heat Transporting Unit, Electronic Circuit Board And Electronic Device," filed on 17 April 2010 with the Japanese Patent Office. The contents of the aforementioned Patent Application is fully incorporated in its entirety herein.

10 **BACKGROUND OF THE PRESENT DISCLOSURE**

[0002] The Present Disclosure relates, generally, to a heat transporting unit and an electronic device that efficiently transports heat received from a heat emitting object such as a semiconductor integrated circuit, an LED element, a power device or an electronic component.

15 [0003] Electronic components such as semiconductor integrated circuits, LED elements and power devices are used in electronic devices, industrial devices, automobiles and the like. These electronic components become heat emitting objects that emit heat due to the electric currents that flow therein. When the heat emitted from the heat emitting object rises above a specific temperature, problems arise in that the operation of the electronic component cannot be guaranteed, and the possibility of an adverse effect on other components exists, and, as a result,
20 the possibility of causing a breakdown of performance of the electronic device itself.

[0004] In order to cool such a heat emitting object, there has been a proposal for a cooling device for diffusing a heat pipe that has a cooling effect through the vaporization and condensation of a sealed refrigerant. In a heat pipe, heat is removed from the heat emitting object when the refrigerant sealed therein is vaporized. The vaporized refrigerant is condensed through the
25 radiation of heat, and the condensed refrigerant moves back. The heat pipe cools the heat emitting object through cycling of this vaporization and condensation. That is, the heat pipe diffuses and transports heat. Moreover, the heat that is diffused and transported by the heat pipe is cooled through combination with a heat radiating member. When compared to a metal heat diffusing member, a heat pipe is able to diffuse and transport heat more efficiently using a
30 refrigerant.

[0005] In recent years, the electronic components that require cooling have not been limited only to relatively large semiconductor integrated circuits such as central processing units (CPUs) or specialty ICs, but are often are extremely small electronic components, such as light emitting devices (LEDs). This type of small electronic component not only is small in terms of its size,
5 but also often a plurality of electronic components together comprise a single set. Because of this, the cooling device which diffuses the heat pipe must cool a plurality of electronic components.

[0006] Often small electronic components of this type are mounted in one portion of an electronic circuit board, leaving no extra room in the location of the mounting, so that the heat
10 cannot diffuse or escape therefrom. Because of this, after the heat has been removed from the electronic components, it is necessary to transport that heat at high speed, and then to perform cooling at the transportation destination. That is, a heat transporting member for transporting heat at a high speed in a specific direction, being a heat transporting member diffuses the vaporization and condensation of a refrigerant, is desirable. There have been proposals for heat
15 pipes that transport, in a specific direction, heat that has been removed from a heat emitting object. See, for example, Japanese Patent Application Nos. H11-101585; 2002-039693; 2010-007905; and 2007-113864.

[0007] In such a heat pipe, heat that has been removed from a heat emitting object, a refrigerant is sealed in an interior space that is formed from an upper plate and a lower plate that are joined
20 together, and the heat of the heat emitting object is transported by the cycle of movement of this sealed refrigerant. In a cooling device diffuses a heat pipe, it is important, in increasing the cooling capability, to increase the heat transporting efficiency (which is determined by the per-cycle speed of the movement of the vaporized refrigerant and the movement of the condensed refrigerant, and by the number of cycles per unit time).

[0008] At this time, the refrigerant that is sealed in the interior space vaporizes due to the heat
25 from the heat emitting object to move within the interior space, and eventually cools and condenses, and moves within the interior space. Because of this, the vaporized refrigerant and the condensed refrigerant interfere with each other while moving in mutually opposite directions within the interior space. When the effects of this interference become large, there is a problem
30 in that this produces an adverse effect on the speed of cycling of the movement of the vaporized refrigerant and the movement of the condensed refrigerant, reducing the speed of transport of the

heat and reducing the transportation efficiency. In order to prevent this interference between the movement of the vaporized refrigerant and the movement of the condensed refrigerant, it is desirable to increase the size of the interior space and to have no obstructions.

[0009] On the other hand, in a structure wherein there are no obstructions within the interior space, the heat pipe would be nothing but the upper plate and the lower plate, and thus extremely weak. Because in a heat pipe the heat emitting object is cooled through the repetitive cycling of vaporizing and condensing the refrigerant that is sealed therein, the heat pipe is subjected to cycling of extremely high internal pressures. If the strength of the heat pipe were weak in such a severe operating environment, the heat pipe would break due to a "popcorn" phenomenon produced through the vaporization of the refrigerant, so that there would be a problem in that the refrigerant would leak out onto the electronic components and the electronic circuit board. If the refrigerant were to leak out, there would be a problem in that it would damage the electronic components or electronic circuit board, and could cause a malfunction of the electronic device.

[0010] Although it is necessary to increase the strength, if, for example, the strength of the upper plate and lower plate themselves were to be increased, this would engender an increase in cost and an increase in thickness, which would be unsuitable for the Present Disclosure, and would also be accompanied by difficulties in assembly. This is because a heat pipe that is excessively thick is not suited to the space wherein light emitting diodes, and the like, are mounted, because of the lack of extra space.

[0011] Because of this, an increase in the strength of the heat pipe necessitates the provision of reinforcing members, such as columns or partitioning plates, within the interior space of the heat pipe. However, the provision of a reinforcing member would interfere with the freedom of movement of the vaporized refrigerant and of the condensed refrigerant within the interior space. The '585 Application and the '693 Application are intended to transport heat from a heat emitting object in a specific direction while increasing the strength of the heat pipe.

[0012] The heat pipe disclosed in the '585 Application discloses a flat heat pipe wherein there is an array of pores (which are actually more ducts than pores). In the heat pipe disclosed in the '585 Application, the individual ducts perform the movement of the vaporized refrigerant and the movement of the condensed refrigerant. The heat pipe disclosed in the '585 Application is able to transport the heat towards the specific direction through these pores. That is, the vaporized refrigerant moves from a first end to a second end of the pores, and the condensed refrigerant

moves from the second end to the first end of these pores. In the technology disclosed in the '585 Application the strength of the heat pipe as a whole is maintained by the layering of the ducts in the crosswise direction.

[0013] However, in the heat pipe disclosed in the '585 Application, adjacent ducts are

5 completely separated from each other, so the movement of the refrigerant only occurs in the lengthwise direction of the heat pipe (the direction along the ducts). Because of this, there is a problem in that there is no cooling effect in the crosswise direction for a small heat emitting object. Moreover, when the heat pipe disclosed in the '585 Application cools a small heat emitting object, the cooling load is applied only to the heat pipe that contacts the heat emitting
10 object directly. That is, only the refrigerant that is in the duct that contacts the heat emitting object directly will be vaporized and move, and will condensed and move. Because of this, the heat pipe disclosed in the '585 Application has a problem in that it is unable to achieve its full performance.

[0014] The heat pipe disclosed in the '693 Application forms movement paths for the vaporized
15 refrigerant and movement paths for the condensed refrigerant through mutually offsetted slits that are provided in layered members. These slits are formed in a specific direction, so that the movement of the refrigerant and the movement will be performed in a specific direction. The result is that the heat pipe disclosed in the '693 Application is able to transport the heat in a specific direction.

20 **[0015]** The '693 Application has the same problem as in the '585 Application, in that, as with the '585 Application, the individual ducts, which are formed by the slits, are independent of each other.

[0016] In the '905 Application, a plurality of plate members are stacked together, in a disclosure of a heat pipe that transports heat through producing capillary forces through the stacking of
25 plate members provided with channels and plate members provided with holes.

[0017] However, while the heat pipe disclosed in the '905 Application is able to transport heat in the long direction, it is difficult for heat to diffuse in the short direction. Because of this, when the heat emitting objects are small, it is possible to transport, in the long direction, the heat of the heat emitting object only in the vicinity that contacts the heat emitting object. Additionally, heat
30 can diffuse non-directionally from a heat emitting object through holes that are provided across the entire surface, making it difficult to transport heat in the specific direction.

[0018] Not only is it not possible for any of the technologies in the '585 Application through the '905 Application to achieve the full performance of the heat pipe when transporting heat from one end portion to the other end portion, but they also cannot achieve their maximum heat pipe performance when transporting heat towards one end portion from the center portion. This is because although the cooling is only for heat that is transported through a specific duct, the cooling will apply also to ducts that are not involved in the transporting of the heat, and thus the cooling member for cooling the heat that is transported by the heat pipe will not be able to exhibit its maximum performance.

[0019] Additionally, the end portion of the heat pipe that transports the heat must achieve either the function of receiving heat from the heat emitting object, the function of cooling the heat that is transported from the other end portion, for both. Because of this, regardless of the size of the heat emitting object and regardless of the size of the cooling member, it is desirable for the heat that is received from the heat emitting object, and the heat that is transported, to diffuse in the crosswise direction.

[0020] However, the heat pipes disclosed in the '585 Application through the '905 Application do not have such a function, so that only heat from a specific location is received and cooled. Because of this, the heat pipes in the '585 Application and the '693 Application have a problem in that they cannot be applied to cooling small heat emitting objects.

[0021] The '864 Application discloses a heat pipe with stacked plate members that are provided with channels in the short direction at the end portions and plate members that are provided with ducts in the lengthwise direction across the entirety. These heat pipes allow the diffusion of heat in the short direction at the end portions, and the movement of heat in the lengthwise direction otherwise.

[0022] However, in the heat pipe disclosed in the '864 Application, the refrigerant can move in the lengthwise direction only in an extremely narrow width, reducing the heat transporting efficiency. In addition, the ducts that are provided in the short direction only partially overlap the ducts that are provided in the lengthwise direction, so there is a problem in that the transmission of heat between the ducts is poor. Furthermore, because the ducts are formed unbalanced within the heat pipe, there is also a problem in that the heat pipe is not strong. As a result, the technology of the '864 Application also has a problem in that it is unable to transport the heat of the heat emitting object efficiently in the specific direction. In addition, the in the heat pipe

disclosed in the '864 Application, there are structural limitations to the position of the contact with the heat emitting object, and thus there is a problem in that it is difficult to use this heat pipe in electronic devices or industrial devices wherein there is high-density packaging.

[0023] As described above, the heat pipes for transporting heat from a heat emitting object in a specific direction according to the conventional technologies have problems in that they cannot achieve the maximum performances thereof. In particular, they have problems in that the cooling by transporting heat from small heat emitting objects is inadequate. Furthermore, they cannot both ensure the strength of the heat pipe and transport heat efficiently while handling flexibly the sizes of the heat emitting objects and the contact positions thereof.

[0024] In contemplation of the problem areas set forth above, the object of the Present Disclosure is provided a heat transporting unit able to transport efficiently heat from a small heat emitting object, while achieving the maximum performance thereof, through: (1) ensuring strength through column portions and reinforcing portions, (2) minimizing obstructions to movement of the refrigerant in the sealed space by the column portions and reinforcing portions, (3) achieving movement of the refrigerant in the required X-axis, Y-axis, and Z-axis directions while minimizing impediments to the movement of the refrigerant, and (4) handling flexibly the sizes of the heat emitting objects and the contact positions thereof. In addition, a heat pipe is provided that can be mounted easily, even in electronic devices and industrial devices with high-density mounting.

[0025] Note that the heat transporting unit has a heat pipe structure diffuses vaporization and condensation of a sealed refrigerant.

SUMMARY OF THE PRESENT DISCLOSURE

[0026] In contemplation of the problem areas set forth above, in the heat transporting unit according to the Present Disclosure, a space is defined by the mutually orthogonal X axis, Y axis, and Z axis, and comprises: an upper plate; a lower plate that faces the upper plate; an interior space that is formed by the upper plate and the lower plate and wherein a refrigerant can be sealed; a first region, that is a region that is part of the interior space and that is provided with a first column portion that forms a plurality of first ducts that extend in the X-axis direction; and a second region that is provided with a second column portion that forms a plurality of second ducts that extend in the X-axis direction and the Y-axis direction, that is a region that is other

than the first region within the interior space; wherein: the first ducts and second ducts connect at a boundary between the first region and the second region.

[0027] The heat transporting unit according to the Present Disclosure is provided with column portions that are different in the first region and the second region, in a sealed space wherein refrigerant is sealed, to thereby not only ensure strength, but to also achieve optimal diffusion and transportation of heat in the X-axis, Y-axis, and Z-axis directions.

[0028] Additionally, by diffusing, in the long direction and in the short direction, the heat that is received at the location of thermal contact with the heat emitting object while transporting the diffused heat in the long direction, the heat transporting unit is able to transport efficiently the heat from the heat emitting object while achieving the maximum performance as a heat pipe.

[0029] The result is that the heat transporting unit according to the Present Disclosure is able to transport efficiently heat from a small heat emitting object.

[0030] Additionally, the heat transporting unit according to the Present Disclosure is also able to transport at high speeds the heat from the heat emitting object while handling also changes in the locations of disposition of the heat emitting objects.

BRIEF DESCRIPTION OF THE FIGURES

[0031] The organization and manner of the structure and operation of the Present Disclosure, 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:

[0032] FIG. 1 is a perspective diagram of a heat transporting unit according to a first form of embodiment according to the Present Disclosure;

[0033] FIG. 2 is an interior perspective diagram of the heat transporting unit according to the first form of embodiment according to the Present Disclosure;

[0034] FIG. 3 is an explanatory diagram for the operation of the heat transporting unit according to the first form of embodiment according to the Present Disclosure;

[0035] FIG. 4 is a conceptual diagram for the operation of the heat transporting unit according to the first form of embodiment according to the Present Disclosure;

[0036] FIG. 5 is an interior perspective diagram of the heat transporting unit according to a second form of embodiment according to the Present Disclosure;

[0037] FIG. 6 is a cross-sectional diagram of the end portion of a heat transporting unit according to a second form of embodiment according to the Present Disclosure;

[0038] FIG. 7 is an interior schematic diagram of the heat transporting unit according to a second form of embodiment according to the Present Disclosure;

5 [0039] FIG. 8 is an enlarged diagram in the vicinity of the second region in a heat transporting unit according to a second form of embodiment according to the Present Disclosure;

[0040] FIG. 9 is a plan view diagram of a heat transporting unit according to a second form of embodiment according to the Present Disclosure;

10 [0041] FIG. 10 is a perspective diagram of a heat transporting unit according to a second form of embodiment according to the Present Disclosure;

[0042] FIG. 11 is an assembly perspective diagram of a heat transporting unit according to a third form of embodiment according to the Present Disclosure;

[0043] FIG. 12 is an explanatory diagram lining up an example of embodiment and comparative examples;

15 [0044] FIG. 13 is a graph illustrating measurement results for the example of embodiment and the comparative examples;

[0045] FIG. 14 is a side view diagram of a heat transporting unit according to a forth example of embodiment according to the Present Disclosure; and

20 [0046] FIG. 15 is a schematic diagram of an electronic device according to a fifth form of embodiment according to the Present Disclosure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

25 [0047] While the Present Disclosure 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 disclosure is to be considered an exemplification of the principles of the Present Disclosure, and is not intended to limit the Present Disclosure to that as illustrated.

[0048] In the embodiments illustrated in the Figures, representations of directions such as up, down, left, right, front and rear, used for explaining the structure and movement of the various elements of the Present Disclosure, are not absolute, but relative. These representations are
30 appropriate when the elements are in the position shown in the Figures. If the description of the position of the elements changes, however, these representations are to be changed accordingly.

[0049] A heat transporting unit according to a first invention according to the Present Disclosure is one wherein a space is defined by the mutually orthogonal X axis, Y axis, and Z axis; and comprises: an upper plate; a lower plate that faces the upper plate; an interior space that is formed by the upper plate and the lower plate and wherein a refrigerant can be sealed; a first region, that is a region that is part of the interior space and that is provided with a first column portion that forms a plurality of first ducts that extend in the X-axis direction; and a second region that is provided with a second column portion that forms a plurality of second ducts that extend in the X-axis direction and the Y-axis direction, that is a region that is other than the first region within the interior space; wherein: the first ducts and second ducts connect at a boundary between the first region and the second region.

[0050] Given this structure, not only is the heat transporting unit able to have improved strength, but is also able to transport, in the lengthwise direction, the heat removed from the heat emitting object using fully the short direction of the heat transporting unit, even with a small heat emitting object.

[0051] In a heat transporting unit according to a second invention according to the Present Disclosure, in addition to the first invention, in a first duct, not only does a vaporized refrigerant move in the X-axis direction, but a condensed refrigerant also moves in the X-axis direction, and in a second duct, not only does the vaporized refrigerant move in the X-axis direction and the Y-axis direction, but the condensed refrigerant also moves in the X-axis direction and the Y-axis direction.

[0052] Given this structure, the heat transporting unit is able to transport, in the long direction, the heat removed from the heat emitting object, while using the short direction fully.

[0053] In a heat transporting unit according to a third invention according to the Present Disclosure, in addition to the first and second inventions, not only does vaporized refrigerant move mutually in the first duct and the second, but also the condensed refrigerant moves mutually in the first duct and the second duct.

[0054] Given this structure, the heat transporting unit is able to transport heat through using efficiently the first region and the second region, which have different functions.

[0055] In a heat transporting unit according to a fourth invention according to the Present Disclosure, in addition to any of the first through third inventions, a second region is provided at

at least one of the two end portions of the interior space, and a first region is provided in a region other than the second region in the interior space.

[0056] Given this structure, the heat transporting unit is able to transport heat from a heat emitting object that is disposed on one end portion to the other end portion.

