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(54) **A vapor-based heat transfer apparatus**

(57) A vapor-based heat transfer apparatus (100) comprising a hollow structure and a working liquid (116) within the hollow structure, wherein the structure is made of a thermally conductive polymer. In some embodiments the apparatus (100) comprises a vapor chamber (110). In some other embodiments, the apparatus comprises a vapor chamber (110), heat pipe and a heat sink (120).

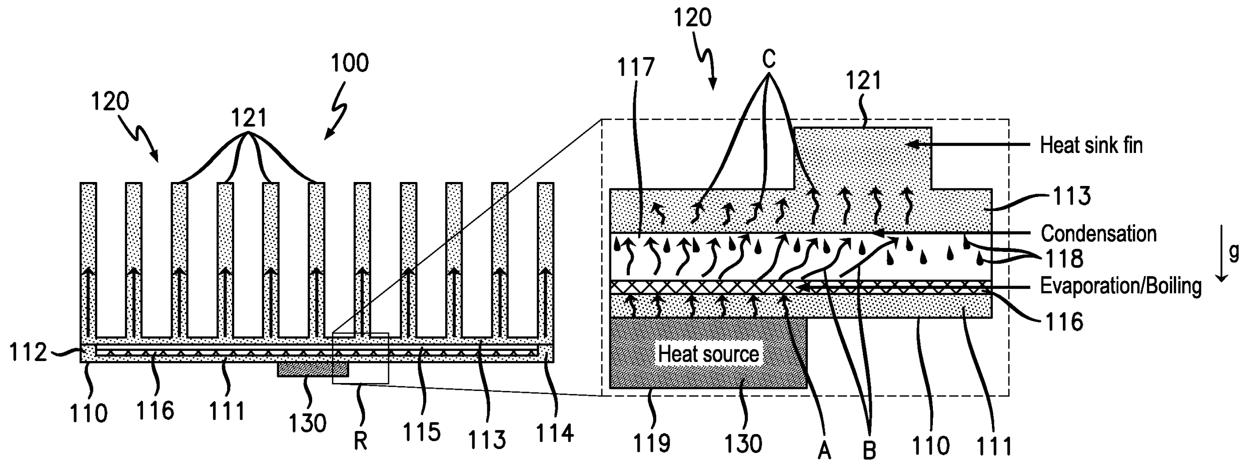

FIG. 1A *FIG. 1B*

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Description

BACKGROUND ART

[0001] Vapor chambers and heat sinks are used in structures employed for cooling electronically operated devices. Typically a vapor chamber is a closed structure having an empty space inside within which a liquid is provided. Vapor chambers are typically passive, two-phase (liquid-vapor) heat transport loops that are used to spread heat from relatively small, high heat-flux sources to a region of larger area where the heat can be transferred elsewhere at a significantly lower heat-flux. Heat sinks are widely known in the related art. In a typical heat sink in operation, heat is conducted from the base of the heat sink to an array of extended surfaces (so-called fins) where it is ultimately transferred to the surrounding air.

SUMMARY

[0002] In a typical vapor chamber heat is conducted from a heat source to a heat sink through an evacuated chamber containing a working fluid such that the internal pressure of the chamber is at the saturated vapor pressure of the working fluid. In operation, the working fluid evaporates or boils as a consequence of receiving heat from the heat source and then re-condenses on the colder (typically upper) regions of the chamber at a nearly identical temperature (*i.e.* the corresponding saturation temperature). The condensate liquid is caused to flow back, often assisted by gravity, in proximity of the heat source inside the chamber. Typically a wicking structure is incorporated into the evaporator (vapor-generating) side of the vapor chamber which may serve to enhance the liquid flow back to the heat source for re-evaporation. The net effect is efficient heat transport from the evaporator section of the vapor chamber to the condenser section of the vapor chamber; this is due to the convective transport of the vapor, and results in a very large effective vapor chamber thermal conductivity, often 10 to 100 times that of copper.

