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(71) Applicant: **HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.** [US/US]; 11445 Compaq Center Drive W., Houston, Texas 77070 (US).

(72) Inventor: **SUTHERLAND, Timothy J.**; 16399 W Bernardo Drive, San Diego, California 92127-1899 (US).

(74) Agent: **MAISAMI, Ceyda Azakli** et al.; HP Inc., Mail Stop 35 3390 E. Harmony Road, Fort Collins, Colorado 80528 (US).

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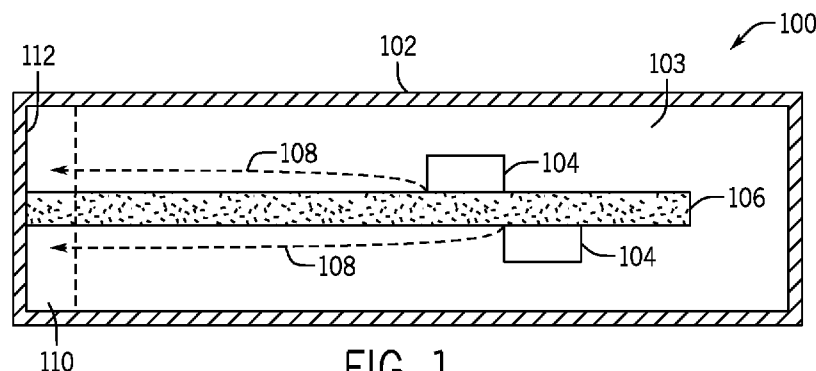


FIG. 1

(57) Abstract: In some examples, an electronic device includes a housing providing a sealed chamber, active electronic components in the sealed chamber, a liquid inside the sealed chamber, the liquid to vaporize into a vapor in response to heat from the active electronic components, a vapor conduit in the sealed chamber to carry the vapor to a cooling region in the sealed chamber, and a liquid path to carry the liquid from the cooling region to the active electronic components.



COOLING COMPONENTS IN AN ELECTRONIC DEVICE

Background

[0001] During operation of an electronic device, active electronic components in the electronic device can produce heat. An electronic device can include a cooling mechanism to cool the heat producing components. The cooling mechanism can include a passive cooling mechanism such as a heat sink that can be attached to a heat producing component. In some examples, the cooling mechanism can include an airflow generator, such as a fan, to generate cooling airflow to assist in cooling the active electronic components.

Brief Description Of The Drawings

[0002] Some implementations of the present disclosure are described with respect to the following figures.

[0003] Fig. 1 is a schematic diagram of an electronic device that provides cooling of components according to some examples.

[0004] Fig. 2 is a schematic diagram of an electronic device that provides cooling of components according to further examples.

[0005] Fig. 3 is a schematic diagram of an electronic device that provides cooling of components in a first portion of the electronic device, according to alternative examples.

[0006] Fig. 4 is a flow diagram of a process of forming an electronic device according to some examples.

Detailed Description

[0007] Examples of electronic devices include any of the following: a desktop computer, a notebook computer, a tablet computer, a smartphone, a game appliance, an electronic device in a vehicle, a wearable device (e.g., a smart watch,

smart eyeglasses, etc.), a server computer, a communication node, or any other type of electronic device.

[0008] An electronic device can include active electronic components. An “active electronic component” can refer to a chip, a circuit board, or any other integrated arrangement of electronic elements (such as transistors, diodes, etc.) that can be powered to perform a respective operation (or operations). An active electronic component can produce heat when in active operation. An active electronic component is an example of a “heat producing component”.

[0009] To dissipate heat from the active electronic components, a cooling mechanism can be included in the electronic device. In some examples, the cooling mechanism can include a heat pipe that contains a working fluid for carrying heat from an active electronic component to a cooling region of the electronic device. A heat pipe can be shaped in the form of a cylindrical tube that extends along a given length, such as from an active electronic component to a cooling region. In other examples, a heat pipe can have a different shape, such as a sheet-like shape.