5 **[0057]** In a heat transporting unit according to a fifth invention according to the Present Disclosure, in addition to any of the first through fourth inventions, a second region is provided in the center portion of the interior space, and a first region is provided in a region other than the second region in the interior space.

10 **[0058]** Given this structure, the heat transporting unit is able to transport, towards both ends, heat of a heat emitting object that is disposed at the middle thereof.

[0059] In a heat transporting unit according to a sixth invention according to the Present Disclosure, in addition to the first through fifth inventions, a second region not only diffuses heat received from a heat emitting object in the X-axis direction and the Y-axis direction, but also moves it to the first region, and the first region transports, in the X-axis direction, the heat moved
15 from the second region.

[0060] Given this structure, the heat transporting unit is able to use the Y-axis direction fully, upon diffusion of the heat removed from the heat emitting object, to transport that heat in the X-axis direction.

[0061] In a heat transporting unit according to a seventh invention according to the Present Disclosure, in addition to the sixth invention, when the second region is provided at a first end portion and at a second end portion that is opposite from the first end portion, within the interior space, the second region of the first end portion side not only causes the diffusion, in the X-axis direction and the Y-axis direction, of the heat received from the heat emitting object, but also causes it to move to the first region, and the first region transports, in the X-axis direction, the
20 heat moved from the second region on the first end portion side, and the second region on the second end portion side diffuses, in the X-axis direction and the Y-axis direction, the heat that has been transported by the first region.

[0062] Given this structure, the heat transporting unit diffuses, in the X-axis direction and the Y-axis direction, using the second region, the heat removed from the heat emitting object, and
25 transports it in the X-axis direction using the first region. Furthermore, the heat transporting unit

radiates heat using the second region wherein no heat emitting object is disposed. The result is the ability of the heat transporting unit to cool the heat emitting object.

[0063] In a heat transporting unit according to an eighth invention according to the Present Disclosure, in addition to the sixth invention, the second region is provided in the center of the interior space, and when the first region is provided at a first end portion and at a second end portion that is on the opposite side from the first end portion, in the interior space, the second region not only diffuses in the X-axis direction and the Y-axis direction the heat that is received from the heat emitting object, but also moves it to the first region, and the first region transports, in the X-direction, the heat moved from the second region.

[0064] Given this structure, the heat transporting unit uses the second region that is positioned at the center to diffuse, in the X-axis direction and the Y-axis direction, the heat of the heat emitting object, and uses the first region, positioned at both ends, to transport it to both ends of the heat transporting unit along the X-axis direction. This is used in a case wherein one wishes to transport the heat of the heat emitting object in multiple directions.

[0065] In a heat transporting device according to a ninth invention according to the Present Disclosure, in addition to any of the first through eighth inventions, additionally, the upper plate and/or the lower plate also has a heat receiving portion that contacts the heat emitting object thermally, and the heat receiving portion is provided spanning the first region and the second region.

[0066] Given the structure, the heat transporting unit receives the heat efficiently from the heat emitting object, enabling transportation in the specific direction. Additionally, this increases the heat transportation efficiency of the heat transporting unit.

[0067] In a heat transporting unit according to a 10th invention according to the Present Disclosure, in addition to any of the first through ninth inventions, a first column portion has a cutout to connect together adjacent first ducts within a plurality of first ducts.

[0068] Given this structure, the refrigerant can be exchanged between first ducts.

[0069] In a heat transporting unit according to an 11th invention according to the Present Disclosure, in addition to any of the first through 10th inventions, the second region has one or more intermediate plates layered in the Z-axis direction, where the intermediate plates form a second column portion that is stacked in the Z-axis direction, and the second column portion forms second ducts in the X-axis direction, the Y-axis direction, and the Z-axis direction.

[0070] Given this structure, the second region can diffuse heat three-dimensionally.

[0071] In a heat transporting unit according to a 12 invention according to the Present Disclosure, in addition to any of the first through 11th inventions, the second column portion comprises a large column member and a small column member that is smaller than the large column member.

[0072] Given this structure, the second ducts have a more complex structure, and produce strong capillary forces. As a result, the second ducts diffuse the vaporized refrigerant and move the condensed refrigerant efficiently.

[0073] In a heat transporting unit according to a 13th invention according to the Present Disclosure, in addition to any of the first through 12th inventions, at least a portion of the first ducts and the second ducts have capillary forces that move the condensed refrigerant.

[0074] Given this structure, the heat transporting unit is able to move the condensed refrigerant, enabling transportation of the heat of the heat emitting object through a cycle of transporting the vaporized refrigerant and moving the condensed refrigerant.

[0075] In a heat transporting unit according to a 14th invention according to the Present Disclosure, in addition to any of the first through 13th inventions, at least a portion of the upper plate, the lower plate, the first column portion, and/or the second column portion has a channel in a surface that is exposed to the interior space.

[0076] The capillary forces of the first duct and the second duct are increased given this structure.

[0077] In a heat transporting unit according to a 15th invention according to the Present Disclosure, in addition to any of the first through 14 inventions, the upper plate and/or the lower plate is further equipped with a heat radiating portion for radiating the transported heat, in a region that faces at least a portion of the first region and/or the second region.

[0078] Given this structure, the heat transporting unit is able to cool the transported heat quickly. As a result, it is possible to increase the efficiency of the cycle for transporting the vaporized refrigerant and moving the condensed refrigerant, enabling the heat transporting unit to transport the heat with high efficiency.

[0079] In a heat transporting unit according to a 16th invention according to the Present Disclosure, in addition to any of the first through 15th inventions, at least a portion of the upper

plate, the lower plate, the first column portion, and/or the second column portion has metal plating on a surface that is exposed to the interior space.

[0080] In a heat transporting unit according to a 17th invention according to the Present Disclosure, in addition to any of the first through 16th inventions, the width of the first region in the Y-axis direction and the width of the second region in the Y-axis direction are essentially identical.

[0081] Given this structure, the heat transporting unit is able to transport the heat using the short direction maximally as well. Because of this, the heat transporting unit does not require excessive mounting space.

[0082] Forms of embodiment according to the Present Disclosure will be explained below in reference to the drawings.

[0083] Note that a heat pipe is a member, component, apparatus, or device that achieves a function of cooling a heat emitting object by repetitively vaporizing a refrigerant that is sealed within an interior space, by receiving heat from the heat emitting object, and cooling and condensing the vaporized refrigerant. The heat transporting unit in the present specification refers to a member, component, device, or apparatus for transmitting heat from a heat emitting unit through the movement of a refrigerant.

[0084] Because the heat transporting unit according to the Present Disclosure uses the function and operation of a heat pipe, the concept of the heat pipe will be explained first.

[0085] The heat pipe has a refrigerant sealed into the interior thereof, where a surface that is a heat receiving surface contacts a heat emitting object, such as an electronic component. The refrigerant in the interior receives the heat from the heat emitting object, to be vaporized, where the heat of the heat emitting object is removed at the time of the vaporization. The vaporized refrigerant moves within the heat pipe. The vaporized refrigerant that has moved then is cooled at a heat radiating surface (or due to a secondary cooling member such as a heat sink or a cooling fan, or the like) to thus condense. The refrigerant, which has become a liquid through condensation, moves within the heat pipe to again move to the heat receiving surface. The refrigerant that has moved to the heat receiving surface is vaporized again to remove the heat of the heat emitting object.

[0086] Through the repetition of the vaporization and condensation of the refrigerant in this way, the heat pipe transports the heat from the heat emitting object, to thereby cool the heat emitting

object. In particular, the heat pipe causes the vaporized refrigerant to move and causes the condensed refrigerant to move within the interior space wherein the refrigerant is sealed, doing so along a specific direction, so that the heat pipe is able to transport, in a specific direction, the heat removed from the heat emitting object.

5 [0087] An overall summary of a heat transporting unit according to a first form of embodiment will be explained using FIG. 1 and FIG. 2.

[0088] FIG. 1 is a perspective view of a heat transporting unit according to a first form of embodiment according to the Present Disclosure. FIG. 2 is an interior perspective view of the heat transporting unit in the first form of embodiment according to the Present Disclosure, shown
10 in a prospective cross-sectional diagram enabling viewing of the interior of the unit during the transportation of heat.

[0089] First, as illustrated in FIG. 1 and FIG. 2, a three-dimensional space is defined by the mutually orthogonal X axis, Y axis, and Z axis. The structure of the heat transporting unit 1 will be explained using the X axis, Y axis, and Z axis. Additionally, while the heat transporting unit 1
15 has a variety of structures therein, it has, when viewed from the outside, a flat rectangular shape, as in the example illustrated in FIG. 1. Of course, a variety of treatments may also be performed on the surface.

[0090] The heat transporting unit 1 is provided with an upper plate 2, a lower plate 3 that faces the upper plate 2, and an interior space 4, wherein a refrigerant can be sealed, formed by the
20 upper plate 2 and the lower plate 3. The interior space 4 has a first region 5 in a region in a portion thereof, and second regions 6 and 7 in regions that form the remaining portion that is not the first region 5. In FIG. 2, the first region is provided in the vicinity of the center in the long direction (the X-axis direction) of the heat transporting unit 1, and the second regions 6 and 7 are provided at both ends in the long direction (the X-axis direction) of the heat transporting unit 1.
25 The first region 5 is provided with a first column portion 8 wherein a plurality of first ducts 9 is formed along the X-axis direction. The first column portion 8 is a three-dimensional member having a long direction along the X-axis direction in the first region 5, and regions that are interposed between a plurality of first column portions 8 form the first ducts 9. In this way, each of a plurality of first column portions 8, which are three-dimensional members having a long
30 direction, is disposed lined up along the X-axis direction, to form a plurality of first ducts 9 that extend in the X-axis direction.

[0091] On the other hand, the second regions 6 and 7 are provided with second column portions 10 that form a plurality of second ducts 11 that run in the X-axis direction and the Y-axis direction. The second column portions 8 are a plurality of three-dimensional members that are lined up in the X-axis direction and the Y-axis direction in the second regions 6 and 7. The regions that are interposed between the plurality of second column portions 10 that are lined up in the X-axis direction form ducts that run in the Y-axis direction, and the regions that are interposed between the plurality of second column portions 10 that are lined up in the Y-axis direction form ducts that run in the X-axis direction, where the ducts that run in the X-axis direction and the ducts that run in the Y-axis direction combine into a grid shape. These grid-shaped ducts form the second ducts 11.

[0092] A refrigerant is sealed within the interior space 4, and heat from the heat emitting object is transported in a specific direction by repeated vaporization and condensation of the sealed refrigerant. However, if the interior space 4 were the entirety of the space, then there would be the possibility that the heat transporting unit 1 would be damaged or would break due to the expansion and contraction thereof due to the loads of increasing and decreasing pressure, produced by the vaporization and condensation of the refrigerant. The first column portions 8 and the second column portions 10 not only ensure the strength of the heat transporting unit 1, but also form the first ducts 9 and the second ducts 11 that are able to diffuse and transport the heat well in the X-axis direction and the Y-axis direction.

[0093] The first ducts 9 and the second ducts 11 connect at a boundary 12 between the first region 5 and the second region 6, and at a boundary 13 between the first region 5 and the second region 7. These connections enable the refrigerant that moves from the second ducts 11 (the vaporized refrigerant and/or the condensed refrigerant) to move into the first ducts 9, to then move through the first ducts 9. Additionally, the Y-axis direction width of the first region 5 in the interior space 4 and the Y-axis direction widths of the second regions 6 and 7 (that is, the widths in the short direction) are essentially identical. Being essentially identical causes the respective widths of the first region 5, for transporting the heat in the X-axis direction, and of the second regions 6 and 7, for diffusing the heat in the X-axis direction and the Y-axis direction, to be identical, so that the entirety of the interior space 4 that can be formed by the dimensions of the heat transporting unit 1 can be used for transporting the heat.

[0094] Note that in FIG. 2, codes are assigned to only a portion of the elements, for preserving clarity in the diagram, in regards to the first column portions 8, the second column portions 10, the first ducts 9, and the second ducts 11; however, those elements that are not labeled with codes correspond, respectively, to the first column portions 8, the second column portions 10, the first ducts 9, and the second ducts 11. For example, the standing members that have shapes identical to those of the first column portions 8, unless specified especially otherwise, are all also first column portions 8. This is true in FIG. 3 and beyond as well.

[0095] FIG. 3 will be used next to explain the operation of the heat transporting unit 1.

[0096] FIG. 3 is an operation explanatory diagram for the heat transporting unit in the first form of embodiment according to the Present Disclosure. While the schematic structure of the interior of the heat transporting unit 1 is illustrated in FIG. 3, the movement of the refrigerant that is sealed in the interior space 4 (that is, the diffusion and transportation of heat) will be explained by the arrows.

[0097] The upper plate 2 and the lower plate 3 have a flat plate shape having a long direction and a short direction, where the X-axis direction is along the long direction and the Y-axis direction is along the short direction. This type of shape for the upper plate 2 and the lower plate 3 causes the heat transporting unit 1 to have a flat shape having a long direction and a short direction.

[0098] A heat emitting object 20 is disposed at the bottom surface of the heat transporting unit 1 (the bottom surface of the lower plate 3). Additionally, the heat emitting object 20 is disposed at a position facing the second region 6 of the bottom surface. Note that the heat emitting object 20 is an element that produces heat, such as an electronic component, an electronic element, a semiconductor integrated circuit, a light emitting element, an electronic circuit board, a mechanical component, a mechanical element, or the like. Additionally, the heat emitting object 20 is disposed in a position facing the second region 6 at the bottom surface. The first region 5 has first ducts 9 that run in the X-axis direction, as described above, and the second regions 6 and 7 have second ducts 11 that run in the X-axis direction and the Y-axis direction.

[0099] The heat transporting unit 1 in the second region 6 removes heat from the heat emitting object 20, because refrigerant is sealed within the interior space 4, the heat from the heat emitting object 20 vaporizes the refrigerant. The evaporating refrigerant moves in the X-axis direction and the Y-axis direction in the second ducts 11 of the second region 6. That is, in the second region 6, the heat removed from the heat emitting object 20 uses the second ducts 11 to diffuse along

the direction of Arrow A (the X-axis direction) and the direction of Arrow B (the Y-axis direction). Of course, in the heat transporting unit 1, a three-dimensional interior space 4 is formed, structured with an X-axis, a Y-axis, and a Z-axis, and thus the vaporized refrigerant moves, and the heat diffuses, also in the Z-axis direction; however, in the first form of embodiment according to the Present Disclosure, the explanation will use the X-axis direction and Y-axis direction, the directions in which the refrigerant moves primarily.

[0100] Next, at the boundary 12 between the second region 6 and the first region 5, the second ducts 11 connect to the first ducts 9. Because of this, the vaporized refrigerant moves from the second ducts 11 into the first ducts 9.

[0101] The first ducts 9 are formed along the X-axis direction in the first region 5, and the vaporized refrigerant moves in the direction indicated by the Arrow C in the first ducts 9. Here, in FIG. 3, the Arrow C is drawn for only one of the first ducts 9; however, the vaporized refrigerant moves similarly in the direction of the Arrow C in the other first ducts 9 as well. The result of the movement is that the heat of the heat emitting object 20 is transported from the second region 6, which is one end portion of the heat transporting unit 1, to the second region 7, which is the other end portion thereof.

[0102] The first ducts 9 and the second ducts 11 connect at the boundary 13 between the first region 5 and the second region 7. Because of this, as illustrated by Arrow C, the vaporized refrigerant that has moved along the first duct 9 moves into the second ducts 11 of the second region 7.

[0103] The second ducts 11 run along the X-axis direction and the Y-axis direction, and thus the vaporized refrigerant that has moved from the first ducts 9 moves along the Arrow D (the X-axis direction) and the Arrow E (the Y-axis direction). That is, in the second ducts 11 of the second region 7, the vaporized refrigerant moves broadly in the short direction and the long direction.

[0104] In the second region 7, the second ducts 11 are used to move the vaporized refrigerant broadly in the X-axis direction and the Y-axis direction, enabling the vaporized refrigerant to cool. This is because the vaporized refrigerant moving broadly through the second region 7, wherein the heat emitting object 20 is not disposed causes the heat that is included therein to escape.

[0105] The vaporized refrigerant that moves through the second region 7 in this way condenses due to the cooling, changing into a refrigerant that is a liquid. The result is that the condensed refrigerant moves in the X-axis direction and the Y-axis direction along the second ducts 11 in the second region 7. Here the flow is as indicated by the Arrow D and the Arrow E.

5 [0106] Here the second ducts 11 of the second region 7 are extremely narrow ducts, and thus can exhibit capillary forces wherein the liquid is moved through capillary action.

[0107] The condensed refrigerant, after moving in the X-axis direction and the Y-axis direction within the second region 7 through the plurality of second ducts 11, arrives at the boundary 13 between the first region 5 and the second region 7. Because the second ducts 11 of the second
10 region 7 are connected to the first ducts 9 of the first region 5, the condensed refrigerant moves from the second ducts 11 into the first ducts 9, as indicated by the Arrow F. At this time, the condensed refrigerant moves in the second ducts 11 not only in the X-axis direction, but in the Y-axis direction as well, and thus the condensed refrigerant spreads in the short direction in the interior space 4 as well. Because of this, at the boundary 13, the condensed refrigerant is able to
15 move within each of the plurality of the first ducts 9 that are lined up in the short direction within the interior space 4.

