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(54) Title: HEAT SINK DEVICE

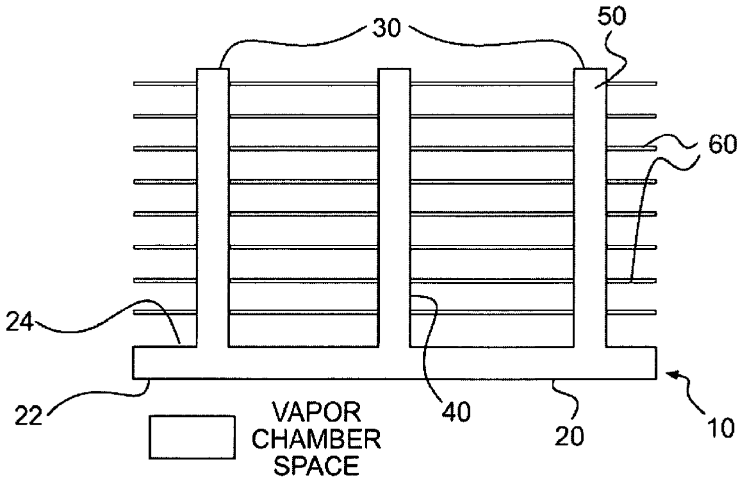

FIG. 2B

(57) **Abstract**: A heat sink is provided. The heat sink contains a first vapor chamber section having a top surface and a bottom surface that is in thermal contact with a heat source, a second vapor chamber section that extends vertically from the top surface of the first vapor chamber section, and heat-dissipating fins that are attached to the second vapor chamber section. The first and second vapor sections are connected to each other forming a continuous vapor chamber space.

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HEAT SINK DEVICE

TECHNICAL FIELD

The technical field relates generally to cooling systems for electronics, and more particularly to a heat sink with vapor chambers and thermal dissipating fins.

BACKGROUND

Increasing levels of component power and power density from electronic devices such as integrated circuits and memory are creating an increased demand for thermal management solutions. For example, high-density blade servers have been in great demand in recent years due to their outstanding performance. This high density computing power, however, comes with very limited space in the server enclosure. Accordingly, high performance heat sinks are necessary for efficient cooling. The heat sinks in use today have reached their limit in dissipating the heat generated by power chips. A need for more efficient cooling exists to expand the thermal dissipation performance envelope.

SUMMARY

A heat sink is disclosed. The heat sink comprises a first vapor chamber section having an upper surface and a lower surface, a second vapor chamber section extending vertically from said upper surface of said first vapor chamber section, and heat-dissipating fins extending horizontally from said second vapor chamber section, wherein said lower surface is in thermal contact with a heat source and wherein said first and second vapor sections are connected to each other, forming a continuous vapor chamber space.

Also disclosed is a heat sink comprising: a hollow-centered base having a top surface and a bottom surface, wherein said bottom surface is in thermal contact with a heat source; two hollow-centered sidewalls located on two opposite sides of the base and extending upwardly from the top surface of the base; and one or more hollow-centered center columns located between the two sidewalls and extending upwardly from the top surface of the base, wherein the hollow centers of said base, said sidewalls and said one or more center columns are connected to each other forming a continuous vapor chamber space, and wherein said sidewalls and said center columns comprise fins for heat dissipation.

Also disclosed is a heat sink comprising: a planar-shaped first vapor chamber having a first surface and a second surface, wherein said first surface is opposite to said second surface and is in contact with a heat source; a second vapor chamber formed on said second surface, said second vapor chamber is connected to said first vapor chamber thus forming a continuous vapor chamber space; and a plurality of planar-shaped heat dissipating fins extending from said second vapor chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements. Embodiments of the invention are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings.

FIG. 1 is a cross-sectional view of a prior art heat sink.

FIGS. 2A and 2B are schematic representations of two embodiments of a heat sink with innovative vapor chamber configuration;

FIG. 3 is a composite of schematic representations of a heat sink with free-standing center column configuration with (upper panel) or without (lower panel) fins;

FIGS. 4A-4C are results of computational fluid dynamics (CFD) analysis of the heat sink configuration shown in FIG. 3;

FIGS. 5A and 5B are results of CFD analysis of the airflow in the heat sink configuration shown in FIG. 3;

FIG. 6 is a schematic representation of a heat sink with wall-like center column configuration;

FIGS. 7A and 7B are results of CFD analysis of the heat sink configuration shown in FIG. 6;

FIGS. 8A and 8B are results of CFD analysis of the airflow in the heat sink configuration shown in FIG. 6.

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description, reference is made to the accompanying drawings which form a part hereof wherein like numerals designate like parts throughout, and in which is shown by way of illustration embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made in alternate embodiments. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of embodiments in accordance with the present invention is defined by the appended claims and their equivalents.

This description is intended to be read in connection with the accompanying drawings, which are to be considered part of the entire written description of this invention. The drawing figures are not necessarily to scale and certain features of the invention may be shown exaggerated in scale or in somewhat schematic form in the interest of clarity and conciseness. In the description, relative terms such as "horizontal," "vertical," "up," "down," "top" and "bottom" as well as derivatives thereof (e.g., "horizontally," "downwardly," "upwardly," etc.) should be construed to refer to the orientation as then described or as shown in the drawing figure under discussion. These relative terms are for convenience of description and normally are not intended to require a particular orientation. Terms including "inwardly" versus "outwardly," "upwardly" versus "downwardly," "longitudinal" versus "lateral" and the like are to be interpreted relative to one another or relative to an axis of elongation, or an axis or center of rotation, as appropriate. Terms concerning attachments, coupling and the like, such as "connected" and "interconnected," refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise. The term "operatively connected" is such an attachment, coupling or connection that allows the pertinent structures to operate as intended by virtue of that relationship.

FIG. 1 is a conceptual illustration of a prior art heat sink with a vapor chamber. The vapor chamber is confined in a base plate having a lower surface and an upper surface. The lower surface is in thermal contact with a heat source and the upper surface comprises planar fins extending vertically from the upper surface for heat dissipation.

FIG. 2A illustrates an embodiment of a heat sink with innovative vapor chamber configuration. Heat sink 10 comprises a vapor chamber base 20, vapor chamber sidewalls 30 and optionally one or more vapor chamber center columns 40. Each of the vapor chamber base 20, vapor chamber sidewalls 30 and vapor chamber center columns 40 is a hollow-centered structure that comprises a vapor chamber space enclosed by surrounding walls. In one embodiment, the vapor chamber base 20, the sidewalls 30 and the center columns 40 are operatively connected to each other to form a continuous vapor chamber space.

The base 20 contains a bottom surface 22 that is in thermal contact with a heat source, and a top surface 24 on which the sidewalls 30 and/or center columns 40 are formed. The base 20 is made of a material having a high thermal conductivity, such as a metal or alloy. In one embodiment, the base 20 is made of copper or aluminum. The base 20 is filled or partially filled with an evaporable working fluid, such as water.

The sidewalls 30 are formed only on selected sides of the base 20 so as to maintain an unobstructed airflow between the sidewalls 30. In the embodiment shown in FIG. 2A, two sidewalls 30 are formed on the opposite sides of the base 20. It should be noted that the sidewalls 30 do not need to be formed on the edges of the base 20. As shown in FIG. 2B, the two sidewalls 30 are formed at locations near the edges of the base 20.