[0010] An outer housing of the heat pipe defines a sealed inner chamber that includes a wick structure that lines the inner surface of the heat pipe outer housing, and a central bore that extends along the length of the heat pipe. The wick structure includes pores that collectively can form a liquid path that allows for a liquid form of the working fluid to move through the liquid path by a capillary action. The liquid is communicated through the liquid path of the wick structure to a region adjacent a heat producing component. The heat of the heat producing component causes the liquid in the wick structure to vaporize into a vapor. The vapor is then communicated through the bore of the heat pipe for communication back to the cooling region, where the vapor is condensed and the condensed liquid is returned by the wick structure to the heat producing component. The foregoing process allows the heat pipe to carry heat away from the heat producing component, so that the heat producing component can be cooled.

[0011] Generally, the outer housing of the heat pipe is formed of a thermally conductive material, such as copper, another metal, or a non-metallic thermally conductive material. The outer surface of the outer housing is thermally contacted to a surface (or multiple surfaces) of the active electronic component, either directly or through a thermally conductive layer, such as a heat sink, a thermal paste, and so forth.

[0012] In an electronic device that includes a number of active electronic components, a heat pipe, or an arrangement of heat pipes, may have to be routed through the inner chamber of the electronic device to the active electronic components. Having to route heat pipes to active electronic components can take up valuable space of the electronic device. Additionally, the presence of other cooling components, such as heat sinks, can also take up valuable space inside the electronic device, which can make it more difficult to reduce the overall size of the electronic device.

[0013] In accordance with some implementations of the present disclosure, as shown in Fig. 1, instead of using discrete cooling components such as discrete heat pipes or heat sinks inside an electronic device 100, the electronic device 100 can be formed with an outer housing 102 that is hermetically sealed to define a sealed inner chamber 103. The outer housing 102 can include a unitary housing structure, or an arrangement of multiple housing structures that are attached or connected to each other. The outer housing 102 can be formed of any rigid material, such as a plastic, a metal, and so forth.

[0014] A hermetically sealed outer housing refers to a housing that prevents gas or liquid from being communicated between an environment outside the outer housing and the inner chamber inside the outer housing.

[0015] A working fluid can be provided inside the sealed inner chamber 103 of the electronic device. The working fluid can include a thermodynamic fluid such as water (e.g., distilled water), alcohol, ammonia, or any other fluid that can exhibit conversion between liquid and vapor to effect heat transfer.

[0016] A capillary structure 106 is arranged in spaces among device components inside the electronic device 100, such that the capillary structure 106 is sandwiched between the device components. In the example of Fig. 1, the capillary structure 106 is thermally contacted to active electronic components 104. The capillary structure 106 can either be directly thermally contacted to the active electronic components 104, or indirectly thermally contacted to the active electronic components 104 through a thermally conductive layer. Although just two active electronic components 104 are shown in Fig. 1, it is noted that in other examples, additional heat producing components may be present in the inner chamber 103.

[0017] The capillary structure 106 includes pores that collectively form a liquid path through the capillary structure 106, where the liquid path can be used to carry a liquid form of the working fluid. The liquid is communicated through the liquid path of the capillary structure 106 by capillary action.

[0018] In some examples, the capillary structure 106 can include an open cell foam, which is a foam that includes cells that are open to one another, such that a liquid can flow from cell to cell of the foam. An open cell foam can be formed of a thermoplastic material, with micro cells. In other examples, the capillary structure 106 can be formed of any compressible material (which can be squeezed in between device components) that includes pores to allow for transport of a liquid by a capillary action.

[0019] In some examples, the capillary structure 106 can fill a vast majority of empty spaces inside the inner chamber 103 of the electronic device 100, where an empty space refers to a space where no device component or other structure is present. By filling the empty spaces with the capillary structure 106, multiple liquid paths can be provided to communicate the liquid form of the working fluid to heat producing components inside the inner chamber 103.