[0108] The condensed refrigerant that has moved into the first ducts 9 moves along the X-axis direction through the first ducts 9, as indicated by the Arrow G. That is, the condensed refrigerant moves through the first ducts 9 from the end portion positioned within the second
20 region 7 towards the end portion positioned within the second region 6. The first ducts 9 are fine ducts with closed peripheries, and thus the first ducts 9 can exhibit capillary forces. The first ducts 9 cause the condensed refrigerant to move in the X-axis direction through these capillary forces.

[0109] The condensed refrigerant that has moved through the first ducts 9 in the X-axis direction
25 arrives at the second region 6 wherein there are extremely fine ducts, and, in this second region 6, receives heat from the heat emitting object 20, to be vaporized again. The vaporized refrigerant moves again through the second ducts 11 in the X-axis direction and the Y-axis direction. In this way, the cycling of the movement of the vaporized refrigerant and the movement of the condensed refrigerant enables the heat transporting unit 1 to transport the heat
30 from the heat emitting object 20 from the end portion positioned in the second region 6 to the end portion positioned in the second region 7. At this time, the heat of the heat emitting object 20

diffuses in the long direction and the short direction of the heat transporting unit 1 within the second region 6, and the first region 5 transports the heat in the long direction of the heat transporting unit 1. Because of this, the heat transporting unit 1 is able to transport the heat of the heat emitting object 20 using the entirety of the interior space 4, while maintaining the strength
5 of the heat transporting unit 1 by the first column portions 8 and the second column portions 10.

[0110] The benefits and features of the heat transportation by the heat transporting unit 1 will be explained in further detail next.

[0111] Depending on the shape and size of the heat emitting object 20, the heat transporting unit 1, even when transporting heat in the long direction, must be able to move the refrigerant using
10 maximally both the long direction and the short direction of the interior space 4 (and other words, of the heat transporting unit 1).

[0112] The refrigerant that has been vaporized by the heat from the heat emitting object 20 that is disposed at the second region 6 is moved not just in the X-axis direction, but in the Y-axis direction as well, by the second ducts 11 of the second region 6. The plurality of first ducts 9 is
15 lined up in the short direction within the interior space 4. The movement of the vaporized refrigerant in the Y-axis direction through the second ducts 11 in the second region 6 enables the vaporized refrigerant, at the boundary 12, to move into each of the plurality of first ducts 9 (while it may be all of them or a portion of them, still it is a plurality of first ducts 9 corresponding to a width that is wider than that of the heat emitting object 20). The vaporized
20 refrigerant that has so move moves using the plurality of first ducts 9 fully.

[0113] As a result, in the first region 5, the plurality of first ducts 9 is used fully to transport the heat in the X-axis direction (that is, from the end portion positioned at the second region 6 to the end portion positioned at the second region 7).

[0114] Additionally, at the second region 7, the second ducts 11 can move the vaporized
25 refrigerant, that has been moved from the first ducts 9, three-dimensionally in the X-axis direction and the Y-axis direction. Because of this, in the second region 7, the vaporized refrigerant can move through a wide space in a short time. As a result, the second region 7 enables the rapid cooling and condensation of the vaporized refrigerant.

[0115] In the second region 7, the condensed refrigerant moves along the X-axis direction and
30 the Y-axis direction in the second ducts 11. Because of this, the condensed refrigerant can move from a plurality of second ducts 11 to a plurality of first ducts 9 at the boundary 13 between the

second region 7 and the first region 5. That is, at the boundary 13, the condensed refrigerant moves in the plurality of individual first ducts 9 (either through all of them or part of them), which are lined up in the short direction of the interior space 4. Additionally, of the plurality of the first ducts 9, only a little of the condensed refrigerant enters into those first ducts 9 wherein there exists primarily a large amount of the vaporized refrigerant, and a large amount of the condensed refrigerant enters into the other first ducts 9 wherein there is not a large amount of the vaporized refrigerant.

[0116] In this way, it is possible to move the condensed refrigerant in the X-axis direction (that is, from the end portion positioned at the second region 7 towards the end portion positioned at the second region 6) through fully using the plurality of first ducts 9 in the first region 5.

[0117] This cycle of movement of the vaporized refrigerant and movement of the condensed refrigerant is the function of heat transportation achieved by the heat transporting unit 1. In other words, the heat transporting unit 1 is able to transport the heat of the heat emitting object in the specific direction (which here is the X-axis direction), efficiently, using fully the heat transporting unit 1, regardless of the size or shape of the heat emitting object 20.

[0118] Note that "using fully" here refers not to the use of all of the plurality of first ducts 9, but rather refers to the use of those first ducts, among the plurality of individual first ducts 9, that fulfill conditions for easy movement of vaporized refrigerant or easy movement of condensed refrigerant (temperature, flow speed, flow rate, pressure, etc.).

[0119] The transportation of heat in the heat transporting unit 1 is illustrated schematically in FIG. 4. FIG. 4 is a diagram illustrating schematically the operation of the heat transporting unit in the first form of embodiment according to the Present Disclosure.

[0120] The heat emitting object 20 is disposed at the bottom surface of the second region 6, which is the bottom surface of the lower plate 3. The heat emitting object 20 and the bottom surface are in thermal contact, so the second region 6 removes heat from the heat emitting object 20. In the second region 6, the refrigerant, which is a liquid, is vaporized by this heat, and the vaporized refrigerant moves in the X-axis direction through the first region 5 following the Arrow H.

[0121] The vaporized refrigerant that arrives at the second region 7 from the first region 5, is cooled and condenses in the second region 7. This cooled refrigerant moves towards the second region 6 from the second region 7 through capillary forces that are produced by the first ducts 9

and the second ducts 11. This is as indicated by the Arrow I. In this way, as can be understood by viewing the heat transporting unit 1 from the side, the heat transporting unit 1 can transport the heat of the heat emitting object 20 efficiently along the X-axis direction.

[0122] The details of each portion will be explained below.

5 **[0123]** The upper plate 2 will be explained next. The upper plate 2 is illustrated in a perspective state in FIG. 2. The upper plate 2 has a flat shape, and preferably is a rectangle having a short direction and a long direction. Of course, it may have a shape that differs from a rectangle in parts, or may have a curved shape or an indented shape. However, having the upper plate 2 be a rectangle having a short direction and a long direction causes the heat transporting unit 1 to be a
10 rectangle having a short direction and a long direction, thus making it possible for the heat transporting unit 1 to transport heat in a specific direction from a heat emitting object that is disposed at the end portion thereof. The upper plate 2 has a structure that matches the outer dimensional shape of the heat transporting unit 1.

[0124] The upper plate 2 is formed out of metal, plastic, or the like, but preferably is formed out
15 of a metal with high thermal conductivity or high resistance to corrosion (or durability thereto), such as copper, aluminum, silver, aluminum alloy, iron, iron alloy, stainless steel, or the like.

[0125] The upper plate 2, together with the lower plate 3, forms the interior space 4. For example, the upper plate 2 or the lower plate 3 has raised portions or wall members, for forming the interior space 4, at the peripheral edges thereof, where the upper plate 2 and the lower plate 3
20 form the interior space 4 between the upper plate 2 and the lower plate 3 through being joined together through these raised portions or wall members. When joined together with the lower plate 3, these raised portions or wall members become the side walls encompassing the interior space 4. Of course, these raised portions or wall members may be either different members or the same member as the upper plate 2.

25 **[0126]** Additionally, the upper plate 2 preferably has metal plating on at least the surface that contacts the interior space 4 (the surface that contacts the vaporized refrigerant and/or the condensed refrigerant). This is because the provision of the metal plating modifies the state of the surface, expediting the movement of the vaporized refrigerant. A metal such as gold, silver, copper, aluminum, nickel, cobalt, or an alloy thereof, or the like, may be selected as this metal
30 plating. Of course, it may be a single layer plating, a multilayer plating, electrolytic plating, or non-electrolytic plating.

[0127] While the upper plate 2 is nominally "upper," physically it need not necessarily be disposed at the top, but rather this is a term for convenience. The heat emitting object may be in contact with the upper plate 2, or may be in contact with the lower plate 3.

[0128] Additionally, the upper plate 2 preferably is provided also with a filling opening, not shown, for filling the refrigerant. This is because it is necessary to seal the refrigerant into the interior space 4 when the upper plate 2 and the lower plate 3 are joined together to form the interior space 4. The filling opening is sealed after the filling of the refrigerant.

[0129] Note that the refrigerant may be filled from the filling opening after the joining together of the upper plate 2 and the lower plate 3, or may be filled at the time of joining. Moreover, the filling of the refrigerant preferably is performed under a vacuum or at a reduced pressure.

Performing the filling under a vacuum or at a reduced pressure causes the refrigerant to be sealed within the interior space 4 in a vacuum or low-pressure state. When under a reduced pressure, there is the benefit of a reduction in the vaporization/condensation temperature of the refrigerant, causing greater activity in the cycling of the vaporization/condensation of the refrigerant.

[0130] Furthermore, the upper plate 2 and/or the lower plate 3 is provided with the first column portions 8 and the second column portions 10. Because the interior space 4 is formed from the upper plate 2 and the lower plate 3, the provision of the first column portions 8 and the second column portions 10 on the upper plate 2 and/or the lower plate 3 makes it possible to provide the interior space 4 with the first column portions 8 and the second column portions 10, or in other words, the first ducts 9 and the second ducts 11, through joining together the upper plate 2 and the lower plate 3. The same is true for the lower plate 3, described below.

[0131] The lower plate 3 will be explained next. The lower plate 3 is a member that is symmetrical to the upper plate 2, and has the same structure and shape as the upper plate 2, and, in FIG. 2, is shown in an oblique state.

[0132] The lower plate 3 has a flat shape, and preferably is a rectangle having a short direction and a long direction. In particular, because the lower plate 3 faces the upper plate 2 and is joined thereto, preferably it has the identical shape and area of the upper plate 2. However, insofar as the lower plate 3 can form the interior space 4 with the upper plate 2, it may have an area or shape that is different from that of the upper plate 2. Of course, it may have a shape that differs from a rectangle in parts, or may have a curved shape or an indented shape. Note that, as with upper plate 2, having the lower plate 3 be a rectangle having a short direction and a long

direction causes the heat transporting unit 1 to be a rectangle having a short direction and a long direction, thus making it possible for the heat transporting unit 1 to transport heat in a specific direction from a heat emitting object that is disposed at the end portion thereof.

[0133] The lower plate 3 is formed out of metal, plastic, or the like, but preferably is formed out of a metal with high thermal conductivity or high resistance to corrosion (or durability thereto), such as copper, aluminum, silver, aluminum alloy, iron, iron alloy, stainless steel, or the like.

[0134] The lower plate 3 is joined to the upper plate 2 perform the interior space, and may have raised portions or wall members for forming the interior space 4 around the periphery edges thereof. When joined to the upper plate 2, these raised portions or wall members form the side walls surrounding the interior space 4. Of course, these raised portions or wall members may be either different members or the same member as the lower plate 3. Note that both the upper plate 2 and the lower plate 3 may have the raised portions or wall members, or only either the upper plate 2 or the lower plate 3 may have the raised portions or wall members.

[0135] As with the upper plate 2, the lower plate 3 may be provided with a refrigerant filling opening.

[0136] The lower plate 3 is joined together facing the upper plate 2 to form the interior space 4.

[0137] Additionally, the lower plate 3 preferably has metal plating on at least the surface that contacts the interior space 4 (the surface that contacts the vaporized refrigerant and/or the condensed refrigerant). This is because the provision of the metal plating modifies the state of the surface, expediting the movement of the vaporized refrigerant. A metal such as gold, silver, copper, aluminum, nickel, cobalt, or an alloy thereof, or the like, may be selected as this metal plating. Of course, it may be a single layer plating, a multilayer plating, electrolytic plating, or non-electrolytic plating.

[0138] While the lower plate 3 is nominally "lower," physically it need not necessarily be disposed at the bottom, but rather this is a term for convenience. The heat emitting object may be in contact with the lower plate 3, or may be in contact with the upper plate 2.

[0139] Additionally, when it comes to the provision of the first column portions 8 and the second column portions 10, the same is true as for the upper plate 2.

[0140] The interior space is formed by the upper plate 2 and the lower plate 3.

[0141] The upper plate 2 and the lower plate 3 have protrusions or columns around the peripheral edges, and the upper plate 2 and the lower plate 3 are joined together facing each other

to form the interior space 4. Additionally, when joining together the upper plate 2 and the lower plate 3, the first column portions 8 and second column portions 10 that are provided on the upper plate 2 and/or the lower plate 3 contact the facing upper plate 2 or lower plate 3. The result is that the first column portions 8 or the second column portions 10 connect between the upper plate 2 and the lower plate 3. The first column portions 8 and second column portions 10 are columns that reach from the upper plate 2 to the lower plate 3 within the interior space 4.

[0142] The refrigerant is sealed within the interior space 4. The refrigerant uses antifreeze, alcohol, pure water, or the like.

[0143] Additionally, the interior space 4 has a first region 5 and second regions 6 and 7. In other words, the interior space 4 is divided into the first region 5 and the second regions 6 and 7. The Y-axis direction widths of the first region 5 and the second regions 6 and 7 are essentially identical, and thus the first region 5 and the second regions 6 and 7 are connected, at the boundaries 12 and 13, across the entire width in the Y-axis direction. That is, the first ducts 9 and boundaries 12 connect across the entirety of the width in the Y-axis direction.

[0144] In the interior space 4, the heat of the heat emitting object is transported in a specific direction through the filled refrigerant the vaporizing and condensing. At this time, the interior space 4 is able to transport the heat of the heat emitting object efficiently through the provision of the first region 5 and the second regions 6 and 7 that have different functions depending on the direction of transportation of the heat (the direction of movement of the refrigerant).

[0145] The region 5 is provided with a plurality of first column portions 8 that form a plurality of first ducts 9 along the X-axis direction. The plurality of first column portions 8 are provided along the X-axis direction. The first column portions 8 are standing members with protruding shapes that are provided on the upper plate 2 and/or the lower plate 3, and when the upper plate 2 and the lower plate 3 are thermally joined, they are joined to the facing member (either the upper plate 2 or the lower plate 3), so that, within the interior space 4, they become standing members that reach from the upper plate 2 to the lower plate 3. The result is that they become reinforcing portions for reinforcing the interior space 4.

[0146] Note that as another structure, the first column portions 8 may be provided on either the upper plate 2 or the lower plate 3, and may be standing members that reach from the upper plate 2 to the lower plate 3 within the interior space 4 when the upper plate 2 and the lower plate 3 are joined together. Conversely, only portions of the required first column portions 8 may be

provided on the upper plate 2 and on the lower plate 3, so that when the upper plate 2 and the lower plate 3 are joined together, all of the required first column portions 8 will be provided within the interior space 4. Conversely, facing portions of the first column portions 8 may be provided at identical positions on both the upper plate 2 and the lower plate 3, so that the portions of the first column portions 8 that are provided on the upper plate 2 and the portions of the first column portions 8 that are provided on the lower plate 3 contact each other to form, together, the required first column portions 8.

[0147] As illustrated in FIG. 2 and FIG. 3, a plurality of first column portions 8 is provided along the X-axis direction, and thus a plurality of first ducts 9 is formed, along the X-axis direction, by adjacent first column portions 8. The plurality of first ducts 9 are the gaps formed by the first column portions 8.

[0148] Additionally, the first ducts 9 run in the X-axis direction in the first region 5, and thus preferably have lengths that are about the same as the X-axis direction lengths of the first region 5. Doing so enables the first region 5 to move the refrigerant along the X-axis direction within the first region 5.

[0149] Additionally, as with the upper plate 2 and the lower plate 3, the first column portions 8 are formed out of metal, plastic, or the like, but preferably are formed out of a metal with high thermal conductivity or high resistance to corrosion (or durability thereto), such as copper, aluminum, silver, aluminum alloy, iron, iron alloy, stainless steel, or the like. Additionally, preferably the metal plating is performed on at least a portion of the surfaces of the first column portions 8 (and, in particular, on a portion or all of the surfaces that are exposed to the interior space 4). This is because the provision of the metal plating modifies the state of the surface, expediting the movement of the vaporized refrigerant. A metal such as gold, silver, copper, aluminum, nickel, cobalt, or an alloy thereof, or the like, may be selected as this metal plating. Of course, it may be a single layer plating, a multilayer plating, electrolytic plating, or non-electrolytic plating.

[0150] The provision of a plurality of first ducts 9 in the first region 5 in this way causes the refrigerant to move while dividing the refrigerant (the vaporized refrigerant or condensed refrigerant) between the plurality of pathways between the boundary 12 and the boundary 13. That is, the first region 5 is able to transport the heat of the heat emitting object 20 between the boundary 12 and the boundary 13. The first region 5 has the function of transporting, in the X-

axis direction, the heat from the heat emitting object 20 through using efficiently the entire width in the Y-axis direction.

[0151] The second regions will be explained next.

[0152] The second regions 6 and 7 are provided in the remainder of the interior space 4 that is not the first region 5. Because of this, the interior space 4 has the first region 5 and the second regions 6 and 7. Note that region 5 and second regions 6 and 7 are spaces having mutually differing functions, and this does not exclude the interior space 4 from including other regions that are unrelated to the first region 5 and to the second regions 6 and 7. The first region and the second regions are elements that indicate that they are regions within the interior space 4 that exhibit their own respective functions, and these are not terms that indicate that the interior space 4 is physically partitioned.