The center column 40 is formed between the sidewalls 30 to further facilitate heat dissipation from the base 20. In one embodiment, the center column 40 is in the form of a free-standing column that serves as a heat pipe. Multiple free-standing center columns 40 may be used to facilitate heat transfer from the base 20 to fins 60. In another embodiment, the center column 40 is in the form of a center wall that is parallel to the sidewalls 30 and extends from one side of the base 20 to the other side of the base 20. Multiple center walls may be formed between the sidewalls 30 to facilitate heat transfer from the base 20 to fins 60. A person skilled in the art would also understand that efficient heat dissipation may be achieved with the sidewalls 30 alone, the center columns 40 alone, or a combination of the sidewalls 30 and the center columns 40. The sidewalls 30 and center columns 40 are made of a material having a high thermal conductivity, such as a metal or alloy. In one embodiment, the sidewalls 30 and center columns 40 made of copper or aluminum.

In one embodiment, the vapor chamber base 20, sidewalls 30 and center columns 40 are filled with a porous material 50. The porous material 50 has a porosity that allows vapor transport from the base 20, where evaporation takes place, to sidewalls 30 and center columns 40, where condensation of the vapor takes place. The capillary forces created by the porous material also facilitate the return of condensed working fluid to the base 20. Examples of the porous material 50 include, but are not limited to, sintered powder wick which can be attached to the vapor chamber base 20, sidewalls 30 and/or center columns 40 by solder.

The sintered powder may be selected from any of the materials having high thermal conductivity and that are suitable for fabrication into porous structures, e.g., carbon, tungsten, copper, aluminum, magnesium, nickel, gold, silver, aluminum oxide, beryllium oxide, or the like, and may comprise either substantially spherical, arbitrary or regular polygonal, or filament-shaped particles of varying cross-sectional shape. In one embodiment, the porous material 50 comprises sintered copper wick. Other wick materials, such as aluminum-silicon-carbide or copper-silicon-carbide may be used with equal effect.

The sidewalls 30 and/or center columns 40 further comprise a plurality of stacked fins 60 for efficient heat dissipation. The fins 60 are attached in horizontal arrangement to the sidewalls 30 and center columns 40. Each fin 60 has a planar-shaped main body having a top surface 62 and a bottom surface 64 opposite to the top surface 62. The top surface 62 of one fin and the bottom surface 64 of the neighboring fin are parallel to each other. The distance (d) between the two neighboring fins 60 may be determined experimentally to allow for efficient cooling of the fins 60 by airflow. In one embodiment, the distance (d) is in the range of 0.5-5 mm. The fins 60 are typically made of a material having high thermal conductivity, such as a metal or an alloy. In one embodiment, the fins 60 are made of aluminum.

The heat sink 10 may be used to cool a heat-generating device which may be an electronic component such as, but not limited to, an integrated circuit, a memory module, a Micro-Electro-Mechanical System (MEMS), a sensor, a resister, or a capacitor. The heat sink 10 may be positioned directly on the electronic component, or on a thermal solution including, but not limited to, a heat pipe, a heat spreader, a heater block, and a thermal transfer plate. A fan may be complementarily positioned to accelerate airflow between fins 60 and increase the rate of heat dissipation. The exact complementary positioning is application dependent, and may be affected by a number of factors, including but not limited to, the amount of heat to be removed, the volume and velocity of the airflow, and so forth. The optimal complementary positioning for a particular application of flow provider and flow modifier may be determined empirically.

During operation, the base 20 of the heat sink 10 absorbs heat generated by the heat-generating device. The working fluid that is contained in the inner side of the base 20 absorbs the heat and evaporates substantially and moves to the sidewalls 30 and/or center columns 40. Evaporated working fluid is cooled and condensed in the sidewalls 30 and center columns 40. The heat is released through fins 60. Finally, the condensed working fluid flows back to the base 20 to begin another cycle. In this way, the working fluid can absorb/release amounts of heat. The heat generated by the heat-generating electronic device is thus transferred from the base 20 to the fins 60 almost immediately.

EXAMPLES

Example 1: CFD analysis of heat sink with free-standing center column configuration

FIGS. 3-5B show results of a CFD analysis of a heat sink with free-standing center column configuration. As shown in FIG. 3, the heat sink device contains six free-standing center columns 40 that are attached to the vapor chamber base 20. The free-standing center columns 40 serve as heat pipes to transfer heat from the base 20 to fins 60. Heat dissipation was achieved by eighteen aluminum plate fins 60 attached to the center columns 40. In this embodiment, the fins have a thickness of 0.5 mm, a surface area of 80 x 85 mm, and a fin-to-fin gap of 1.1 mm. FIGS. 4A-4C show heat distribution on the center columns 40 (FIG. 4A) and fins 60 (FIG. 4B) and the base plate 20 (FIG. 4C). FIGS. 5A and 5B show the airflow generated by fins 60.

Example 2: CFD analysis of heat sink with wall-like center column configuration

FIGS. 6A-8B show results of a CFD analysis of a heat sink with wall-like center column configuration. As shown in FIGS. 6A-6C, the heat sink device contains a base vapor chamber, two sidewalls and a wall-like center column. The sidewalls 30 and the center column 40 are operatively connected to base 20 and form a continuous vapor chamber space. Heat dissipation was achieved by eighteen aluminum plate fins attached to the center columns. The fins have a thickness of 0.5 mm, a surface area of 80 x 85 mm, and a fin-to-fin gap of 1.1 mm. FIGS. 7A-7B show heat distribution on the base plate 20 (FIG. 7A) and fins 60 (FIG. 7B). FIGS. 8A and 8B show the airflow generated by fins 60.

Under the same heat generation and air flow rate settings, the heat sink with wall-like center column configuration was able to achieve a 11°C improvement over the heat sink with free-standing center column configuration, *i.e.*, having a source temperature of 45°C (FIG. 7B) vs. 56°C (FIG. 4C).

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to accommodate various modifications and equivalent arrangements. It will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent embodiments or implementations calculated to achieve the same purposes may be substituted for the embodiments shown and described. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that embodiments in accordance with the present invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A heat sink comprising:

a first vapor chamber section having an upper surface and a lower surface;

a second vapor chamber section extending vertically from the upper surface of said first vapor chamber section; and

heat-dissipating fins extending horizontally from said second vapor chamber section,

wherein said lower surface is in thermal contact with a heat source and wherein said first and second vapor sections are connected to each other, forming a continuous vapor chamber space.

2. The heat sink of claim 1, wherein said second vapor chamber section is in the form a hollow-centered sidewall.

3. The heat sink of claim 1, wherein said second vapor chamber section is in the form a hollow-centered center column.

4. The heat sink of claim 3, wherein said hollow-centered center column is in the form of a free-standing column.

5. The heat sink of claim 3, wherein said hollow-centered center column is in the form of a center wall.

6. The heat sink of claim 1, wherein said first and second vapor chambers comprise a porous material.

7. The heat sink of claim 6, wherein said porous material comprises sintered powder wick.

8. The heat sink of claim 7, wherein said sintered powder wick comprises a material selected from the group consisting of carbon, tungsten, copper, aluminum, magnesium, nickel, gold, silver, aluminum oxide, and beryllium oxide.