[0003] Typically the low heat flux side of vapor chambers are coupled to a heat sink in order to more effectively reject the heat to a surrounding fluid medium (usually air) via convection (either natural or forced).

[0004] As it is known, electronic components are experiencing continued increase in device density which in turn typically gives rise to an increase in heat generation within the equipment they are used. This increase in heat generation requires more efficient cooling systems.

[0005] One way vapor chambers and heat sink effectiveness may be increased is by making the devices larger in size which may have the effect of both lowering the heat sink thermal resistance and serve to increase the surface area for conduction or convection at the free surfaces. However this may result in larger and heavier devices causing a significant drawback. Another approach may be to use a higher conductivity metal (*e.g.* copper, gold or silver), however typically, higher-conductivity materials correspond to both higher density (increased weight) and greater cost.

[0006] It is therefore desired to provide a vapor-based heat transfer apparatus which while present improved effectiveness (*i.e.* have a lower thermal resistance) have, as much as possible, a light weight.

[0007] The vapor-based heat transfer apparatus may be a vapor chamber or a vapor chamber heat sink, or a heat pipe.

[0008] Some embodiments of the present disclosure relate to a vapor-based heat transfer apparatus using a thermally conductive polymer as the solid enclosure thereof. The inventors have realized that the heat spreading and corresponding high thermal effectiveness of these devices are primarily due to the vaporization and condensation of the working fluid occurring internally. Therefore, the thermal conductivity of the outer enclosure may play a relatively minor role on the overall system performance. Furthermore, by using a relatively thin and thermally conductive polymer, good thermal performance can still be achieved while minimizing weight (*e.g.* as opposed to using metals).

[0009] Herein, a thermally conductive polymer is to be understood as a polymer matrix loaded with conductive particle filler materials in order to improve the overall bulk thermal conductivity of the base polymer. Examples of such thermally conductive polymers include but are not limited to polymers such as liquid crystaline polymers (LCP), polyamides, polycarbonate, polypropolene, polyphthalamide, polyphenylene Sulfides or thermoplastic elastomers. Filler particles may include, but are not limited to, a range of metal or ceramic particles such as aluminium oxide, boron nitride, silver or variations of carbon-based graphite or graphene particles. It is to be noted that within the context of the present disclosure, the term "particle" may - in addition to its common meaning relating to small pieces, bodies or the like - be understood to encompass fibers. Accordingly, some embodiments of the disclosure feature a vapor-based heat transfer apparatus comprising a hollow structure and a working liquid within the hollow structure, wherein the structure is made of a thermally conductive polymer.

[0010] According to some specific embodiments the apparatus comprises a vapor chamber.

[0011] According to some specific embodiments, the apparatus comprises a vapor chamber and a heat sink such that the at least a portion of the heat sink comprises a conductive polymer material.

[0012] These and further features and advantages of the present invention are described in more detail, for the purpose of illustration and not limitation, in the following description as well as in the claims with the aid of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Figures 1a and 1b are exemplary schematic representations of a vapor chamber according to some embodiments of the disclosure wherein the vapor chamber is shown assembled to a heat sink and heat source.

Figures 2a and 2b are exemplary schematic representations of a vapor chamber and heat sink according to some embodiments of the disclosure wherein the vapor chamber is shown assembled to a heat source.

Figure 3 is an exemplary schematic representation another embodiment of the disclosure wherein the vapor chamber is shown assembled to a heat source.

Figures 4a, 4b and 4c are exemplary schematic representations of a portion of a vapor chamber heat sink according to some embodiments of the disclosure wherein the vapor chamber is shown assembled to a heat source.

Figures 5a and 5b are exemplary schematic representations of another embodiment of the disclosure wherein the vapor chamber is shown assembled to a heat source.

Figure 6 is an exemplary schematic representation of another embodiment of the disclosure wherein the vapor chamber is shown assembled to a heat source.

Figures 7a and 7b are exemplary schematic representations of another embodiment of the disclosure wherein the vapor chamber is shown assembled to a heat source.