[0153] The second regions 6 and 7 are provided with a plurality of second column portions 10 that form a plurality of second ducts 11 that run in the X-axis direction and the Y-axis direction. The plurality of second column portions 10 is provided along the X-axis direction. At this time, in the second regions 6 and 7, the plurality of second column portions 10 is provided in a given line in the X-axis direction. For example, in FIG. 2, in the second region 6, two second column portions 10 are lined up along the X-axis direction. Additionally, in the second region 7, four second column portions 10 are lined up in the X-axis direction. Moreover, the plurality of second column portions 10 that is provided in a line in the X-axis direction in this way is lined up in a plurality along the Y-axis direction.

[0154] The provision of the plurality of second column portions 10 in both the X-axis direction and the Y-axis direction enables the plurality of second column portions 10 to form gaps in both the X-axis direction and the Y-axis direction. The respective gaps in the X-axis direction and the Y-axis direction form a plurality of second ducts 11 that run in the X-axis direction and the Y-axis direction. In these second ducts 11, the vaporized refrigerant and condensed refrigerant move along the X-axis direction and the Y-axis direction in accordance with the gaps in the second column portions 10.

[0155] The second column portions 10 are standing members with protruding shapes that are provided on the upper plate 2 and/or the lower plate 3, and when the upper plate 2 and the lower plate 3 are thermally joined, they are joined to the facing member (either the upper plate 2 or the lower plate 3), so that, within the interior space 4, they become standing members that reach

from the upper plate 2 to the lower plate 3. The result is that they become reinforcing portions for reinforcing the interior space 4.

[0156] Note that as another structure, the second column portions 10 may be provided on either the upper plate 2 or the lower plate 3, and may be standing members that reach from the upper plate 2 to the lower plate 3 within the interior space 4 when the upper plate 2 and the lower plate 3 are jointed together. Conversely, only portions of the required second column portions 10 may be provided on the upper plate 2 and on the lower plate 3, so that when the upper plate 2 and the lower plate 3 are joined together, all of the required second column portions 10 will be provided within the interior space 4. Conversely, facing portions of the second column portions 10 may be provided at identical positions on both the upper plate 2 and the lower plate 3, so that the portions of the second column portions 10 that are provided on the upper plate 2 and the portions of the second column portions 10 that are provided on the lower plate 3 contact each other to form, together, the required second column portions 10.

[0157] Additionally, as with the upper plate 2 and the lower plate 3, the second column portions 10 are formed out of metal, plastic, or the like, but preferably are formed out of a metal with high thermal conductivity or high resistance to corrosion (or durability thereto), such as copper, aluminum, silver, aluminum alloy, iron, iron alloy, stainless steel, or the like. Additionally, preferably the metal plating is performed on at least a portion of the surfaces of the second column portions 10 (and, in particular, on a portion or all of the surfaces that are exposed to the interior space 4). This is because the provision of the metal plating modifies the state of the surface, expediting the movement of the vaporized refrigerant. A metal such as gold, silver, copper, aluminum, nickel, cobalt, or an alloy thereof, or the like, may be selected as this metal plating. Of course, it may be a single layer plating, a multilayer plating, electrolytic plating, or non-electrolytic plating.

[0158] The provision of the plurality of second ducts 11 in this way in the second regions 6 and 7 causes the vaporized refrigerant and the condensed refrigerant to be divided, to be moved through fully using the plurality of the first ducts 9, which are lined up in the Y-axis direction, at the boundary 12 and the boundary 13.

[0159] In this way, the second regions 6 and 7 achieve the function of exchanging the refrigerant, while using fully the plurality of individual first ducts 9 that are lined up in the Y-axis direction, while achieving the function of moving the vaporized refrigerant and the

condensed refrigerant in the X-axis direction and Y-axis direction in the second regions 6 and 7. Of course, the second column portions 10 that are provided in the second regions 6 and 7 achieve the function of reinforcing the interior space 4.

[0160] As described above, the heat transporting unit 1 in the first form of embodiment is able to diffuse the heat from the heat emitting object 20 in the X-axis direction and the Y-axis direction, and is able to transport the heat from the heat emitting object 20 in the X-axis direction. While the object is for the heat transporting unit 1 to transport the heat from the heat emitting object 20 along the X-axis direction (that is, to transport heat along the X-axis direction towards the far end from the position wherein the heat from the heat emitting object 20 is received), it is

desirable to transport in the X-axis direction while using the entire width of the Y-axis direction of the heat transporting unit 1. Because of this, the second region 6 that is in thermal contact with the heat emitting object 20 diffuses, in the X-axis direction and the Y-axis direction, the heat from the heat emitting object 20, to use the entire width in the Y-axis direction to move the heat to the first region 5. The first region 5 is able to transport the heat along the X-axis direction, so that, as a result, the heat transporting unit 1 is able to transport the heat from the heat emitting object 20 along the X-axis direction while using the entire width thereof in the Y-axis direction.

[0161] At this time, the first column portions 8 and the second column portions 10 are able to ensure the strength of the interior space 4 (or in other words, of the heat transporting unit 1).

[0162] In this way, by innovating the structure of the column portions for reinforcing the interior space 4 in the regions in interior space 4 it is possible to have the heat transporting unit 1 in the first form of embodiment secure increases in both strength and in heat transportation efficiency.

[0163] Second forms of embodiment will be explained next.

[0164] Various examples of modifications of the heat transporting unit 1 will be explained in the second forms of embodiment.

[0165] FIG. 5 is an interior perspective view of a heat transporting unit according to a second form of embodiment according to the Present Disclosure. FIG. 5 shows a state wherein a portion of the interior of the heat transporting unit 1 is visible. Second region 6 is provided with second column portions 10, where gaps along the X-axis direction and the Y-axis direction are produced by the second column portions 10, where these gaps form second ducts 11. The vaporized refrigerant moves in the X-axis direction and the Y-axis direction in these second ducts 11, and

the condensed refrigerant moves in the X-axis direction and in the Y-axis direction in these second ducts 11.

[0166] Here, as illustrated in FIG. 5, the second column portions 10 are preferably provided with large column members 30 and small column members 31 that are smaller than the large column members 30. As illustrated in FIG. 5, the large column members 30 are disposed within the second region 6, and the small column members 31 are provided in locations other than those of the large column members 30. The large column members 30 may have a size that is larger than that of the small column members 31, and the large column members 30 and the small column members 31 may be lined up in a line, or may be lined up randomly.

[0167] Having the second column portions 10 be structured from a mixture of the large column members 30 and the small column members 31 in this way, makes the shape of the second ducts 11 more complex. In particular, the multiple second ducts 11 are adjacent to each other with respective gaps in the X-axis direction and the Y-axis direction. Because a plurality of gaps is formed through the mixture of the large column members 30 and the small column members 31, the adjacent distances between gaps is made smaller, and the intersections between the gaps is made larger. The second ducts 11, which are formed through the combination of these complex gaps, has strong capillary forces.

[0168] The second ducts 11 are able to move the condensed refrigerant efficiently and rapidly through these strong capillary forces.

[0169] Additionally, the second ducts 11 that are formed by the combination of the complex gaps together are able to retain, across a broad range, the refrigerant that is a liquid in the second region 6. Because of this, it becomes easier for the second region 6, which receives the heat from the heat emitting object 20, to vaporize the refrigerant quickly. Of course, the vaporized refrigerant can move quickly and in a broad range within the second ducts 11.

[0170] Additionally, structuring the second column portions 10 from the large column members 30 and the small column members 31 further increases the strength of the second regions 6. Because of the thermal contact with the heat emitting object 20, the expansion and contraction of the second region 6 due to temperature variations is large. Because of this, a greater degree of strength is required, and thus increased strength is desirable.

[0171] Note that the difference in size between the large column members 30 and the small column members 31 is defined by the differences in the size of the cross-sectional areas in the

vertical direction relative to the standing direction. Because of this, the "large" and "small" terminology for the large column members 30 and the small column members 31 can be defined for both the cases wherein there are differences in the cross-sectional areas through different shapes, and differences in the cross-sectional areas with identical shapes.

5 **[0172]** Preferably channels are provided on the surfaces that are exposed to the interior space 4 in at least a portion of the first column portions 8, second column portions 10, and the upper plate 2 and the lower plate 3.

[0173] FIG. 6 is a cross-sectional diagram of an end portion of a heat transporting unit in a second form of embodiment according to the Present Disclosure. FIG. 6 illustrates a state
10 wherein surfaces that are exposed to the interior space 4 of the heat transporting unit 1 are provided with channels 40 through 42. Note that while FIG. 6, for convenience in illustrating in a cross-section, shows only the second region 6, similarly channels are provided also in the first region 5 and the first column portions 8.

[0174] The second column portions 10 are provided with channels 41 on the surfaces that are
15 exposed to the interior space 4. The channels 41 may be formed through cutting or milling the surfaces of the second column portions 10, or the channels 41 may be formed in advance when the second column portions 10 are formed. Note that although not shown in FIG. 6, channels are formed similarly also in the surfaces of the first column portions 8 that are exposed to the interior space 4.

20 **[0175]** The formation of channels in this way in at least a portion of the upper plate 2, the lower plate 3, the first column portions 8, and the second column portions 10 provides the first ducts 9 and the second ducts 11 with channels. The provision of the first ducts 9 and the second ducts 11 with channels makes it possible to increase the capillary forces, thereby facilitating the movement of the condensed refrigerant along the channels. The condensed refrigerant and the
25 vaporized refrigerant are moved by the first ducts 9 and the second ducts 11, respectively, and thus when it is possible to move the condensed refrigerant along the channels, the first ducts 9 and the second ducts 11 use the space other than the channels to facilitate the movement of the vaporized refrigerant.

[0176] The result is that the first ducts 9 and the second ducts 11 are able to move the vaporized
30 refrigerant and the condensed refrigerant while preventing interference between the respective refrigerants. That is, the first ducts 9 move the vaporized refrigerant along the X-axis direction

from the second region 6 to the second region 7. On the other hand, the first ducts 9 move the condensed refrigerant along the X-axis direction from the second region 7 to the second region 6. At this time, the channels are able to reduce the interference between the vaporized refrigerant and the condensed refrigerant in the first ducts 9.

5 [0177] As described above, at least a portion of the upper plate 2, the lower plate 3, the first column portions 8, and the second column portions 10 are provided with channels, thus making it possible for the heat transporting unit 1 to accelerate the cycle of the movement of the vaporized refrigerant and the movement of the condensed refrigerant, enabling the heat to be transported more quickly.

10 [0178] A modified example wherein the first column portions 8 are provided with cutouts will be explained next.

[0179] The plurality of first column portions 8 form a plurality of first ducts 9 through the gaps that are formed between adjacent first column portions 8. Because the refrigerant moves in the X-axis direction in each of the plurality of first ducts 9, ducts are formed along the X-axis
15 direction in the range of the first region 5. This will be explained using FIG. 7. In FIG. 7, a cutout 35 that connects between adjacent first ducts 9 are provided part way through the first column portions 8. FIG. 7 is an interior schematic diagram of the heat transporting unit 1 in the second form of embodiment according to the Present Disclosure.

[0180] The cutout 35 connects between adjacent first ducts 9, thus making it possible for the
20 vaporized refrigerant or condensed refrigerant that is passing through the first duct 9 to pass through the cutout 35 to move to another first duct 9.

[0181] If, for example, the heat emitting object 20 is extremely small (to take one example, the heat emitting object 20 may be a light-emitting diode element (hereinafter termed an "LED")), then there may be cases where, in the second region 6, the diffusion will be inadequate even
25 when the heat from the heat emitting object 20 is diffused by the second ducts 11. In such a case, it would be necessary to transport a large amount of heat through those first ducts 9 that are positioned near to the position wherein the heat emitting object 20 is disposed, from among the plurality of first ducts 9, where the other first ducts 9 would not have to transport a large amount of heat. In this case, the first ducts 9 that are positioned near to the heat emitting object 20 would
30 require more refrigerant, requiring movement of refrigerant beyond the capability thereof.

[0182] When one first duct 9 and another first duct 9 are connected through a cutout 35, the one first duct 9 and the other first duct 9 are able to exchange the needed refrigerant and the unneeded refrigerant through the cutout 35.

[0183] FIG. 7 further illustrates a state wherein one first duct 9A and another first duct 9 exchange refrigerant. In FIG. 7, an extremely small heat emitting object 20 is disposed in essentially the center, in the Y-axis direction, of the bottom surface of the second regions 6. The second region 6 removes heat from the heat emitting object 20, the refrigerant is vaporized, and the vaporized refrigerant moves through the second ducts 11 in the X-axis direction and the Y-axis direction. Here the heat emitting object 20 is extremely small, and thus the ability of the vaporized refrigerant to diffuse in the Y-axis direction in the second ducts 11 tends to be smaller than the ability to diffuse in the X-axis direction. Because of this, the vaporized refrigerant tends to move in the first duct 9A that is near to the position at which the heat emitting object 20 is disposed, when moving from the second region 6 to the first region 5.

[0184] On the other hand, in order to transport larger amounts of heat, it is necessary to have a greater amount of refrigerant. In the state in FIG. 7, the first duct 9A has the primary responsibility in the transportation of heat (noting that this is not to say that the other first ducts 9 do not transport heat, but rather the heat that diffuses in the Y-axis direction through the second ducts 11 is transported in the X-axis direction through most of the plurality of first ducts 9, where saying that the first duct 9A has the primary responsibility is just stating a comparative level), and thus the first duct 9A requires more refrigerant than in the other first ducts 9. Because the vaporized refrigerant moves to the plurality of individual first ducts 9 from the second ducts 11, if the first duct 9A is able to obtain vaporized refrigerant from the other first ducts 9, then the first duct 9A will be able to transport a greater amount of heat. The first duct 9A transports vaporized refrigerant (heat) in the X-axis direction, as illustrated by the Arrow N. Here refrigerant can be received through the cutouts 35 from the other first ducts 9, as with Arrow K and Arrow M. The reception of the refrigerant makes it possible for the first duct 9A to transport heat using a greater amount of refrigerant. Additionally, the first duct 9A must transport a greater amount of vaporized refrigerant in order to transport a greater amount of heat. However, because the area of the first duct 9A is limited, there is a limit to the transportation capacity of the vaporized refrigerant in the first duct 9A. In this case, as indicated by Arrow J and Arrow L, the first duct 9A is able to move vaporized refrigerant to other first ducts 9 through the cutouts 35.

The result is that the vaporized refrigerant that transports the heat is moved efficiently in the X-axis direction through the plurality of first ducts 9.

[0185] Moreover, in order to hold a greater amount of the condensed refrigerant in the vicinity of the heat emitting object 20, it is necessary to move the condensed refrigerant into the vicinity of the heat emitting object 20. Because the refrigerant is vaporized by the heat of the heat emitting object 20, there will always be a state wherein the amount of condensed refrigerant in the vicinity of the heat emitting object 20 will be small. Because of this, a greater amount of condensed refrigerant, when compared to the other first ducts 9 will move into the vicinity of the heat emitting object 20 along the first duct 9A through capillary forces. At this time, there will be a tendency for the refrigerant that is in the vicinity of the heat emitting object 20, which produces a greater amount of heat than in the other regions, to be vaporized, meaning that there will be a high likelihood that the amount of condensed refrigerant will be inadequate. Here the provision of the cutouts 35 makes it possible for the first duct 9A to receive, through the cutout 35, the deficient amount of condensed refrigerant from the other first ducts 9. By receiving this refrigerant, the first duct 9A becomes able to move a greater amount of refrigerant to the vicinity of the heat emitting object 20, resulting in the ability to transport a great amount of heat.

[0186] As described above, the provision of the cutouts 35 makes it possible to further increase the efficiency with which the heat transporting unit 1 transports the heat of the heat emitting object 20.

[0187] An example of modification of the second ducts will be explained next.

[0188] The heat transporting unit 1 is provided further with an intermediate plate that is stacked between the upper plate 2 and the lower plate 3, where the second regions 6 and 7 are stacked in different positions in the Z-axis direction, where, preferably, the second ducts are provided with a structure along the Z-axis direction as well.

[0189] FIG. 8 is an enlargement of the vicinity of the second region of a heat transporting unit according to a second form of embodiment according to the Present Disclosure. In FIG. 8, the heat transporting unit 1 is stacked with an intermediate plate 50 between the upper plate 2 and the lower plate 3.

[0190] The lower plate 3 is provided with large column members 30 and small column members 31 that structure the second column portions 10. Moreover, the upper plate 2 is provided with large column members 51 and small column members 52 that structure second column portions

54. Furthermore, the intermediate plate 50 is provided with opening portions 53 for connecting between the gaps that are formed, respectively, between the second column portions 10 that are formed on the lower plate 3 and the second column portions 54 that are formed on the upper plate 2.

5 **[0191]** In the lower plate 3, second ducts 11 are formed by the second column portions 10. Moreover, in the upper plate 2, second ducts 55 are formed by the second column portions 54. The second column portions 10 and the second column portions 54 (or in other words, the large column members 30 and large column members 51, and the small column members 31 and the small column members 52), are provided facing each other in different locations relative to the
10 Z-axis direction. Because of this, when the upper plate 2, the first region 50, and the lower plate 3 are stacked together, the second ducts 11 and the second ducts 55 are connected in a state wherein each is slightly shifted. The opening portions 53 connect the second ducts 11 and the second ducts 55, which are connected in a state wherein they are each slightly shifted.