9. The heat sink of claim 8, wherein said sintered powder wick is sintered copper wick.

10. The heat sink of claim 1, wherein said first and second vapor chambers comprise a material of high thermal conductivity.

11. The heat sink of claim 10, wherein the material of high thermal conductivity comprises copper or aluminum.

12. The heat sink of claim 1, wherein said heat dissipating fins are planar-shaped and are attached in horizontal arrangement to said second vapor chamber section.

13. The heat sink of claim 12, wherein said heat dissipating fins comprises a material of high thermal conductivity.

14. The heat sink of claim 13, wherein the material of high thermal conductivity comprises copper or aluminum.

15. The heat sink of claim 1, wherein said first vapor chamber section contains a working fluid.

16. The heat sink of claim 15, wherein said working fluid is water.

17. A heat sink comprising:

a hollow-centered base having a top surface and a bottom surface, wherein said bottom surface is in thermal contact with a heat source;

two hollow-centered sidewalls located on two opposite sides of the base and extending upwardly from the top surface of the base; and

one or more hollow-centered center columns located between the two sidewalls and extending upwardly from the top surface of the base,

wherein the hollow centers of said base, said sidewalls and said one or more center columns are connected to each other forming a continuous vapor chamber space, and wherein said sidewalls and said center columns comprise fins for heat dissipation.

18. The heat sink of claim 16, wherein said fins have a planar shape and extend in directions parallel to said top surface of said hollow-centered base.

19. A heat sink comprising:

a planar-shaped first vapor chamber having a first surface and a second surface, wherein said first surface is opposite to said second surface and is in contact with a heat source;

a second vapor chamber formed on said second surface, said second vapor chamber is connected to said first vapor chamber thus forming a continuous vapor chamber space; and

a plurality of planar-shaped heat dissipating fins extending from said second vapor chamber.

20. The heat sink of claim 19, wherein said second vapor chamber is a wall-like vapor chamber.

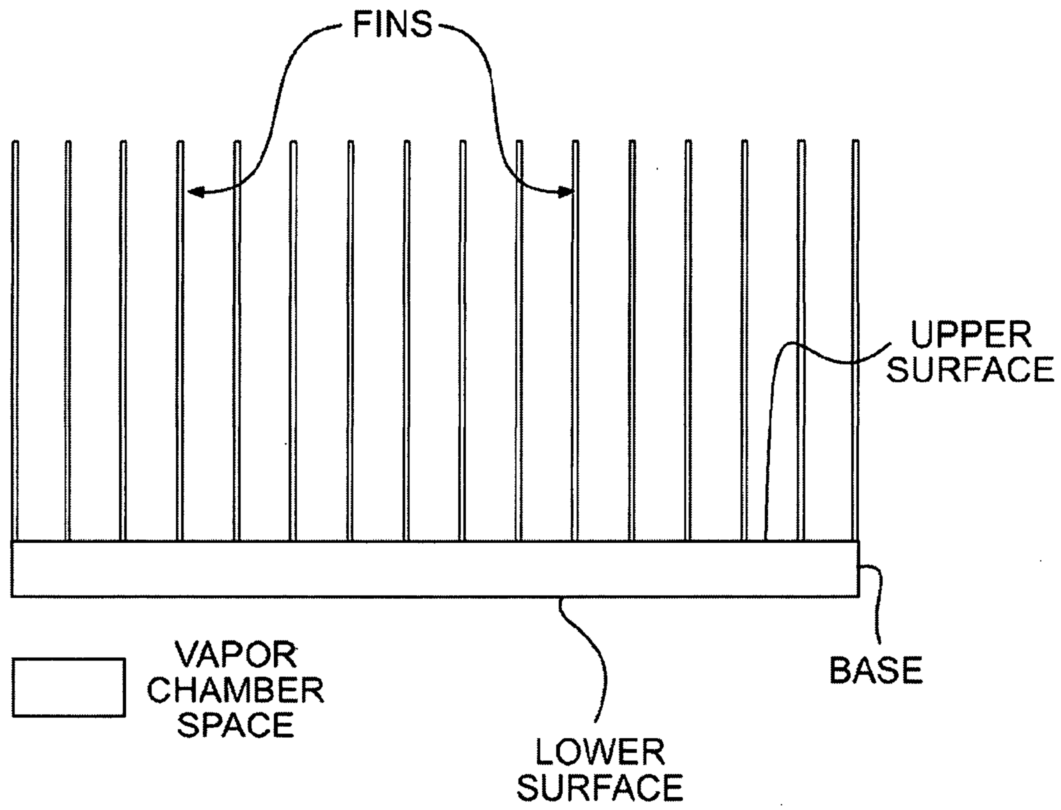
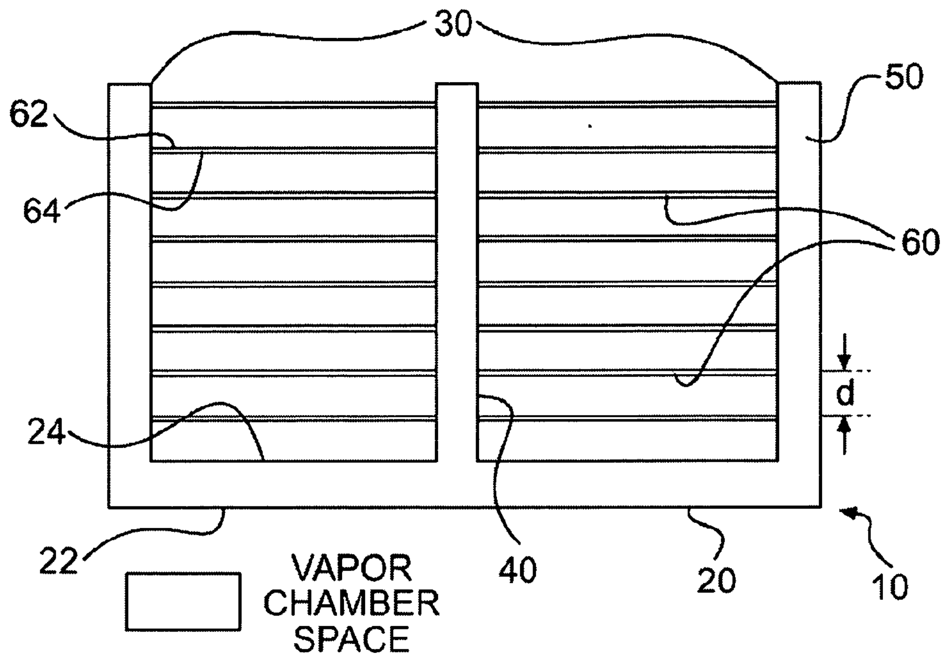


FIG. 1
(Prior Art)