DETAILED DESCRIPTION

[0014] In the following, examples of embodiments are provided related to vapor chambers and/or vapor chamber and heat sinks. This however is only exemplary. Indeed, those skilled in the art will realize that embodiments of the invention are not limited to only vapor chambers or vapor chambers and heat sinks and that other vapor-based heat transfer apparatus such as for example polymer heat pipes may also be considered within the scope of the present disclosure. Referring to figures1a and 1b exemplary schematic representations of a vapor chamber according to some embodiments of the disclosure are provided where the vapor chamber is shown assembled together with a heat sink. The assembly 100 of figure 1a comprises a vapor chamber 110 and a heat sink 120. The vapor chamber 110 comprises a structure comprising walls 111, 112, 113 and 114 (111-114). The walls 111-114 define an enclosed space 115 which is hollow. Inside the hollow space 115 a working liquid 116 is provided. The working liquid may be for example water, acetone, methanol, ammonia or any number of refrigerants or liquid salts or liquid metals, depending on desired operating characteristics.

[0015] According to the embodiments of the disclosure, the vapor chamber 110 is made of thermally conductive polymer.

[0016] The heat sink 120 comprises an array of extending bodies, or fins, 121 which serve for transporting heat away from the vapor chamber and dissipating the heat in the surrounding ambient, which may be air.

[0017] In the illustrative example of figures 1a and 1b the vapor chamber is further shown to be in assembled position over a heat source 130 (an electronic device which in operation generates heat and which is intended to be cooled off). Figure 1b illustrates in further detail, a portion - represented by reference R - of the assembly of figure 1a in heat transferring operation. In figure 1b, like elements have been given like reference numerals as those of figure 1a. Referring to figure 1b, the heat source 130 is shown in thermal contact with the vapor chamber 110. In operation, heat is transferred from the heat source 130 to the vapor chamber 110 through the wall 111 of the vapor chamber as schematically shown by arrows A.

[0018] The heat received by the vapor chamber 110 causes the liquid 116 inside the vapor chamber to evaporate and the vapor may then move toward another (*e.g.* upper) wall 113 of the vapor chamber 110 as schematically shown by arrows B. Upon arrival at the wall 130, the vapor condenses on the surface 117 of the wall 113 and is converted back to liquid. Heat is thereby transferred from the wall 113 of the vapor chamber to the heat sink120 as shown by arrows C which in turn is dissipated to the ambient using fins 121. After condensation, the liquid returns back to the side adjacent to the heat source 130 in order to undergo another evaporation-condensation cycle as described above.

[0019] As the material of the vapor chamber is made of a thermally conductive polymer, heat is effectively and satisfactorily transferred from the heat source to the vapor chamber and also from the vapor chamber to the heat sink. In this manner, the thermal effectiveness of the devices is ensured by the vaporization and condensation of the working fluid occurring inside the vapor chamber while the weight of the device is maintained low as compared to known solutions where metal is typically used.

[0020] Furthermore, by using a relatively thin thermally conductive polymer, a good thermal performance may be achieved while weight is still further minimized. Another significant advantage of the solution proposed herein over the known solutions is the possibility of constructing the vapor chamber or extended vapor chamber heat sink (as will be described further below) using an injection molded high-conductivity plastic. It is to be noted that the use of plastics in conventional-design vapor chambers or vapor chamber and heat sinks is generally considered as an option that would significantly undermine the performance of the resulting device (due to the relatively low thermal conductivity of even the optimum conductive plastics). Therefore, it may be possible that a person skilled in the related art, following a typically predominant general opinion would discard the use of plastics for such constructions. In contrast, in the present disclosure the contribution of the solid phase thermal conductivity has little effect on the thermal performance of the vapor chamber or the vapor chamber and heat sink as a whole due to the highly effective heat transport of the vapor chamber region. Although the level of heat transfer may vary from low heat flux regions (e.g., the condenser section) to high heat flux regions (e.g., near the heat source), it may be possible to select design parameters and materials such that the overall heat transfer response of the device meets the specific requirements of a particular application.