[0192] The result is that the entirety of the second ducts (the ducts that are the second ducts 11
15 and the second ducts 55 together) are structured along the Z-axis direction, in addition to the X-axis direction and the Y-axis direction. Because of this, in the entirety of the second ducts, the vaporized refrigerant can move, and the condensed refrigerant can move, in the X-axis direction, the Y-axis direction, and the Z-axis direction.

[0193] By the entirety of the second ducts being able to diffuse heat in the X-axis direction, the
20 Y-axis direction, and the Z-axis direction, the second region 6 is able to diffuse in three dimensions the heat removed from the heat emitting object 20. The ability of the second region 6 to diffuse in three dimensions the heat of the heat emitting object 20 makes it possible for the second region 6 to move heat across a broader range to the first region 5. As a result, the first region 5 is able to use fully the plurality of first ducts 9 to move the vaporized refrigerant (to
25 transport the heat).

[0194] While the vaporized refrigerant received from the first region 5 is condensed in the second region 7, the entirety of the second ducts is able to diffuse the refrigerant in three dimensions, and thus, in the second region 7, the vaporized refrigerant can be cooled while diffusing in three dimensions, to efficiently condense the vaporized refrigerant. Additionally, in
30 the second region 7, the condensed refrigerant can move three-dimensionally, and thus the condensed refrigerant can move to the first region 5 at a high speed. Additionally, in the entirety

of the second ducts of the second region 7, the condensed refrigerant can move to the first region 5 across a broad range, enabling the first region 5 to move the condensed refrigerant using the plurality of first ducts 9 fully.

[0195] Additionally, the first region 50 is stacked between the upper plate 2 and the lower plate 3, so the provision of the first region 50 further increases the strength of the heat transporting unit 1, and more clearly partitions between the ducts of the first ducts 9 and the second ducts 11 and 55, enabling the first ducts 9 and the second ducts 11 and 55 to transport the heat more reliably.

[0196] An example wherein there is a modification that to the first region 5 and the second regions 6 and 7 will be explained next.

[0197] The interior space 4 is provided with a first region and a second region have different functions in heat transportation. The first region is positioned in any region in the interior space 4, and the second region is positioned in another portion that is not the first region. The positioning of the first region and the second region may be determined in a variety of ways.

[0198] FIG. 2, which was used in the first form of embodiment, illustrates a heat transporting unit 1 wherein the second region 6 and the second region 7 are provided at both ends of the interior space 4, and the first region 5 is provided interposed between these second region 6 and second region 7.

[0199] In a heat transporting unit 1 having this type of structure, the heat from the heat emitting object that is disposed facing the second region 6 is received by the second regions 6 and diffuses in the X-axis direction and the Y-axis direction (and further, in the Z-axis direction). Moreover, the second region 6 moves the heat to the first region 5.

[0200] Following this, the first region 5, which has received the heat from the second region 6, transports the heat in the X-axis direction. The first region 5 transports, to the second region 7, the heat that has been transported in the X-axis direction. Moreover, the second region 7 that has received the heat from the first region 5 performs cooling while the heat diffuses in the X-axis direction and Y-axis direction (and further, in the Z-axis direction). The refrigerant condenses through being cooled, and the second region 7 moves the refrigerant, through the first region 5, to the second region 6.

[0201] In this way, the heat transporting unit 1, which has a structure that is provided with the second regions 6 and 7 at both end portions and that is provided with the first region 5 interposed

between the second regions 6 and 7, is able to allocate the three roles of diffusing the heat, transporting the heat, and cooling the heat into the respective regions. The result is that the heat transporting unit 1, having such a structure, is able to transport the heat efficiently.

[0202] Additionally, the second region 6 may be provided at one end portion in the interior space 4 and the first region 5 may be provided in the regions thereof other than the second region 6. That is, the heat transporting unit 1, as illustrated in FIG. 9, may be provided with a second region 6 at only one end portion in the interior space 4, with a structure wherein the remaining portion is provided as first regions 5.

[0203] FIG. 9 is a plan view diagram of a heat transporting unit according to a second form of embodiment according to the Present Disclosure. FIG. 9 shows the interior of the heat transporting unit 1 in a visible state. The heat transporting unit 1 illustrated in FIG. 9 has a second region 6 at only one end portion within the interior space 4, and a first region 5 in the region that is not the second region 6. The heat emitting object 20 is disposed facing the second region 6. The second region 6, as explained in the first and second forms of embodiment, is provided with second column portions 10 and second ducts 11.

[0204] The second region 6 uses the second ducts 11 to diffuse the heat removed from the heat emitting object 20 in the X-axis direction and the Y-axis direction (and further, in the Z-axis direction). Additionally, the second region 6 moves the diffused heat to the first region 5. Specifically, it moves the vaporized refrigerant to the first region 5.

[0205] The first region 5 transports the heat in the X-axis direction using the first ducts 9. The first region 5 is provided with first ducts 9 along the long direction (the X-axis direction), so the first region 5 is able to cool the heat during the transportation of the heat using the long first ducts 9. The vaporized refrigerant is condensed through the cooling of the heat in the first ducts 9. Because the first ducts 9 have capillary forces, the condensed refrigerant moves along the X-axis direction towards the second region 6. This is because in the vicinity of the second region 6, the refrigerant is vaporized by the heat of the heat emitting object 20, causing a state wherein there is little condensed refrigerant, and thus the condensed refrigerant tends to be moved to the second region 6 by the capillary forces.

[0206] The heat transporting unit 1 that is provided with the second region 6 at only one end of the interior space 4 in this way has a simple structure, and thus can reduce manufacturing costs. Additionally, if there is little difference between the width of the heat emitting object 20 in the

Y-axis direction and the width of the heat transporting unit 1 in the Y-axis direction (the length in the short direction), then the second region 6 can adequately diffuse the vaporized refrigerant in the Y-axis direction, enabling movement of the vaporized refrigerant to all of the first ducts 9. Because of this, the vaporized refrigerant is more easily cooled, during movement, within the first ducts 9, so the second region 7 becomes unnecessary. From this point as well, preferably the heat transporting unit 1 is provided with a structure such as in FIG. 9.

[0207] Yet another example of a modification to the first region and the second region will be explained next. A structure will be explained wherein a second region is provided in the center of the interior space 4, and first regions are provided at both ends of the interior space 4.

[0208] FIG. 10 is a perspective diagram of a heat transporting unit according to a second form of embodiment according to the Present Disclosure. FIG. 10 illustrates the internal structures in a visible state. The heat transporting unit 1 illustrated in FIG. 10 has a structure that is provided with a second region 60 in the center portion of the interior space 4, and provided with first regions 61 and 62 at both ends of the second region 60 (that is, at both ends of the interior space 4). Note that the second region 60 has structures and functions identical to those of the second regions 6 and 7 explained in the first and second forms of embodiment. That is, it is provided with second column portions 10, and with second ducts 11 that are formed by the second column portions 10. The first regions 61 and 62 have structures and functions that are identical to those of the first region 5 that was explained in the first and second forms of embodiment. That is, they are provided with first column portions 8, and provided with first ducts 9 that are formed by the first column portions 8.

[0209] The heat emitting object 20 (not shown, both in FIG. 10 and below) is disposed facing the bottom surface of the second region 60. The second region 60 removes heat from the heat emitting object 20. The second region 60 has second ducts 11 along the X-axis direction and the Y-axis direction (and further, along the Z-axis direction), and thus is able to move, in the X-axis direction and Y-axis direction (and further, in the Z-axis direction), the refrigerant that is vaporized by the heat of the heat emitting object 20. Furthermore, the second region 60 moves the vaporized refrigerant to the first regions 61 and 62. The first regions 61 and 62 are provided at both sides of the second region 60, and the second region 60 moves the vaporized refrigerant in the X-axis direction as well, and thus the second region 60 moves the vaporized refrigerant to both the first region 61 and the first region 62. Additionally, the second region 60 moves the

vaporized refrigerant in the Y-axis direction as well, and thus moves the vaporized refrigerant from the second region 60 using fully the crosswise direction of the Y-axis direction of the first regions 61 and 62. That is, in both the first regions 61 and 62, the plurality of first ducts 9 that are provided are used fully to enable movement of the vaporized refrigerant in the X-axis direction.

[0210] The vaporized refrigerant that has moved to both the first region 61 and the first region 62 is moved in the X-axis direction by the plurality of first ducts 9 in both the first region 61 and the first region 62.

[0211] At this time, in the respective first region 61 and first region 62, the vaporized refrigerant is moved towards the respective end portions, so as to move away from the second region 60. In the respective first regions 61 and 62, the vaporized refrigerant is cooled during the movement towards the end portions. The refrigerant is condensed through this cooling. In the respective first regions 61 and 62, the condensed refrigerant moves along the X-axis direction due to the capillary forces of the first ducts 9. At this time, in the respective first regions 61 and 62, the contents refrigerant is moved towards the second region 60.

[0212] As described above, the heat transporting unit 1 illustrated in FIG. 10 transports the heat of the heat emitting object 20, disposed at the center portion thereof, towards both ends. For example, when one wishes to exhaust, to the periphery, heat that is produced by a given electronic component or mechanical component, then preferably a heat transporting unit 1 having the structure illustrated in FIG. 10 will be used.

[0213] The heat transporting unit 1 in the second form of embodiment is able to transport and exhaust heat of a heat emitting object while being compatible with a variety of structures, shapes, sizes, mounting conditions, and the like, of the heat-emitting object to which it is applied.

[0214] A third form of embodiment will be explained next.

[0215] Various relationships between the position of the heat-emitting object and the heat transporting unit will be explained using the third form of embodiment.

[0216] FIG. 11 is a perspective assembly diagram of a heat transporting unit according to the third form of embodiment according to the Present Disclosure. FIG. 11 illustrates a state wherein the upper plate 2 is at the bottom and the lower plate 3 is at the top, and, in order to cause the interior to be visible, illustrates a state wherein the outer surface of the lower plate 3 has been removed.

[0217] The heat transporting unit 1 is provided with a heat receiving portion 70 for making thermal contact with a heat emitting object at the upper plate 2 and/or at the lower plate 3. The heat transporting unit 1 in FIG. 11 is provided with the heat receiving region 70 at the lower plate 3.

5 [0218] The heat receiving region 70 is positioned where the heat emitting object is disposed, and the heat transporting unit 1 removes heat from the heat emitting object through the heat receiving region 70. Thereafter, the heat transporting unit 1 transports the heat of the heat emitting object in the X-axis direction from the second region 6 through the first region 5.

[0219] The heat receiving region 70 may be provided as a member for positioning the heat
10 emitting object, as illustrated in FIG. 11. In this case, the heat receiving region 70 may have a flat shape or a frame shape of members having high thermal conductivity, such as a metal, and alloy, or the like. Conversely, the heat transporting unit 1 may be provided with a heat receiving region 70 as a target position for positioning the heat emitting object, without having to provide a separate element or member as the heat receiving region 70. That is, in the heat receiving region
15 70, there is no need for the explicit provision of a member on the surface of the lower plate 3, but rather it may be a position, region, or location for the placement of the heat emitting object 20. What is necessary is for the user of the heat transporting unit 1 to understand, as the heat receiving region 70, the region or location for positioning that selects the position for the placement of the heat emitting object 20, in order to use the functions of the heat transporting
20 unit 1. In this point, the responsibility of the party providing the heat transporting unit 1 to recommend the position for placing the heat emitting object 20 is defined identically to that for recommending the heat receiving region 70.

[0220] The provision of the heat receiving region 70 in the heat transporting unit 1 is because this facilitates the definition of the target for the position for the placement of the heat emitting
25 object, and because this facilitates the achievement of cooling the heat emitting object more efficiently, as in the experimental results, described below.

[0221] Here the heat receiving region 70 being provided spanning the boundary 12 of the first region 5 and the second region 6 is preferred from the perspective of the efficiency of heat transportation in the heat transporting unit 1.

[0222] The inventors performed experiments regarding this point, and the experimental results will be described. FIG. 12 is an explanatory diagram listing an example of embodiment and comparative examples.

[0223] In the example of embodiment, the heat emitting object 20 (that is, the heat receiving region 70) is provided spanning the boundary 12 of the second region 6 and the first region 5.

[0224] In the first comparative example, the heat emitting object 20 (that is, the heat receiving region 70) is provided at the bottom surface of the second region 6, where the heat emitting object 20 is in a state that is essentially within the bottom surface of the second region 6.

[0225] In the second comparative example, the heat emitting object 20 (that is, the heat receiving region 70) is provided at the bottom surface of the second region 6, and the heat emitting object 20 is included further within the bottom surface of the second region 6 than in the first comparative example, and the heat emitting object 20 covers the second region 6 more broadly than in the case of the second comparative example.

[0226] Heat was actually applied to the heat emitting object 20, and the surface temperature of the heat emitting object 20 was measured, based on these three types of structures.

[0227] FIG. 13 is a graph showing the measurement results in the example of embodiment and in the comparative examples. As is clear from the graph in FIG. 13, in the example of embodiment the surface temperature of the heat emitting object 20 was 73.4° C. In the first comparative example, the surface temperature of the heat emitting object 20 was 73.8°C. In the second comparative example, the surface temperature of the heat emitting object 20 was 76.0°C.

[0228] As can be understood from these results, the structure of the example of embodiment was most able to cool the heat of the heat emitting object (that is, most able to transport the heat). That is, the heat receiving region 70 preferably is provided spanning the boundary 12 of the first region 5 and the second region 6.

[0229] Note that the position of placement of the heat receiving region 70 does not depend on only the cooling effect of this type of heat emitting object, and thus should be determined in accordance with parameters such as, for example, the size, shape, mounting position, and the like of the heat emitting object 20, and the third form of embodiment does not limit particularly the position of placement of the heat receiving region 70. Moreover, the surface temperatures obtained through the measurement results are only examples, and, of course, will vary depending

on a variety of parameters such as the size, shape, and mounting position of the heat emitting object, and on measurement environment conditions, type of refrigerant, and so forth.

[0230] As described above, the heat transporting unit 1 in the third form of embodiment is able to transport heat of the heat emitting object more efficiently through the specification of the position of placement of the heat emitting object.

[0231] A fourth form of embodiment will be explained next.

[0232] A case wherein the heat transporting unit is further provided with a heat radiating portion for radiating the transported heat will be explained using the fourth form of embodiment.

[0233] FIG. 14 is a side view diagram of a heat transporting unit according to a fourth form of embodiment according to the Present Disclosure. The heat transporting unit 1, as with that which was explained in FIG. 2, is provided with a first region 5, a second region 6, and a second region 7 within the interior space 4. A heat emitting object 20 is positioned in the vicinity of the boundary between the second region 6 and the first region 5, and the second region 6 diffuses the heat removed from the heat emitting object 20.

[0234] The heat diffused by the second region 6 moves to the first region 5, and the first region 5 transports the heat towards the second region 7. The heat that arrives at the second region 7 diffuses within the second region 7.

[0235] A cooling fan 80 is illustrated in FIG. 14 as an example of a heat radiating portion. The cooling fan 80 cools the second region 7. In the second region 7, the heat that was transported from the heat emitting object 20 arrives and is cooled, to condense the vaporized refrigerant. The cooling fan 80 expedites the condensation of the refrigerant. The condensed refrigerant moves from the second region 7 to the second region 6. The heat transporting unit 1, through producing this movement, produces heat cycling, enabling the effective transportation and cooling of the heat of the heat emitting object 20.

[0236] The heat transportation effectiveness of the heat transporting unit 1 is improved involves the transportation of the cooled heat in the opposite direction (that is, the movement of the condensed refrigerant) in addition to the transportation of the heat of the heat emitting object 20 (that is, the movement of the vaporized refrigerant). Because of this, the heat transporting efficiency of the heat transporting unit 1 is improved through increasing the efficiency and the speed of movement of the condensed refrigerant through the heat radiating portion.

[0237] In this way, the provision of the additional heat radiating portion enables the heat transporting unit 1 to transport the heat with high efficiency.

[0238] While a cooling fan was shown in FIG. 14 as an example of a heat radiating portion, instead of a cooling fan, a liquid-cooled jacket, a Peltier element, a heat sink, or any other member capable of radiating heat can be used as the heat radiating portion.

[0239] The heat transporting unit 1 can replace a heat radiating fin or liquid cooling device, or the like, that is mounted in a notebook PC, a mobile terminal, a computer terminal, or the like, and can replace a cooling device that is mounted in an industrial device, or replace a heat radiating case or a cooling device that is mounted in a control computer unit, or the like. The heat transporting unit 1 can transport heat at a higher speed than a heat pipe that has been used conventionally, and thus can be applied to cooling a variety of electronic components. The result is that the heat transporting unit 1 can be used in a broad scope of applications.

[0240] The heat transporting unit 1 in the fourth form of embodiment transports the heat of the heat emitting object more efficiently.

[0241] A heat transporting unit 1 as explained in any of the first through fourth forms of embodiment can be applied well to an electronic device that is provided with a heat transporting unit 1, a heat emitting object 20 that is in thermal contact with at least a portion of the surface of the heat transporting unit 1 (or which may be in contact with the heat receiving portion explained in the third form of embodiment), an electronic circuit board whereon the heat emitting object 20 is mounted, and a case for housing the electronic circuit board.