30
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64
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d
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22
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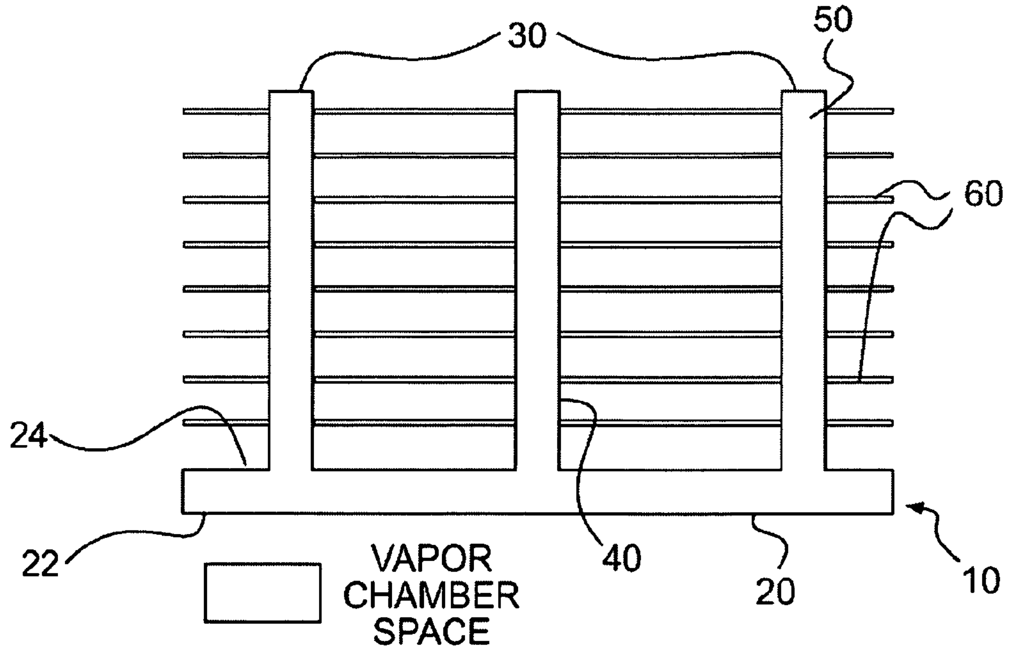
20
10
VAPOR
CHAMBER
SPACE

FIG. 2A


30
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24
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VAPOR
CHAMBER
SPACE