[0020] The liquid in the capillary structure 106 when heated by the active electronic components 104 is vaporized to form a vapor form of the working fluid. The vapor is transported by a vapor conduit 108 inside the inner chamber 103 of the

electronic device 100. In Fig. 1, multiple vapor conduits 108 are depicted to transport vapor from respective active electronic components 104 to a cooling region 110. A vapor conduit 108 can be formed of a collection of gaps among device components inside the inner chamber 103. The gaps that make up a vapor conduit 108 include voids where no device component, capillary structure 106, and other structure is present.

[0021] The vapor conduits 108 extend between the active electronic components 104 and the cooling region 110 of the electronic device 100. The cooling region 110 is a region inside the electronic device 100 that is away from heat producing components. The outer housing portion adjacent the cooling region 110 radiates heat away from the outer housing 102 to the environment outside the outer housing 102.

[0022] Although just one cooling region 110 is shown in Fig. 1, it is noted that in other examples, multiple cooling regions can be provided in the sealed inner chamber 103 of the electronic device 100, where vapor can be communicated along the vapor conduits 108 to such other cooling region(s).

[0023] By using the arrangement shown in Fig. 1, the entire electronic device 100 effectively becomes a heat pipe, where this heat pipe contains the heat producing components that are to be cooled (in contrast to arrangements in which an external surface of a heat pipe is thermally contacted to a heat producing component). The working fluid inside the outer housing 102 of the electronic device 100 evaporates from hot areas proximate surfaces of heat producing components such as the active electronic components 104, where the evaporation produces a vapor that is communicated to colder areas, such as the cooling region 110. The vapor condenses in the colder areas into a liquid that is then communicated back to the hotter areas through the capillary structure 106.

[0024] By using techniques or mechanisms according to some implementations of the present disclosure, discrete cooling components (e.g., such as discrete heat pipes, heat sinks, etc.) do not have to be specifically provided at target locations

proximate heat producing components. By making the entirety of the portion of the electronic device 100 that includes the heat producing components a heat pipe, heat is automatically carried from the hot areas (the areas corresponding to heat producing components) to the colder areas (the areas away from the heat producing components).

[0025] Because the active electronic components 104 are exposed to a liquid inside the electronic device 100, the active electronic components 104 (as well as any other device components that is sensitive to the presence of liquids) can be coated with a protective layer to protect the device components from damage due to exposure of the device components to the liquid. For example, the active electronic components 104 can each be coated with a liquid repellant nano coating. The nano coating can be an ultrathin polymer layer applied onto the outer surface of the active electronic component 104. In other examples, other types of liquid repellant protective layers can be applied to coat active electronic components 104 to protect the active electronic components 104 from the working fluid inside the sealed inner chamber 103.

[0026] Fig. 2 is a sectional view of an electronic device 200 according to further examples. The electronic device 200 includes an outer housing 202 that is a hermetically sealed to define a sealed inner chamber 203. In the example of Fig. 2, a circuit board 204 is provided inside the inner chamber 203. Active electronic components can be mounted to surfaces of the circuit board 204, including a processor 206 mounted to a first surface of the circuit board 204, and a memory device 208 mounted to a second surface of the circuit board 204.

[0027] Another device component that is part of the electronic device 200 is a display panel 210 that can be used to display an image. In the example of Fig. 2, the display panel 210 in combination with the outer housing 202 form the sealed inner chamber 203.

[0028] In addition, a battery 212 is also located in the inner chamber 206, where the battery 212 provides power to various active electronic components of the

electronic device 200. It is noted that there can be additional device components arranged in the inner chamber 203 of the outer housing 202, where such additional device components can include active electronic components as well as passive components such as support structures and so forth.

[0029] Capillary structures 214 are provided in spaces between device components inside the inner chamber 203. Each capillary structure 214 includes a liquid path to allow for a liquid form of a working fluid inside the inner chamber 203 to be communicated to the heat producing components (e.g., the processor 206 and the memory device 208) that are to be cooled. Note that the working fluid in the inner chamber 203 can also be used to cool the display panel 210 and the battery 212.