[0242] FIG. 15 is a schematic diagram of an electronic device according to the fifth form of embodiment according to the Present Disclosure. The electronic device 90 houses, within a case 91, a heat transporting unit 1 for cooling an electronic circuit board 92 and a heat emitting object 20, mounted thereon. The electronic circuit board 92 has a variety of electronic components mounted thereon, so the heat transporting unit 1 transports heat, with those electronic components requiring the transportation of heat as the heat emitting object 20.

[0243] Additionally, the heat transporting unit 1, if necessary, may be provided with a heat radiating portion, as represented by the cooling fan 80.

[0244] This type of electronic device 90 can be cooled when the heat of the heat emitting object is transported in a specific direction, thus making it possible to prevent malfunction of or damage to the electronic device, enabling higher performance to be achieved.

[0245] The electronic device is of a thin shape such as an automobile television or personal monitor, or may be a mobile terminal that must be of a small size. Conversely, the electronic device includes also mobile telephones, mobile music playing equipment, mobile mail terminals, PDAs, digital cameras, digital video cameras, mobile recorders, smartphones, and mobile video recording equipment.

[0246] The electronic device 90 in the fifth form of embodiment is able to transport effectively, to the periphery, the heat of those electronic components and mechanical components that have high heat production, thus making it possible to prevent in advance malfunctions or failures of the electronic device 90.

[0247] Note that while in the forms of embodiment in the Present Disclosure the heat emitting object was thermally connected to either the upper plate or the lower plate, instead it may be thermally connected to both the upper plate and the lower plate. Furthermore, the heat emitting object may be connected thermally through a heat receiving member, having high thermal conductivity, which is a separate member, to the upper plate and/or the lower plate. The provision of the heat receiving member enables its use as a positioner or a securing member when connecting thermally to the heat emitting object.

[0248] While a preferred embodiment of the Present Disclosure 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:**

- 5 1. A heat transporting unit having a space defined by mutually orthogonal X, Y and
Z axes, comprising:
 an upper plate;
 a lower plate that faces the upper plate;
 an interior space that is formed by the upper plate and the lower plate and wherein
10 a refrigerant can be sealed;
 a first region, that is a region that is part of the interior space and that is provided
with a first column portion that forms a plurality of first ducts that extend in the X-axis direction;
and
 a second region that is provided with a second column portion that forms a
15 plurality of second ducts that extend in the X-axis direction and the Y-axis direction, that is a
region that is other than the first region within the interior space;
 wherein the first ducts and second ducts connect at a boundary between the first
region and the second region.
- 20 2. The heat transporting unit of Claim 1, wherein, in the first duct, not only does a
vaporized refrigerant move in the X-axis direction, but a condensed refrigerant also moves in the
X-axis direction.
3. The heat transporting unit of Claim 2, wherein, in the second duct, not only does
25 the vaporized refrigerant move in the X-axis direction and the Y-axis direction, but the
condensed refrigerant also moves in the X-axis direction and the Y-axis direction.
4. The heat transporting unit of Claim 3, wherein not only does vaporized refrigerant
move mutually at the boundary between the first duct and the second duct, but also the
30 condensed refrigerant moves mutually at the boundary between the first duct and the second
duct.

5. The heat transporting unit of Claim 4, wherein a second region is provided at at least one of the two end portions of the interior space.

5 6. The heat transporting unit of Claim 5, wherein a first region is provided in a region other than the second region in the interior space.

7. The heat transporting unit of Claim 4, wherein a second region is provided in the center portion of the interior space.

10 8. The heat transporting unit of Claim 7, wherein a first region is provided in a region other than the second region in the interior space.

9. The heat transporting unit of Claim 4, wherein a second region not only diffuses
15 heat received from a heat emitting object in the X-axis direction and the Y-axis direction, but also moves it to the first region.

10. The heat transporting unit of Claim 9, wherein the first region transports, in the X-axis direction, the heat moved from the second region.

20 11. The heat transporting unit of Claim 10, wherein, when the second region is provided at a first end portion and at a second end portion that is opposite from the first end portion, within the interior space, the second region of the first end portion side not only causes the diffusion, in the X-axis direction and the Y-axis direction, of the heat received from the heat
25 emitting object, but also causes it to move to the first region.

12. The heat transporting unit of Claim 11, wherein, when the second region is provided at a first end portion and at a second end portion that is opposite from the first end portion, within the interior space, the first region transports, in the X-axis direction, the heat
30 moved from the second region on the first end portion side.

13. The heat transporting unit of Claim 12, wherein, when the second region is provided at a first end portion and at a second end portion that is opposite from the first end portion, within the interior space, the second region on the second end portion side diffuses, in the X-axis direction and the Y-axis direction, the heat that has been transported by the first region.

14. The heat transporting unit of Claim 10, wherein, when the second region is provided in the center of the interior space, and the first region is provided at a first end portion and at a second end portion that is on the opposite side from the first end portion, in the interior space, the second region not only diffuses in the X-axis direction and the Y-axis direction the heat that is received from the heat emitting object, but also moves it to the first region.

15. The heat transporting unit of Claim 14, wherein, when the second region is provided in the center of the interior space, and the first region is provided at a first end portion and at a second end portion that is on the opposite side from the first end portion, in the interior space, the first region transports, in the X-direction, the heat moved from the second region.

16. The heat transporting unit of Claim 10, wherein the upper plate and/or the lower plate also has a heat receiving portion that contacts the heat emitting object thermally.

17. The heat transporting unit of Claim 16, wherein the heat receiving portion is provided spanning the first region and the second region.

18. The heat transporting unit of Claim 17, wherein a first column portion has a cutout to connect together adjacent first ducts within a plurality of first ducts.

19. The heat transporting unit of Claim 18, wherein the second region has one or more intermediate plates layered in the Z-axis direction.

20. The heat transporting unit of Claim 19, wherein the intermediate plates form the second column portion that is stacked in the Z-axis direction.

21. The heat transporting unit of Claim 20, wherein the second column portion forms second ducts in the X-axis direction, the Y-axis direction, and the Z-axis direction.

5 22. The heat transporting unit of Claim 21, wherein the second column portion comprises a large column member and a small column member that is smaller than the large column member.

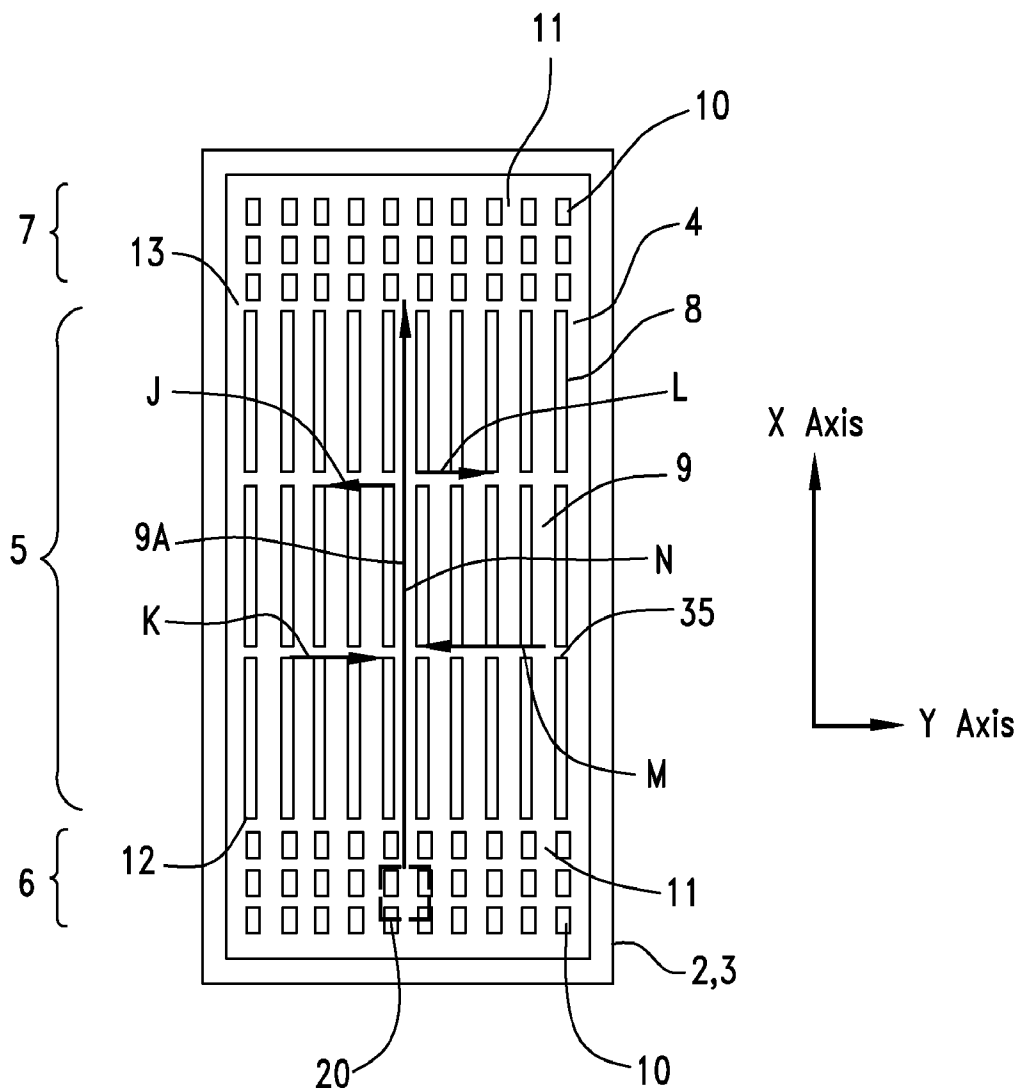
10 23. The heat transporting unit of Claim 22, wherein at least a portion of the first ducts and the second ducts have capillary forces that move the condensed refrigerant.

24. The heat transporting unit of Claim 23, wherein at least a portion of the upper plate, the lower plate, the first column portion, and/or the second column portion has a channel in a surface that is exposed to the interior space.

15 25. The heat transporting unit of Claim 24, wherein the upper plate and/or the lower plate is further equipped with a heat radiating portion for radiating the transported heat, in a region that faces at least a portion of the first region and/or the second region.

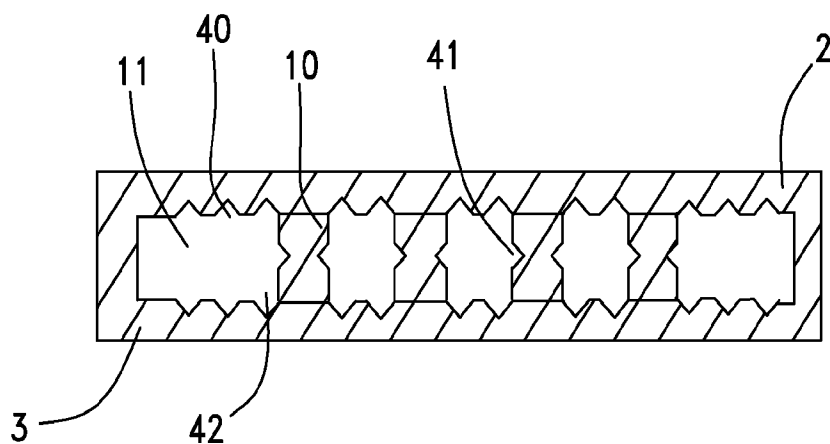
20 26. The heat transporting unit of Claim 25, wherein at least a portion of the upper plate, the lower plate, the first column portion, and/or the second column portion has metal plating on a surface that is exposed to the interior space.

25 27. The heat transporting unit of Claim 26, wherein the width of the first region in the Y-axis direction and the width of the second region in the Y-axis direction are essentially identical.