FIG. 2B

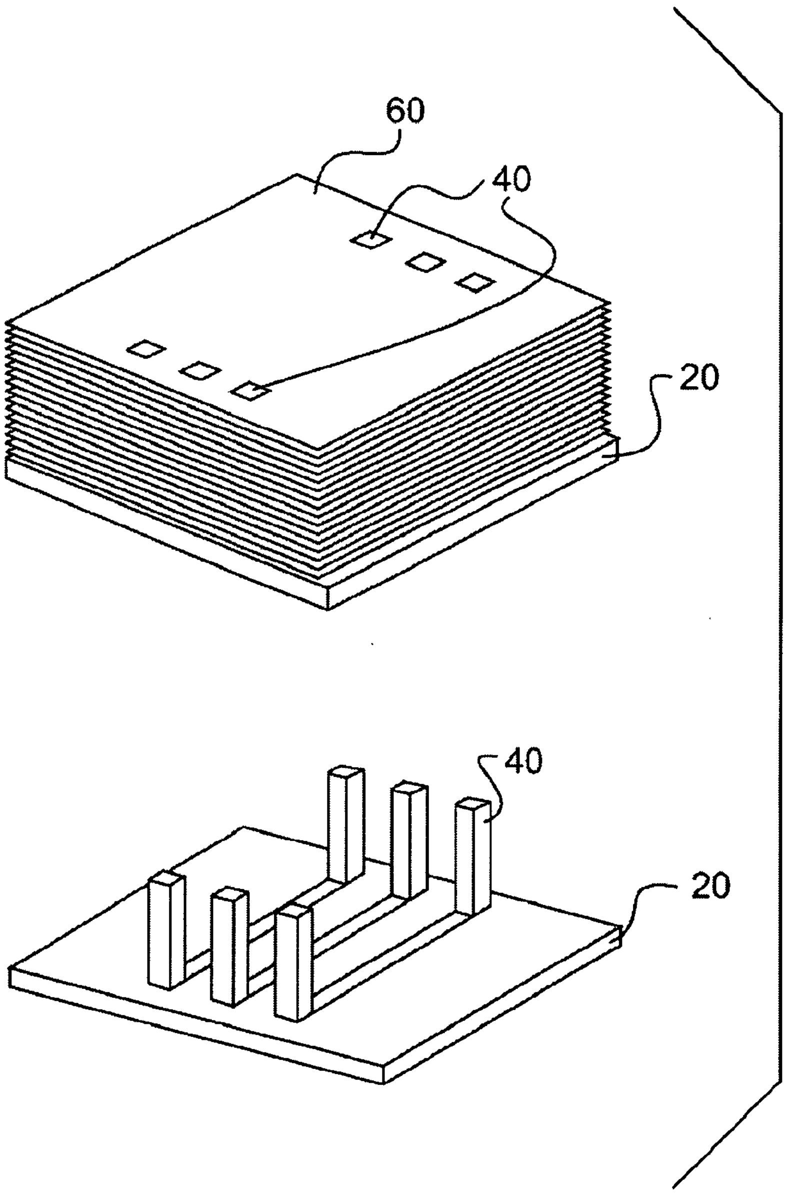

FIG. 3

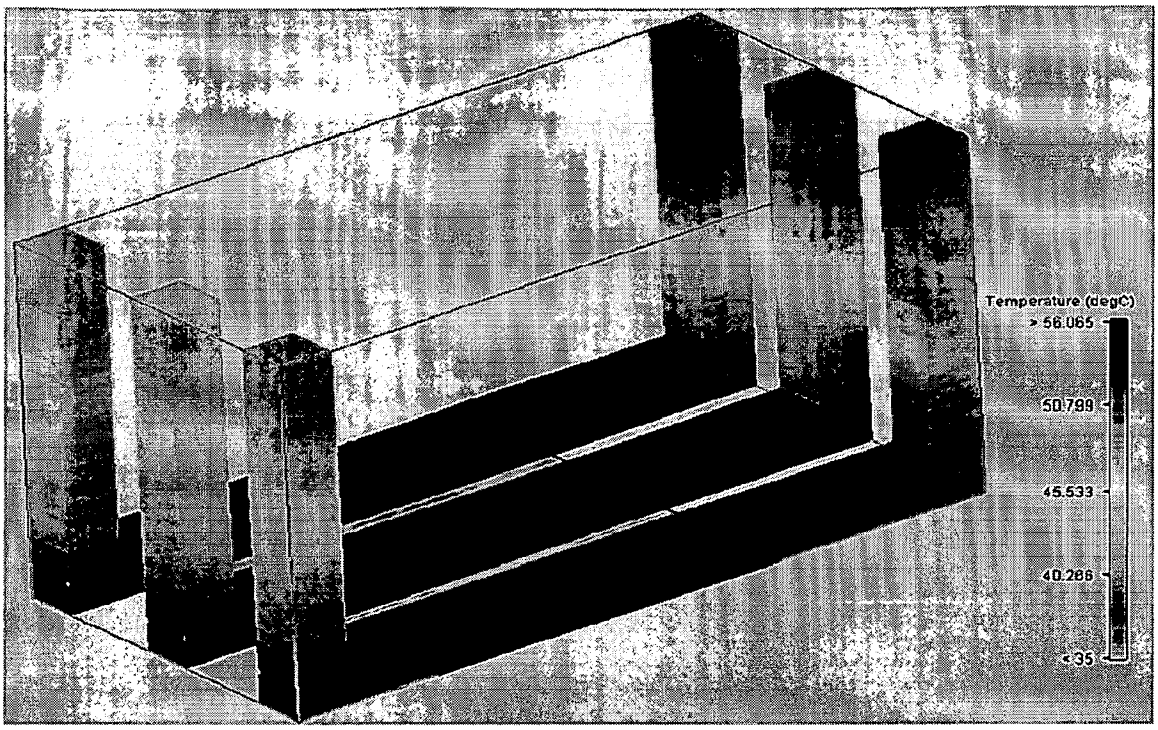

FIG. 4A

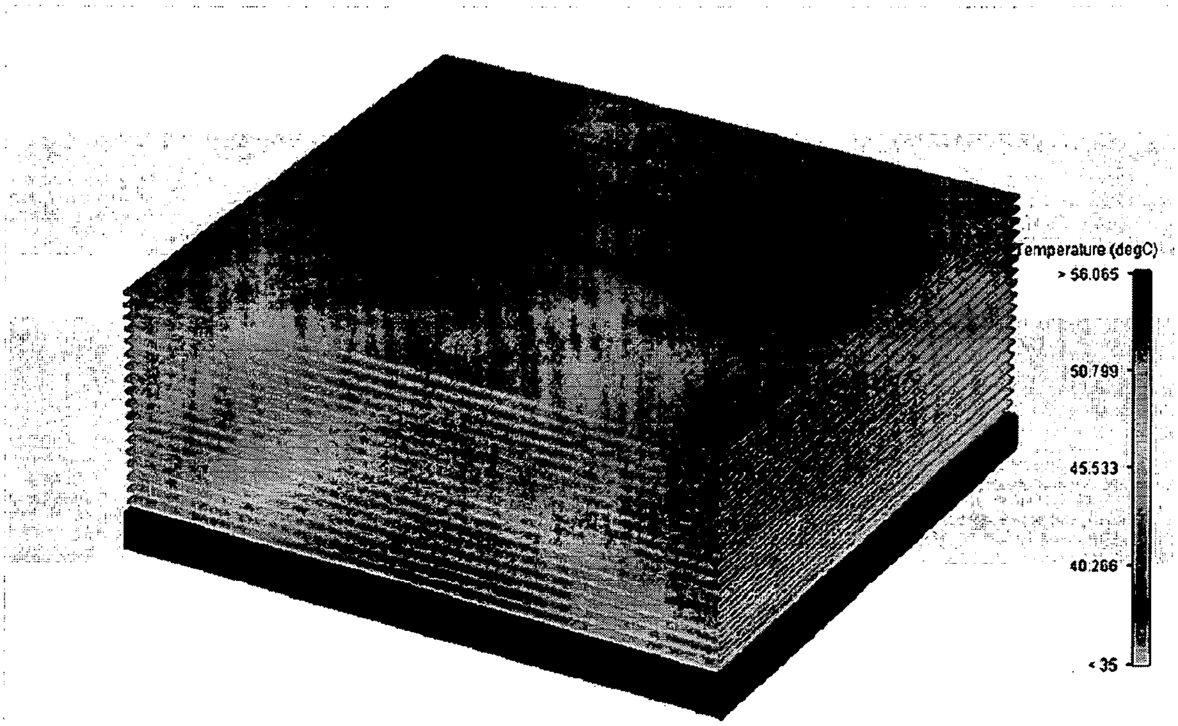

FIG. 4B

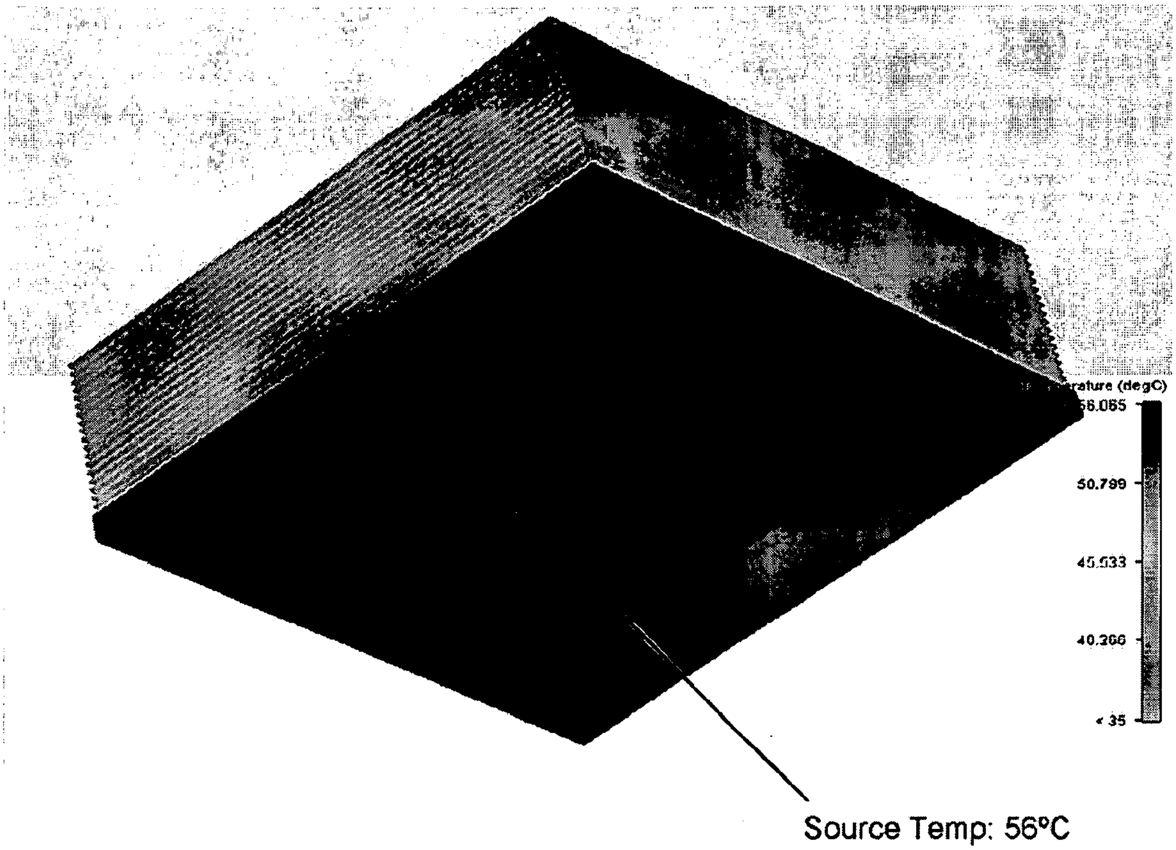

FIG. 4C

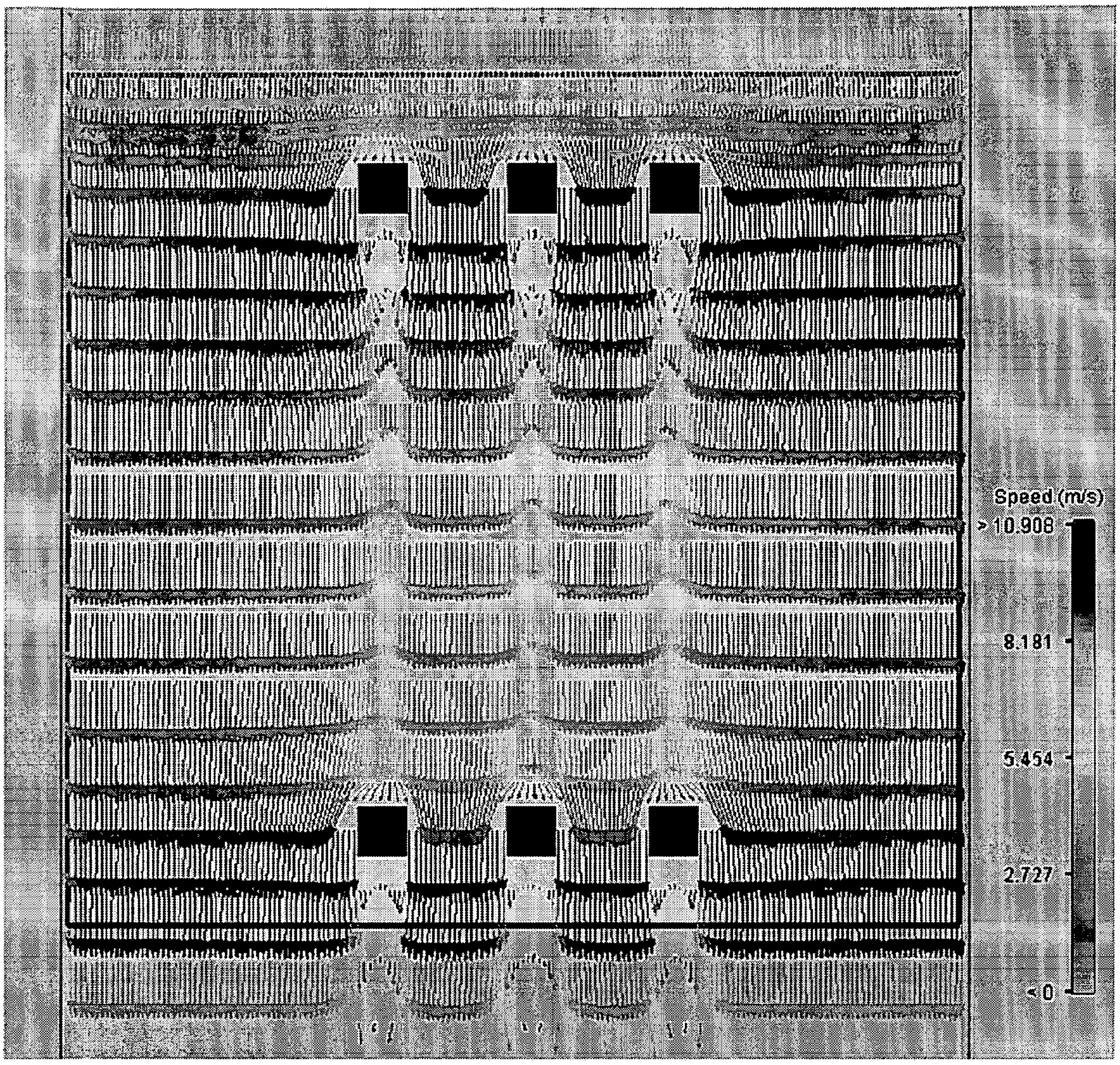

FIG. 5A

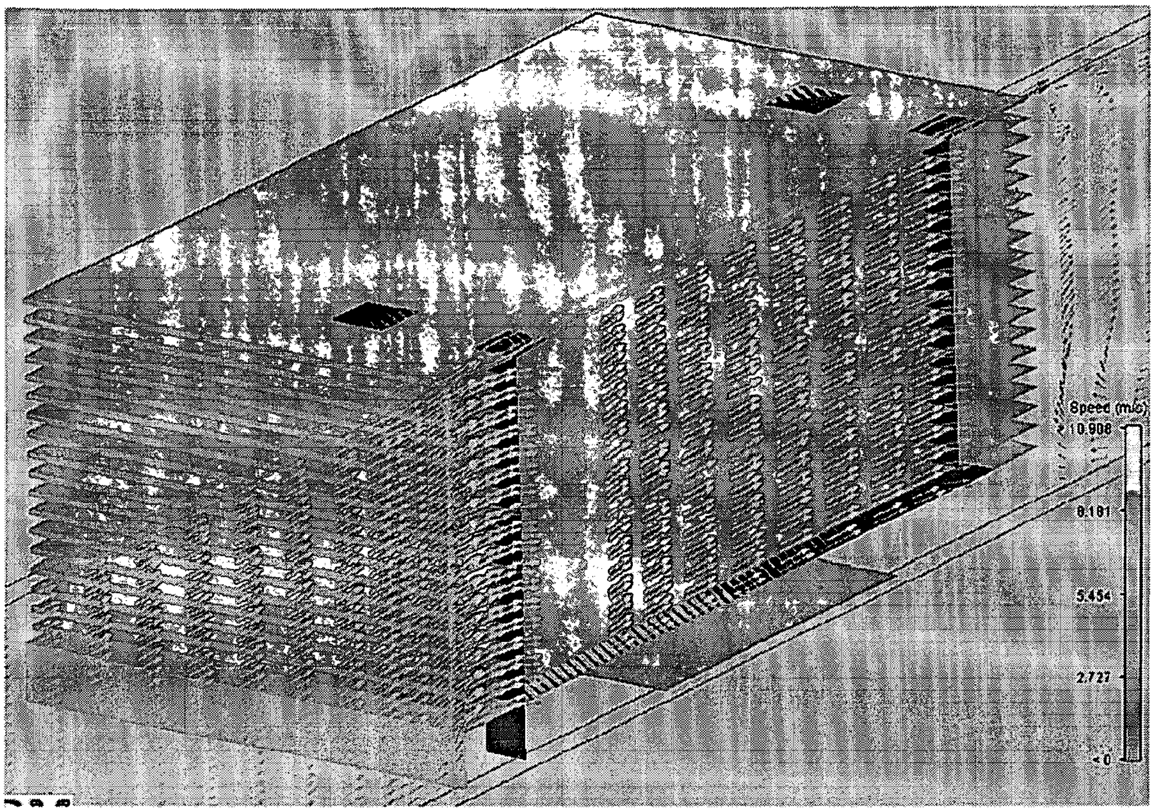

FIG. 5B

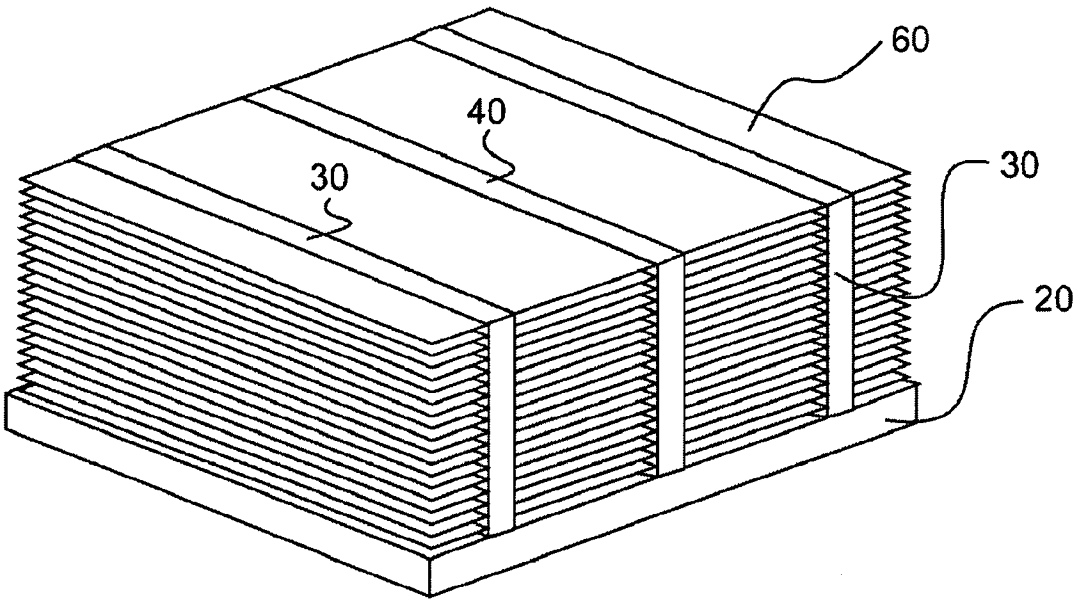

FIG. 6

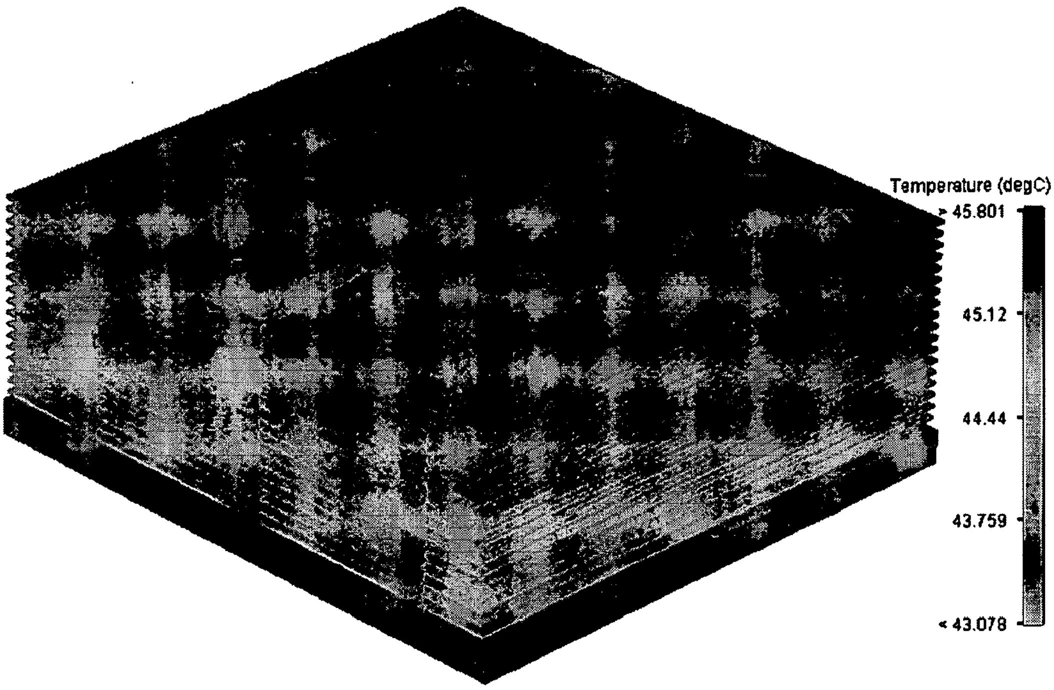

FIG. 7A

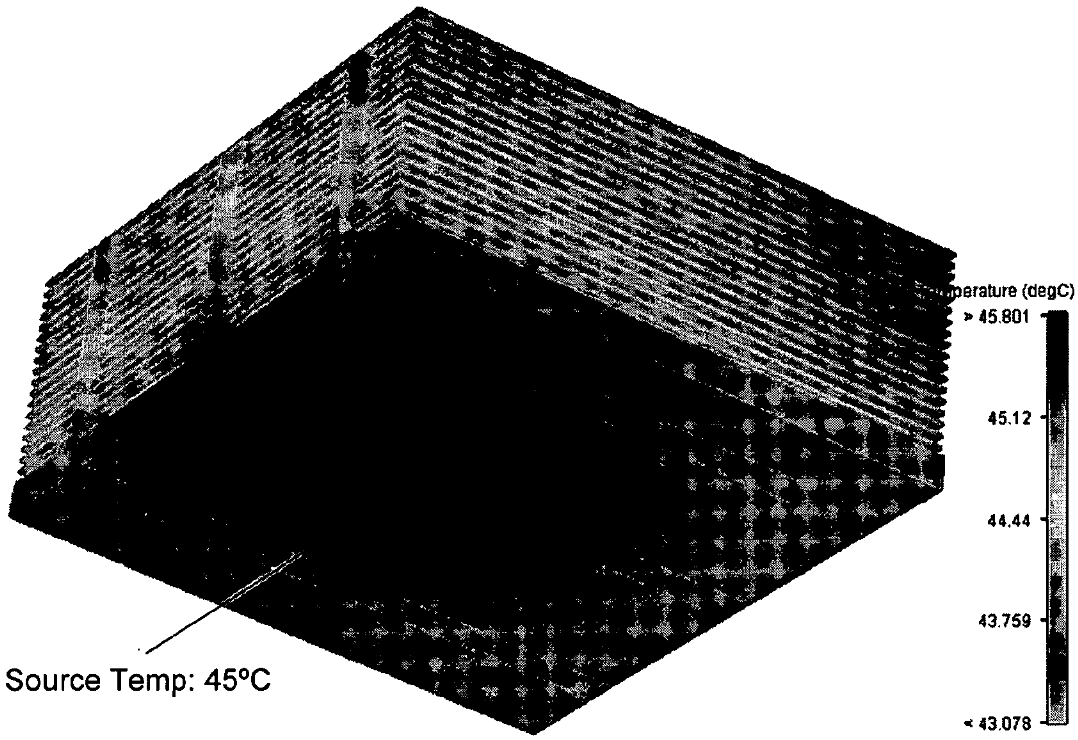

FIG. 7B

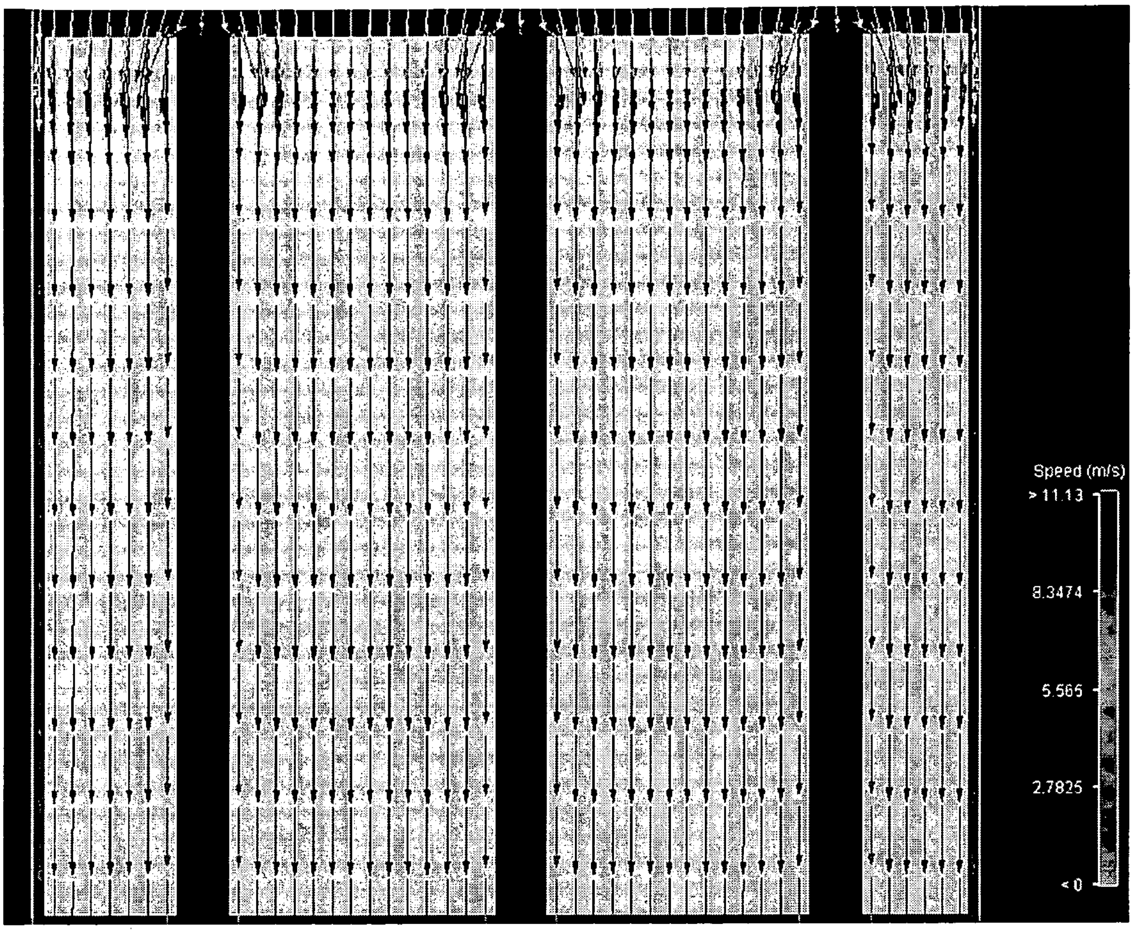