[0030] Vapor conduits 216 are also provided in the inner chamber 203. The vapor conduits 216 are made up of gaps between device components where the capillary structure 214 is not provided. Each vapor conduit 216 transports a vapor produced by evaporation of the liquid carried by the capillary structures 214 to cooling regions 218. In the cooling regions 218, the vapor is condensed into a condensed liquid, which is then transported by the capillary structures 214 along liquid paths to the heat producing components that are to be cooled.

[0031] In examples according to Fig. 1 or Fig. 2, the entirety of the electronic device 100 or 200 makes up a heat pipe. In other examples, just a portion of an electronic device can form the heat pipe, where this portion is the portion that includes heat producing components to be cooled. For example, as shown in Fig. 3, an electronic device 300 includes an outer housing 302 that defines a sealed first inner chamber 303. Active electronic components 304 are located in the first inner chamber 303.

[0032] A second inner chamber 305 of the electronic device 300 can include other types of components that do not produce heat or produces just a small amount of heat during operation. A barrier 306 divides the sealed first inner chamber 303 from the second inner chamber 305. A working fluid is provided in the sealed first

inner chamber 303 to cool heat producing components, but a working fluid is not provided in the second inner chamber 305.

[0033] A capillary structure 308 is provided in the sealed first inner chamber 303 to carry a liquid form of the working fluid to the active electronic components 304. The liquid is vaporized by heat produced by the active electronic components 304, to produce a vapor that is transported through vapor conduits 310 back to cooling regions 314.

[0034] Fig. 4 is a flow diagram of a process of forming an electronic device, according to some examples. The process includes hermetically sealing (at 402) an outer housing to define a sealed inner chamber containing a working fluid. The process further includes arranging (at 404) active electronic components in the sealed inner chamber. The process further includes thermally contacting (at 406) a capillary structure to the active electronic components, the capillary structure comprising a liquid path to carry a liquid form of the working fluid to the active electronic components. The process further includes arranging (at 408) a vapor conduit in the sealed inner chamber to carry, to a cooling region in the sealed inner chamber, a vapor generated by vaporizing the liquid form of the working fluid by heat from the active electronic components.

[0035] In some examples, the sealed chamber is partially evacuated prior to hermetically sealing the outer housing. Partially evacuating the inner chamber refers to partially removing any gas or liquid from the inner chamber. A working fluid is introduced into the inner chamber of the electronic device. Note that the working fluid partially fills the inner chamber.

[0036] In the foregoing description, numerous details are set forth to provide an understanding of the subject disclosed herein. However, implementations may be practiced without some of these details. Other implementations may include modifications and variations from the details discussed above. It is intended that the appended claims cover such modifications and variations.

What is claimed is:

- 1 1. An electronic device comprising:
2 a housing providing a sealed chamber;
3 active electronic components in the sealed chamber;
4 a liquid inside the sealed chamber, the liquid to vaporize into a vapor in
5 response to heat from the active electronic components;
6 a vapor conduit in the sealed chamber to carry the vapor to a cooling region in
7 the sealed chamber; and
8 a liquid path to carry the liquid from the cooling region to the active electronic
9 components.
- 1 2. The electronic device of claim 1, wherein the housing is an outer housing of
2 the electronic device, and wherein the outer housing, the vapor conduit, and the
3 liquid path form a heat pipe that contains the active electronic components.
- 1 3. The electronic device of claim 1, further comprising a capillary structure
2 comprising pores that collectively form the liquid path, the capillary structure
3 sandwiched between device components inside the housing.
- 1 4. The electronic device of claim 3, wherein the capillary structure comprises an
2 open cell foam.
- 1 5. The electronic device of claim 3, wherein the active electronic components
2 are coated with a liquid repellant layer.
- 1 6. The electronic device of claim 3, wherein the vapor conduit comprises a
2 collection of gaps between the device components, wherein the capillary structure is
3 not present in the gaps.

1 7. The electronic device of claim 1, wherein the active electronic components
2 comprise a processor and a memory device.