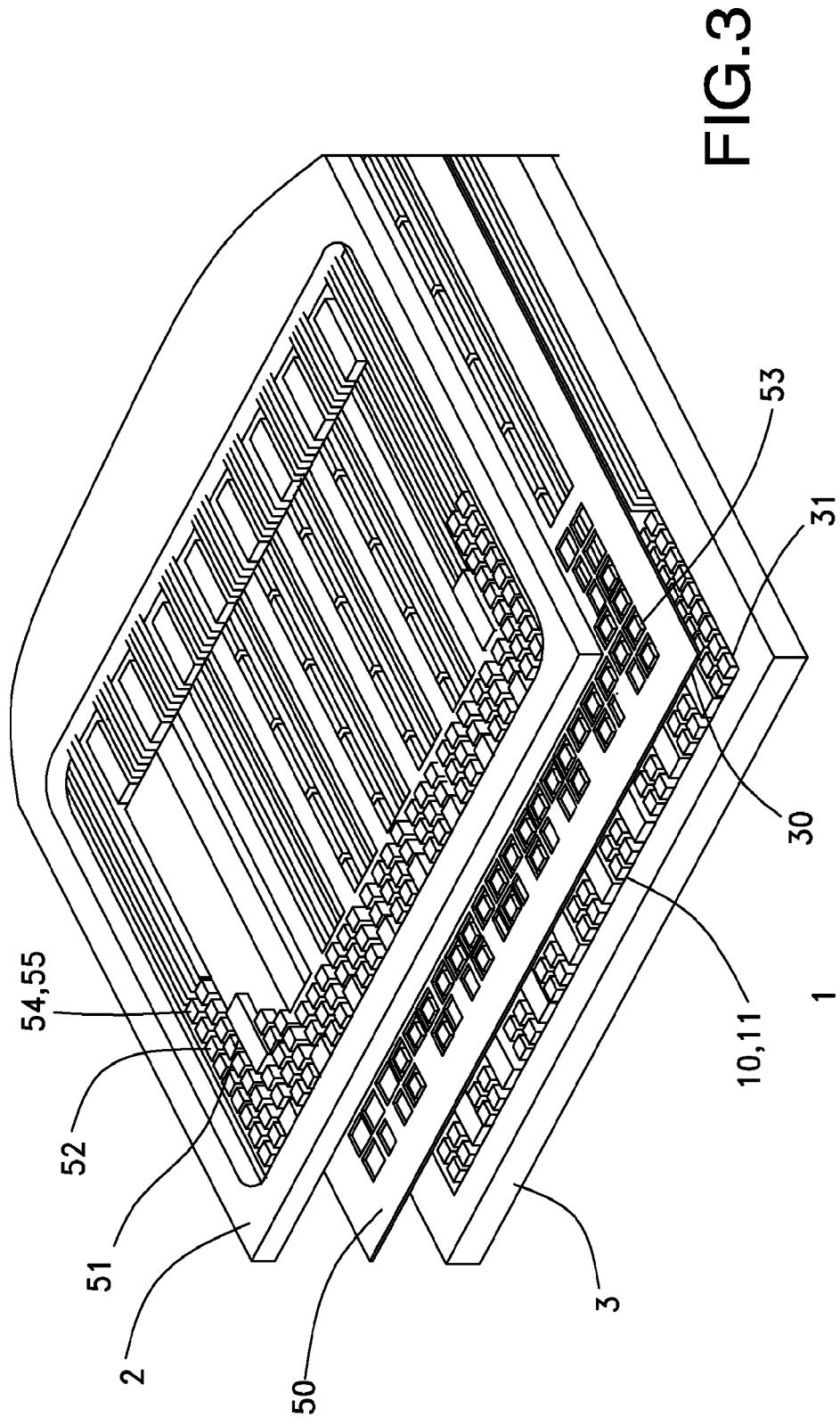
1

FIG.1



1

FIG.2



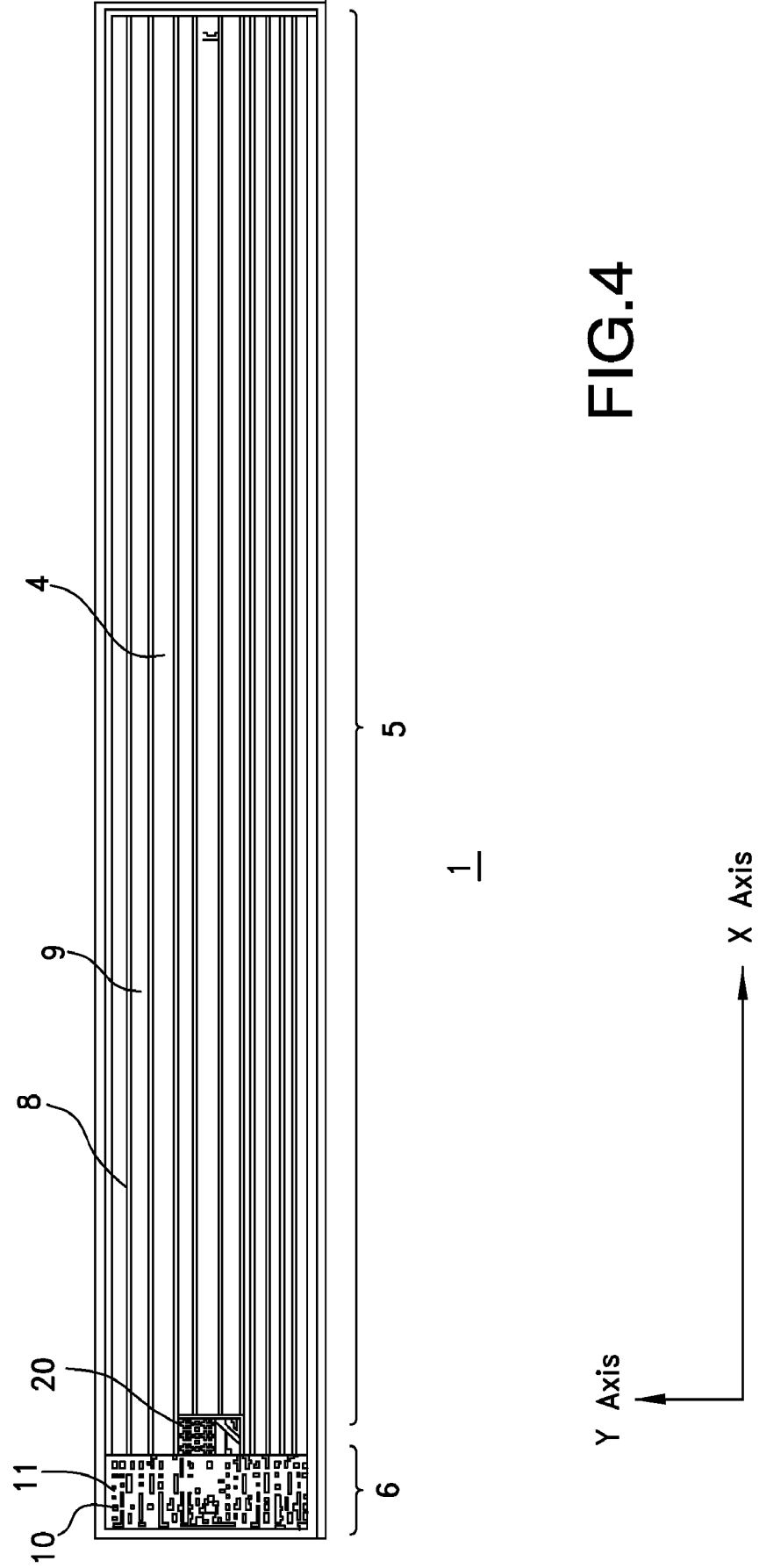
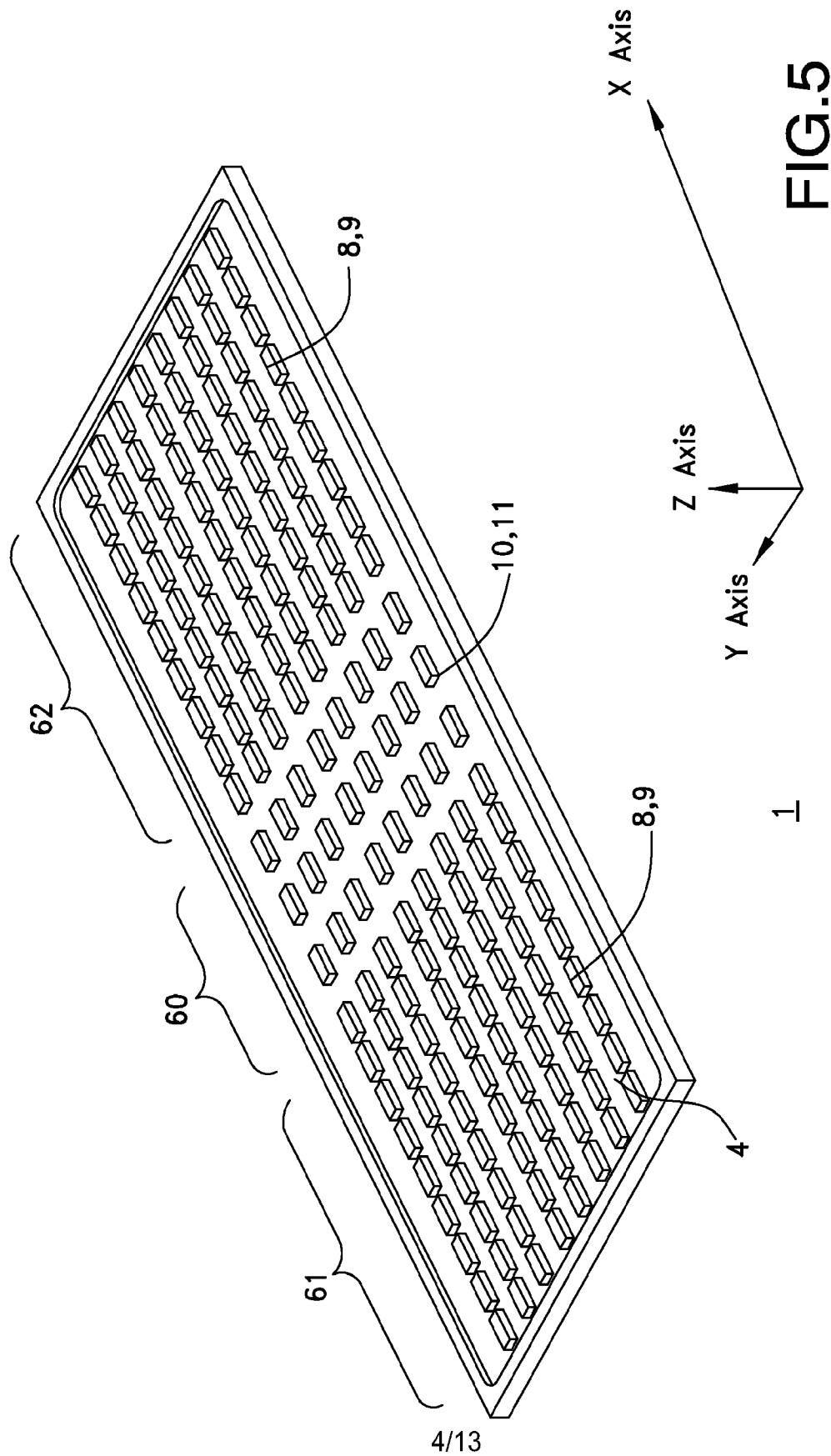


FIG.4



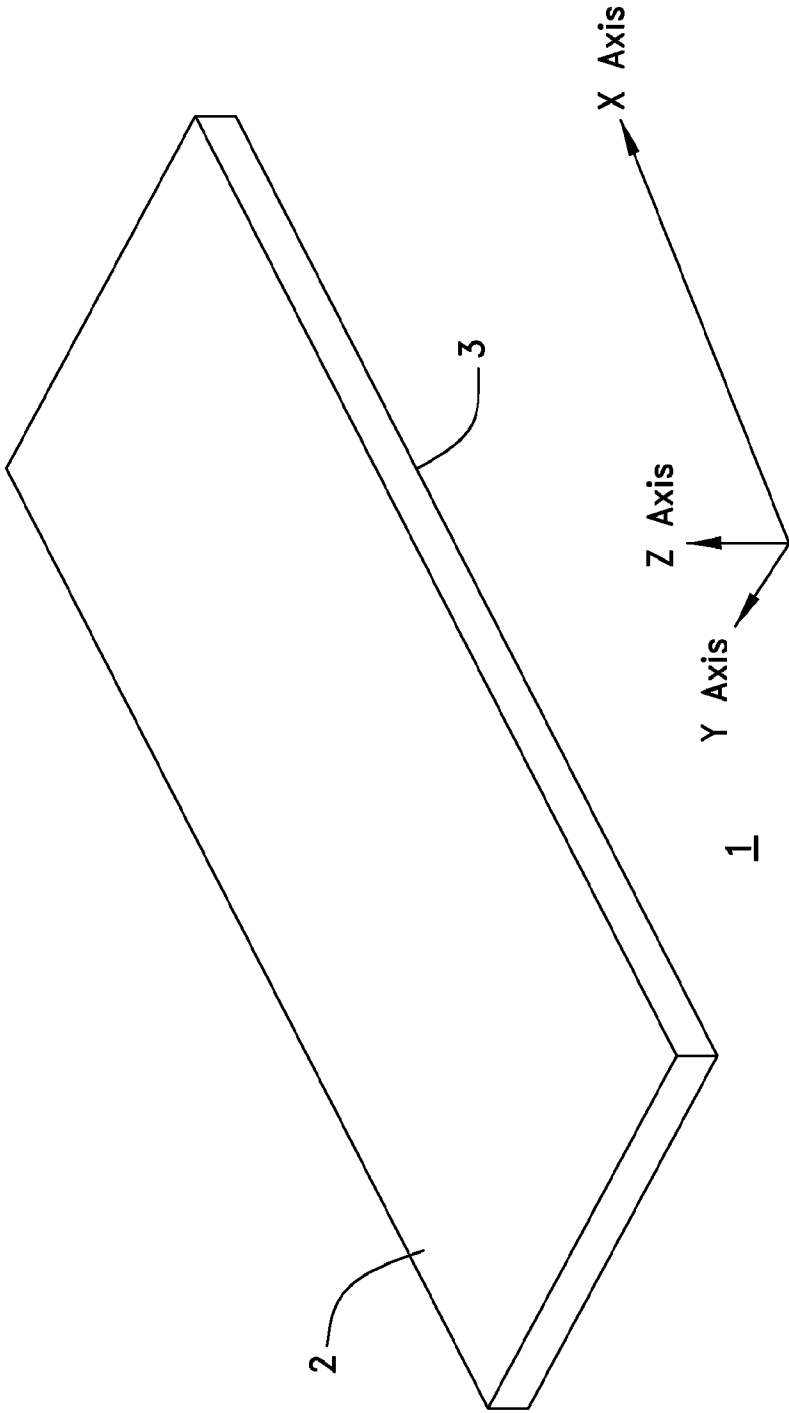


FIG. 6

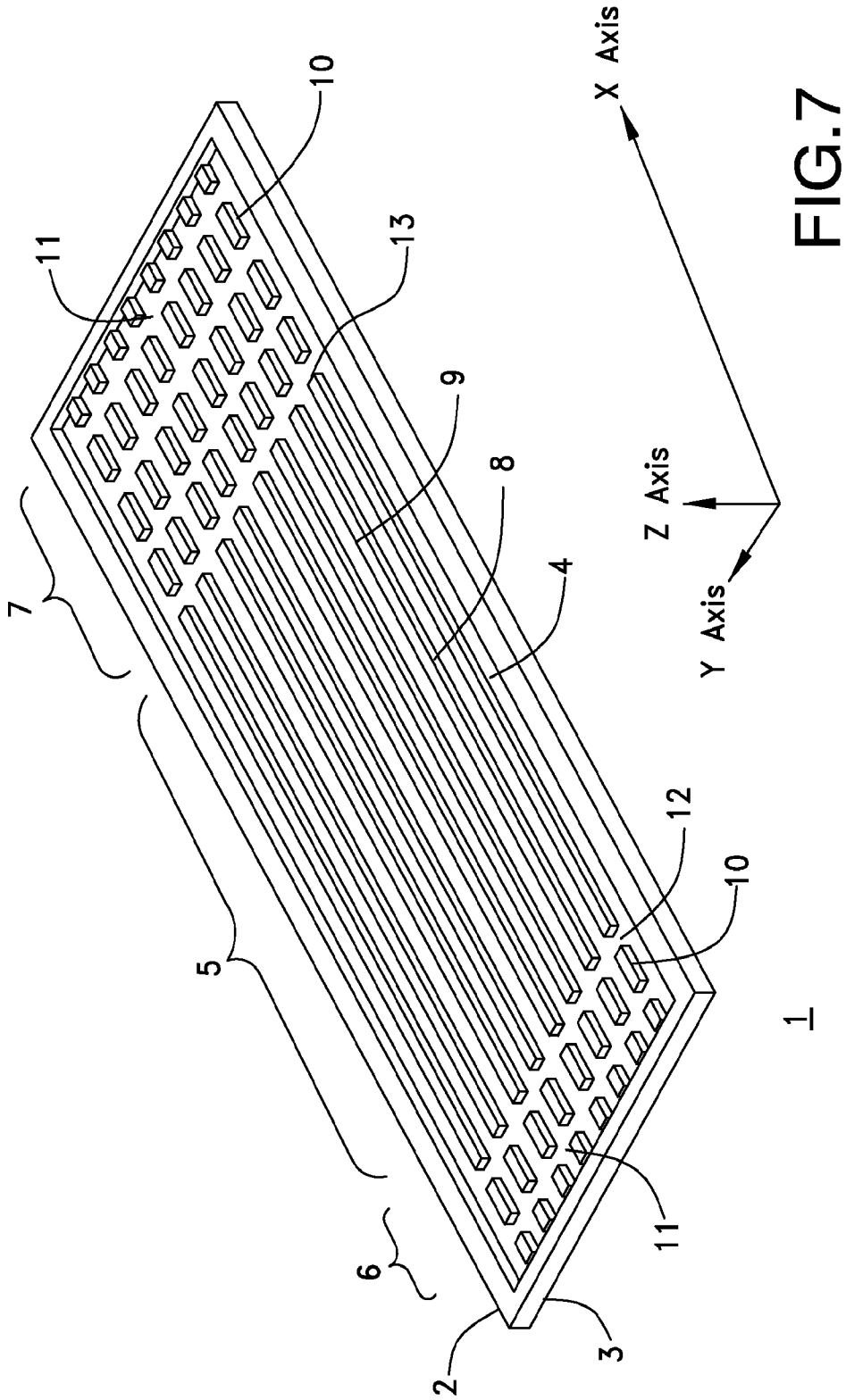
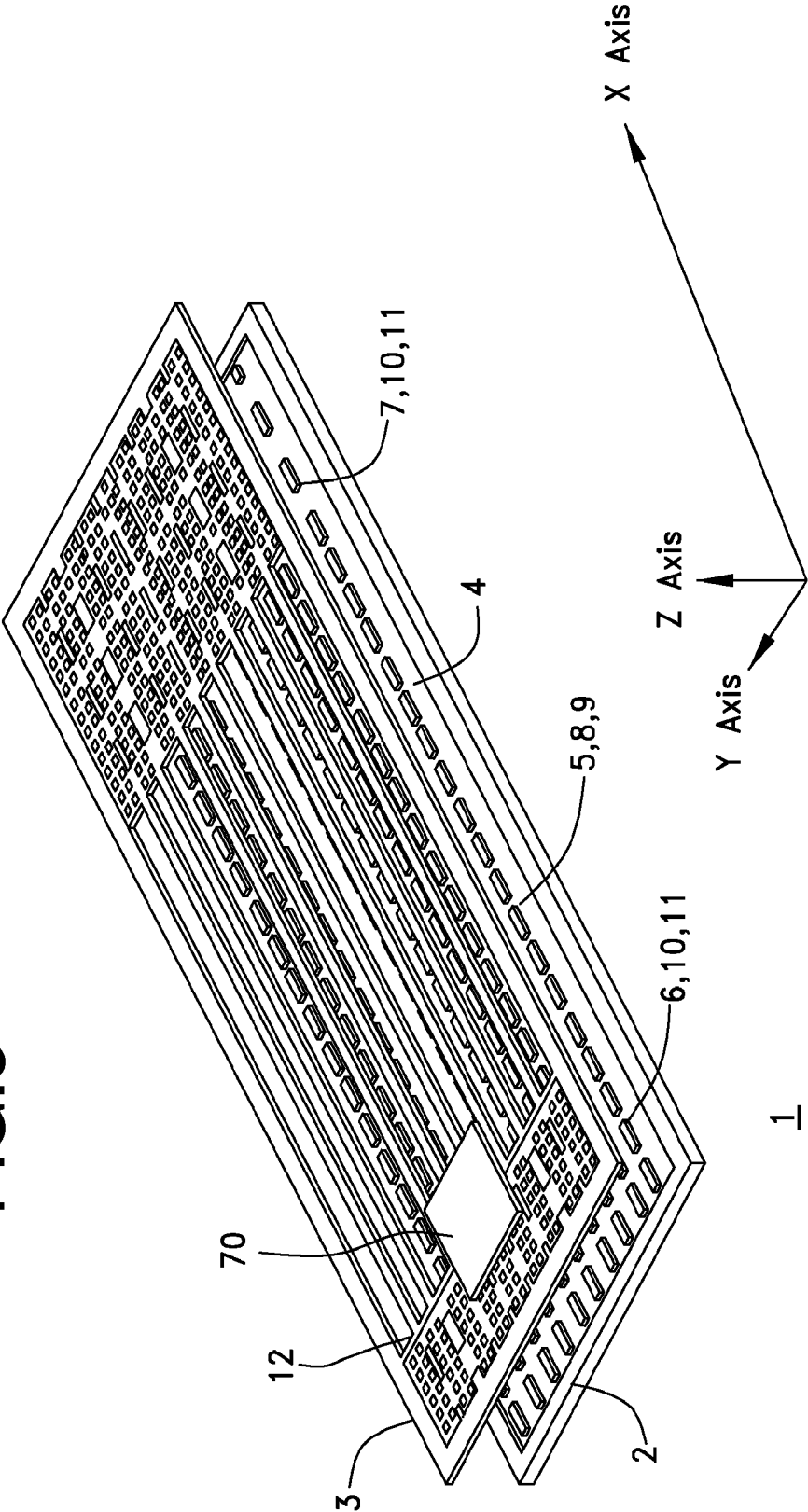
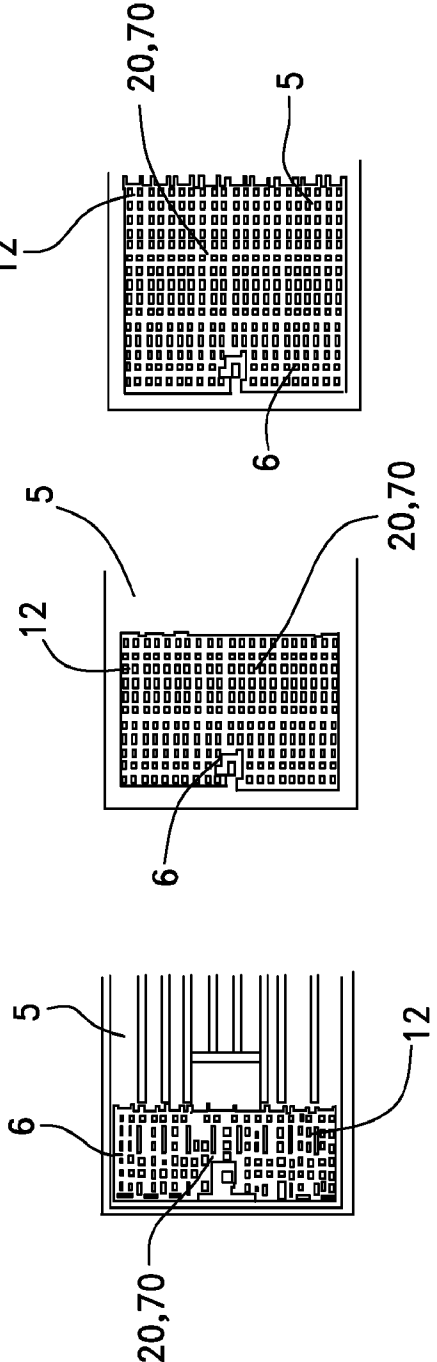
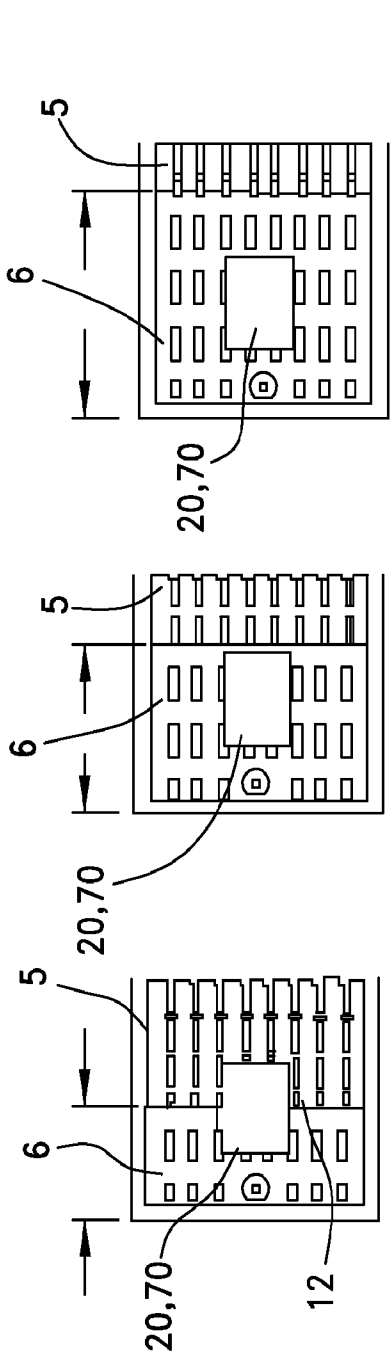