FIG. 8A

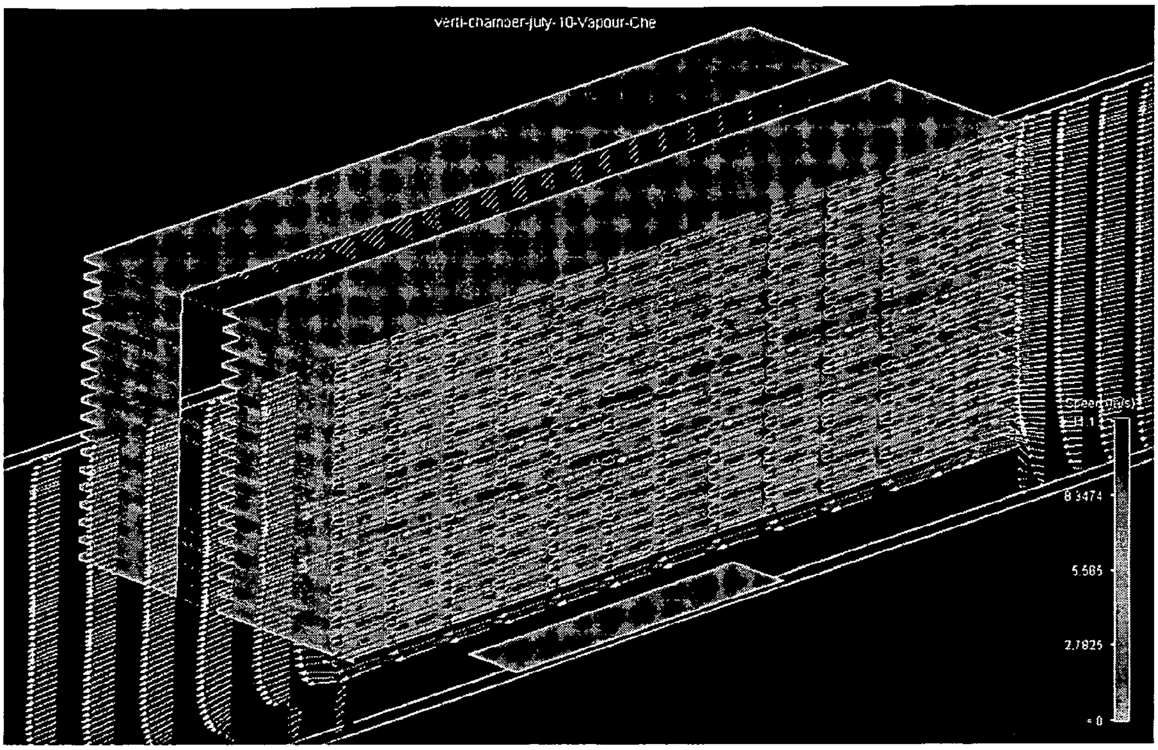

FIG. 8B

INTERNATIONAL SEARCH REPORT	International application No. **PCT/US2008/055126**

A. CLASSIFICATION OF SUBJECT MATTER

H05K 7/20(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 :H05K

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

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and applications for Utility models since 1975

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

eKIPASS(KIPO internal, Keyword: " heat, sink, vapor, chamber, fins, vertical, horizontal and the similar terms")

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7193851 B2(Yatskov) 20 March 2007 See abstract; Figs 2-4; column 3, line 52-column 4, line 13	1-20
A	US 7184269 B2(Campbell et al.) 27 February 2007 See abstract; Figs 7-9; column 11, line 22-column 12, line 46	1-20
A	US 6966361 B2(Connors) 22 November 2005 See abstract; Figs 1-3; column 2, line 53-column 5, line 20	1-20
A	US 6714413 B1(Ghosh et al.) 30 March 2004 See abstract; Figs 2, 6-8; column 4, line 63-column 5, line 10; column 8, line 3-column 11, line 11	1-20

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 OCTOBER 2008 (06.10.2008)	**06 OCTOBER 2008 (06.10.2008)**

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Authorized officer

KIM, Ki Wan

Telephone No. 82-42-481-5682

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2008/055126

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