1 8. The electronic device of claim 1, wherein the housing is hermetically sealed to
2 provide the sealed chamber.

1 9. An electronic device comprising:
2 a housing defining a sealed inner chamber;
3 a working fluid in the sealed inner chamber;
4 heat producing components in the sealed inner chamber;
5 a capillary structure in the sealed inner chamber and in contact with the heat
6 producing components, the capillary structure comprising a liquid path through which
7 a liquid form of the working fluid is able to flow; and
8 a vapor conduit in the sealed inner chamber and extending from the heat
9 producing components to a cooling region, the vapor conduit to carry a vapor
10 generated by vaporization of the liquid form of the working fluid by the heat
11 producing components to the cooling region to condense the vapor into a condensed
12 liquid, and the capillary structure to carry the condensed liquid through the liquid path
13 to the heat producing components.

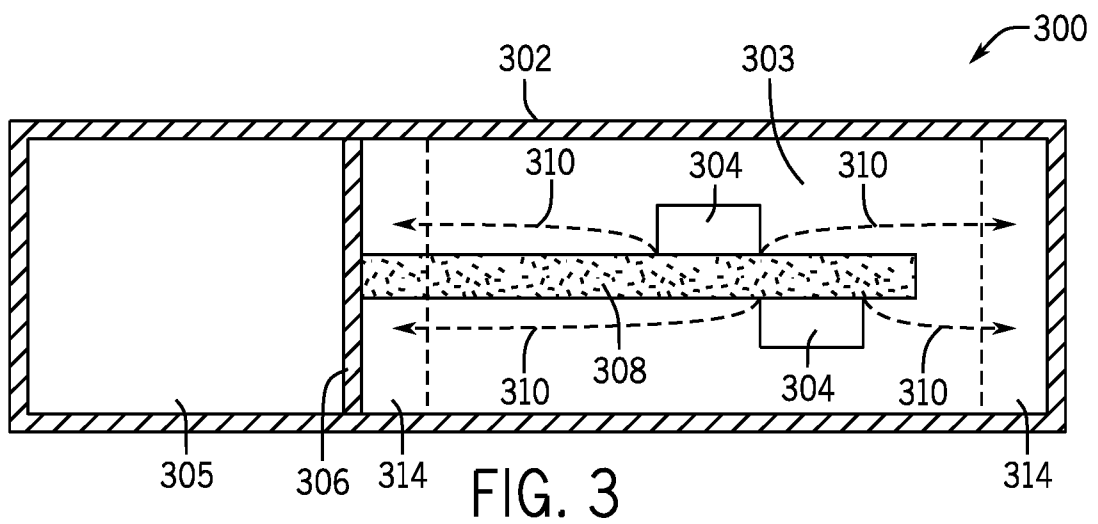
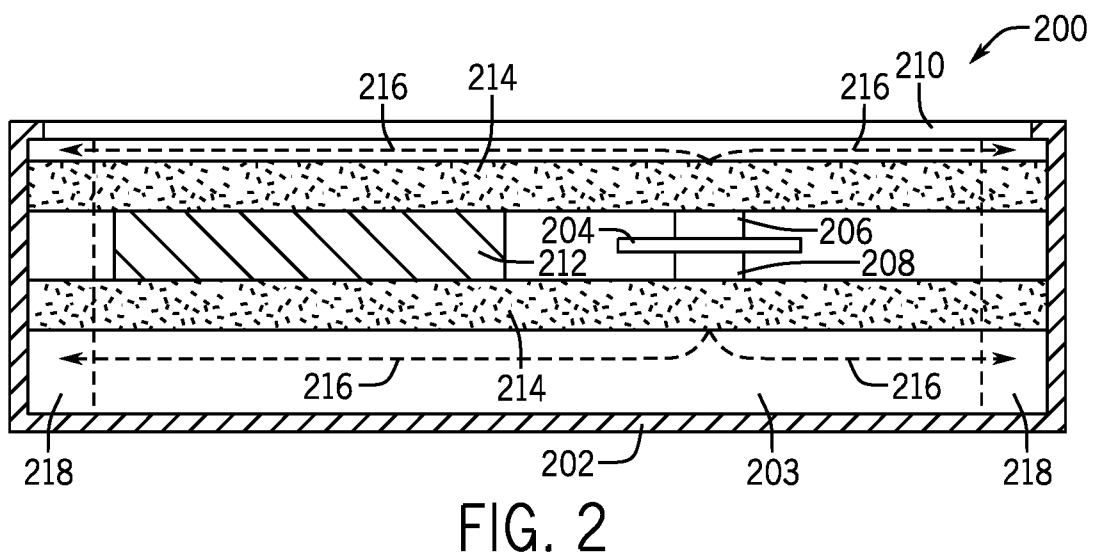
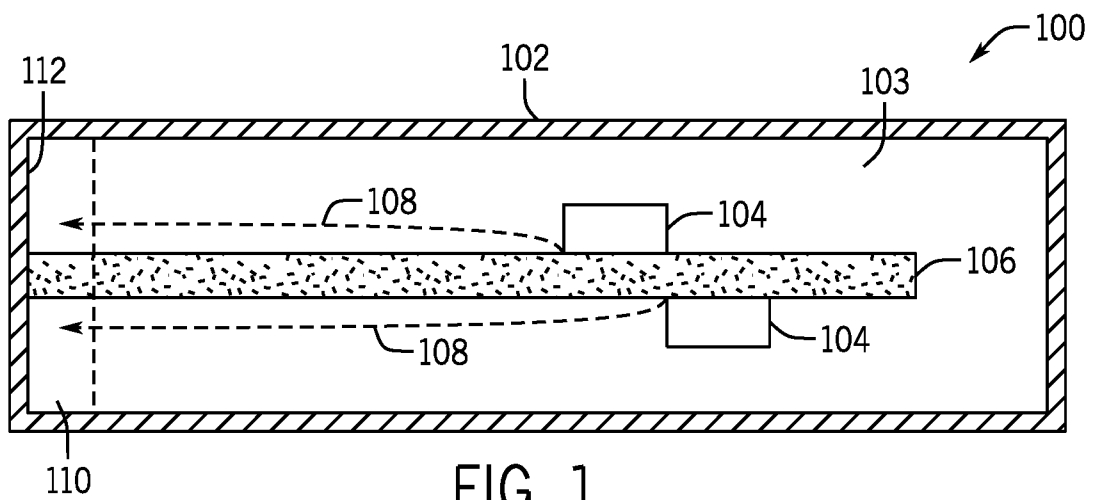
1 10. The electronic device of claim 9, further comprising:
2 device components, wherein the capillary structure is arranged in spaces
3 between the device components and the heat producing components, and in spaces
4 between the housing and the heat producing components.