FIG. 7

FIG.8





Comparative Example 2

Comparative Example 1

Example of Embodiment

FIG.9

FIG.10

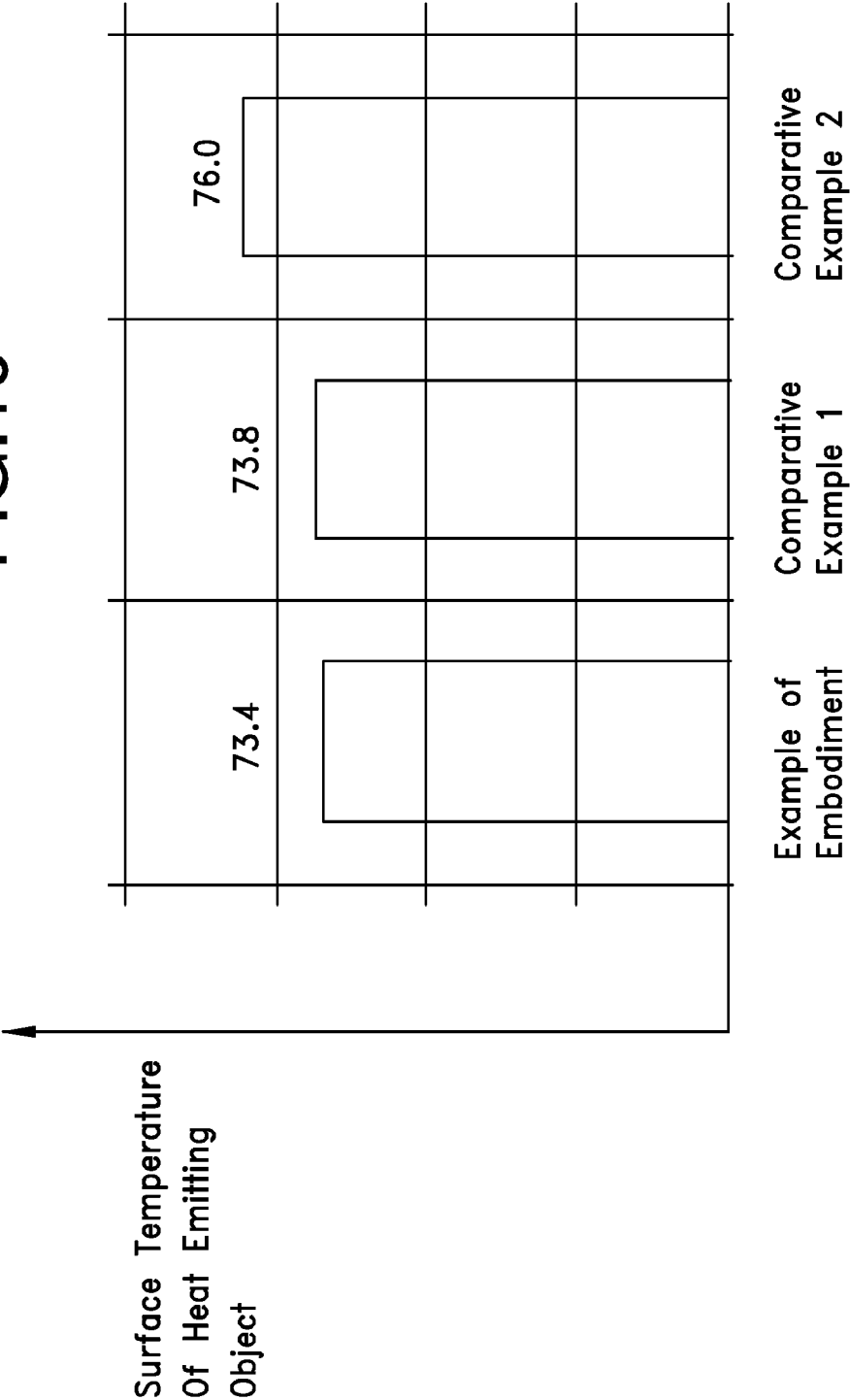


FIG.11

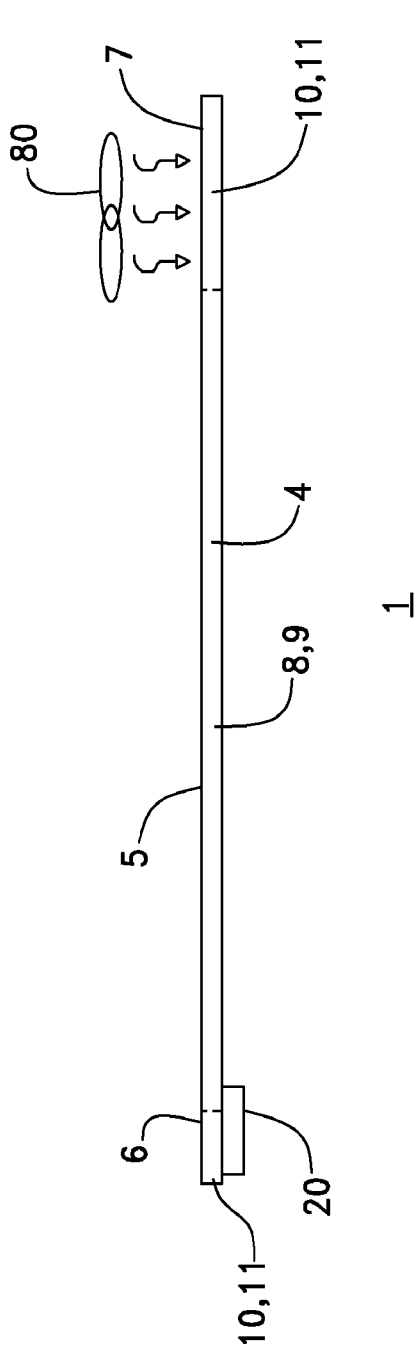
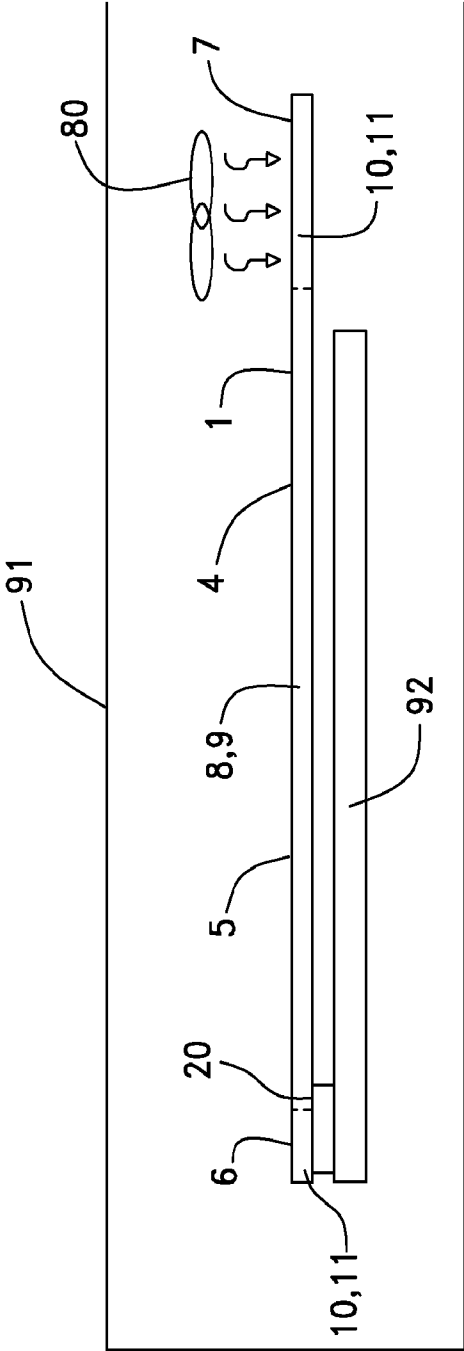


FIG.12



90

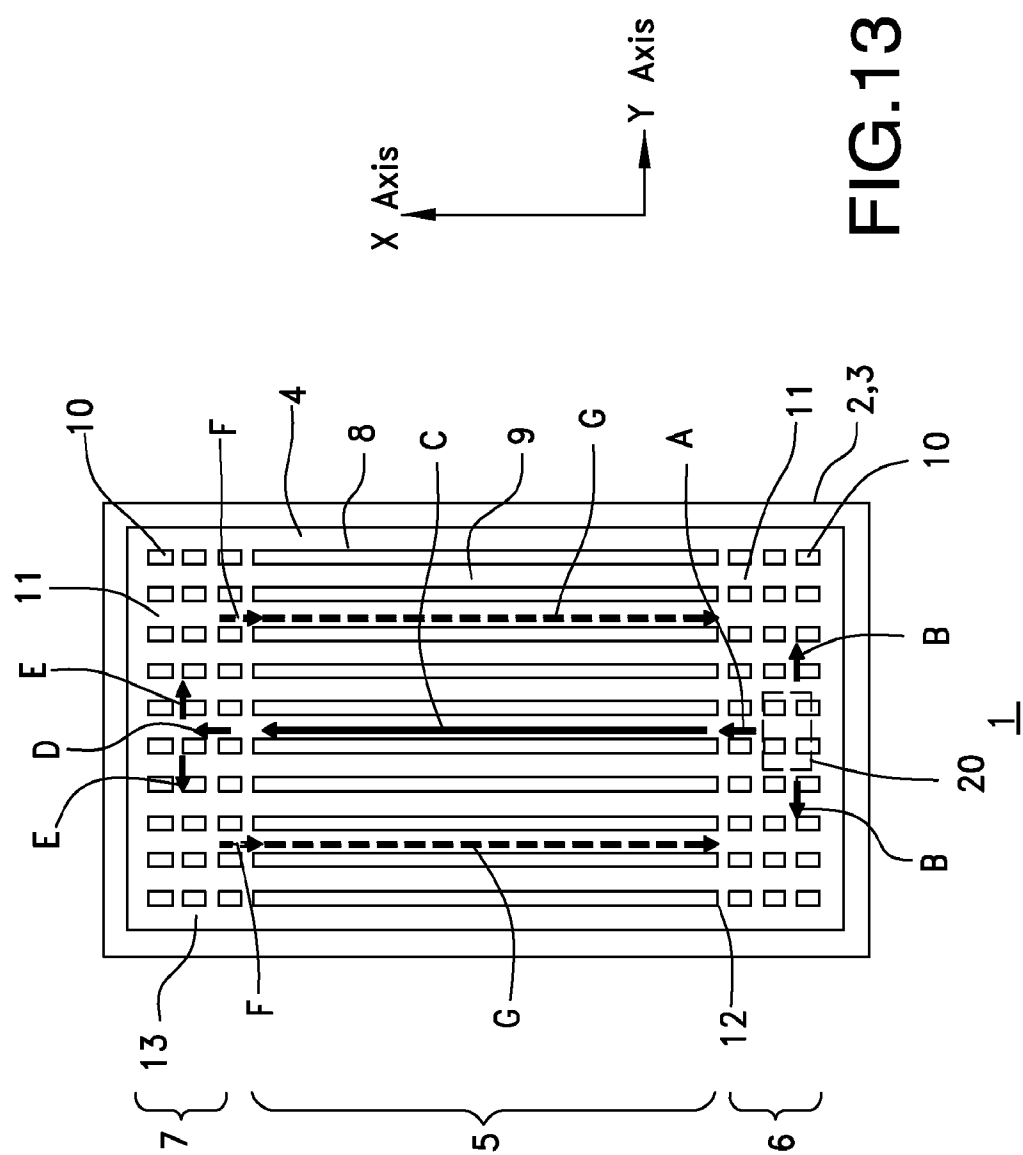


FIG.13

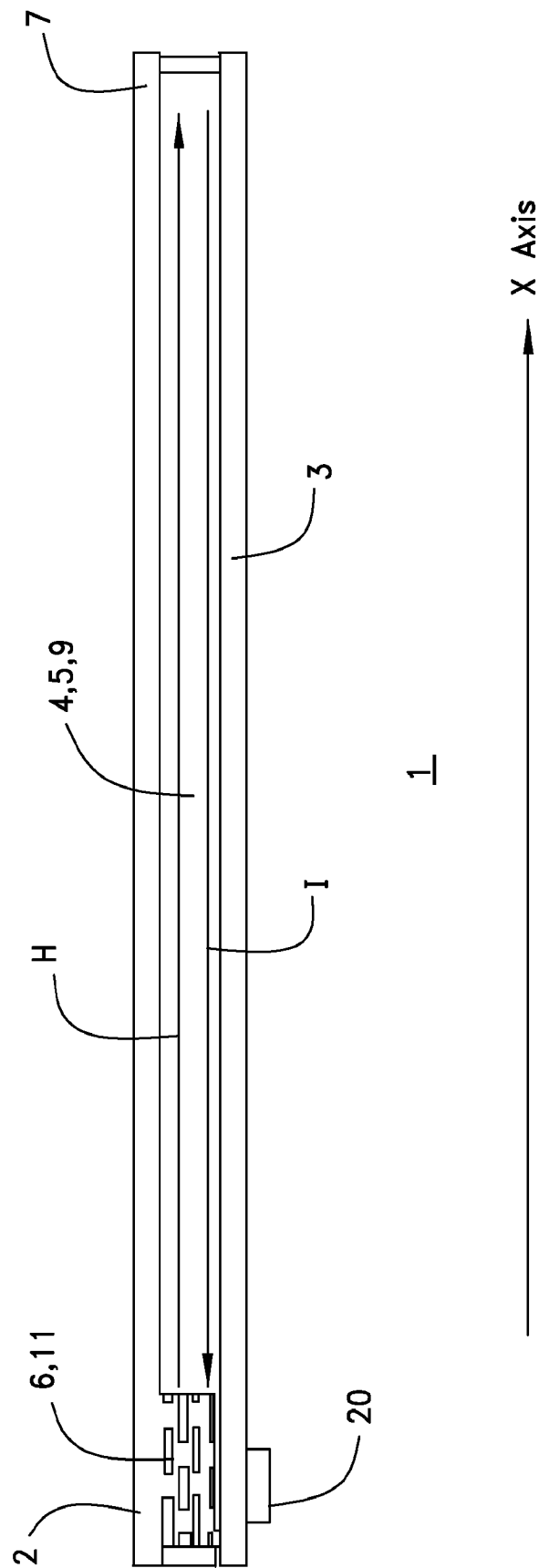


FIG.14