1 11. The electronic device of claim 10, wherein the device components comprise a
2 display panel and a battery.

1 12. The electronic device of claim 10, wherein gaps between the device
2 components, the active components, and the capillary structure form the vapor
3 conduit.

- 1 13. A method of forming an electronic device, comprising:
2 hermetically sealing an outer housing to define a sealed inner chamber
3 containing a working fluid;
4 arranging active electronic components in the sealed inner chamber;
5 thermally contacting a capillary structure to the active electronic components,
6 the capillary structure comprising a liquid path to carry a liquid form of the working
7 fluid to the active electronic components; and
8 arranging a vapor conduit in the sealed inner chamber to carry, to a cooling
9 region in the sealed inner chamber, a vapor generated by vaporizing the liquid form
10 of the working fluid by heat from the active electronic components.
- 1 14. The method of claim 13, further comprising partially evacuating the sealed
2 chamber prior to hermetically sealing the outer housing.
- 1 15. The method of claim 13, wherein the capillary structure comprises pores that
2 collectively provide the liquid path to transport the liquid form of the working fluid by a
3 capillary action.

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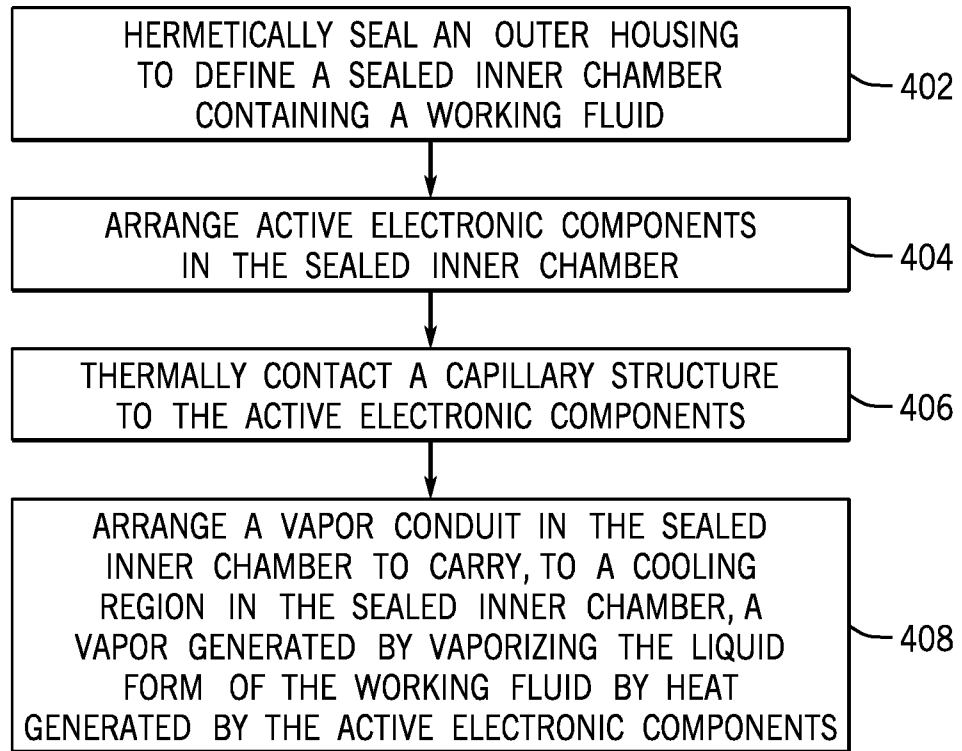


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2016/039868

A. CLASSIFICATION OF SUBJECT MATTER		
G12B 15/04 (2006.01) H05K7/20 (2006.01) G06F 1/20 (2006.01)		
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)		
G12B 15/00, 15/04, H05K 7/00, 7/20, G06F 1/00, 1/20, H01L 23/00, 23/34, 23/44, F28D 15/00, F25D 23/00, 23/12		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RU 2066518 C1 (INSTITUT TEPILOFIZIKI SO RAN), 10.09.1996, fig. 1, 2,	1-2, 7-8
Y	c. 3, col. 1, lines 1-6, col. 2, lines 24-50	3-6, 9-15
Y	SU 1751830 A1 (IVANOVSKI ENERGETICHESKI INSTITUT) 30.07.1992, fig. 1, col. 4, lines 1-31	3-6, 9-15
Y	SU 1734250 A1 (TEPMAN I.A.) 15.05.1992, fig. 1, col. 3, lines 16-25	14
Y	US 5642776 A (THERMACORE, INC.) 01.07.1997, fig. 1, col. 3, lines 33-54	4
Y	US 6176098 B1 (MITSUBISHI DENKI KABUSHIKI KAISHA) 23.01.2001, fig. 1-3, col. 3, lines 42-67, col. 4, lines 1-23	5, 12
Y	EA 007175 B1 (SHIN ELENA ILINICHNA) 24.02.2006, fig. 2, claims	11
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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Date of the actual completion of the international search	Date of mailing of the international search report	
07 April 2017 (07.04.2017)	20 April 2017 (20.04.2017)	
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer O. Gudkova Telephone No. 84992402591	