[0021] In this regard it may be said that in low heat transfer regions a reasonably thermally conductive polymer material may be suitable for heat transfer, as the thermal resistance across such a material would not generate too large of a temperature drop due to the low heat flux. On the other hand, in the high heat flux regions, the use of some metal may be appropriate to contribute to improving the heat transfer.

[0022] Therefore, estimation may be made to determine what a reasonable range of polymer thermal conductivities would be for the device to provide a desired heat transfer response. For example, in a device with a condenser area being 20 times that of the evaporator area, a thermally conductive polymer that presents a thermal conductivity of 1/20 of that of a metal (e.g. copper) would have a similar temperature drop across both the evaporator and condenser walls.

[0023] The vapor chamber may preferably comprise a wick structure 119 to enhance liquid flow to the vicinity of the heat source 130 and may contribute to further assisting the evaporation and boiling of the liquid.

[0024] Figures 2a and 2b are exemplary schematic representations of a vapor chamber heat sink according to some embodiments of the disclosure. In the example of figures 2a and 2b, like elements have been given like reference numeral as those of figures 1a and 1b. Here also, figure 2b shows in further detail a portion R of the assembly of figure 2a.

[0025] The structure and the mode of operation of the assembly shown in figures 2a and 2b are in many aspects similar to those of the example of figures 1a and 1b, with a difference that in the example of figures 2a and 2b, the vapor chamber 110 is integrated into the base 120a of the heat sink 120. As shown in figures 2a and 2b, the fins 121 of the heat sink 120 are hollow thereby providing additional internal space 115a for the vapor and therefore additional surface for liquid condensation thereby improving heat transfer. This option therefore has the advantage of allowing for an enhanced spreading of the heat, which may include the body of the vapor chamber 110 (similar to the example of figures 1a and 1b) as well as the entire domain of extended surfaces of the fins 121 of the heat sink 120.

[0026] Therefore while the working fluid is evaporated at vicinity of the heat source 130, the working fluid 116 is allowed to re-condense the full (or any available) length and height of each fin (or pin or any other extended surface used for heat dissipation). Furthermore, this approach allows for effectively removing or at least reducing the contribution of fin thermal resistance (which can be considerable) to the total resistance of the heat sink and making the entire heat sink a contiguous vapor chamber.

[0027] As this solution effectively creates a hollow heat sink, the entire inner core of the overall structure becomes a single vapor chamber capable of operating at a near isothermal condition due to the evaporation and subsequent condensation of the working fluid from hot regions to cold regions in the chamber. This effect would improve considerably the heat spreading not only through the base of the heat sink but also into the fins thereby dramatically increasing the overall effectiveness of the heat sink while significantly reducing its weight (as compared to known solutions).

[0028] From the standpoint of thermal effectiveness, the inner walls of this vapor chamber or vapor chamber heat sink may be made thin, for example less than about 1 mm, to limit their possible contribution to the thermal resistance of the device and to allow adequate internal space for the condensate to flow.

[0029] It is to be noted that the solution according to the embodiments of figures 2a and 2b is in some aspects contrary to a conventional conduction heat sink (or indeed a conventional vapor chamber heat sink) where in such conventional solutions an incentive lies in providing thicker fins in order to reduce contribution of fin thermal resistance.

[0030] Similar to what was mentioned in relation to the embodiment of figures 1a and 1b, this embodiment may also allow for the construction of the vapor chamber and the vapor chamber and heat sink using an injection molded high-conductivity plastic and thus encompasses similar advantages. The embodiment of figures 2a and 2b also allows for a number of unique construction options and embodiments which are described in the following.

[0031] The use of an injection molded plastic to create a vapor chambers or extended vapor chamber heat sink would allow for the construction of thin walls that would otherwise be impossible or at least very difficult to form by other high-volume processes such as metal casting or extrusion. Additionally, injection molding may allow for at least certain parts of the complex extended vapor chamber side of the heat sink to be created as one piece thereby decreasing the otherwise more intensive construction process of conventional vapor chamber heat sinks. For example the extended fins and the top portion of the vapor chamber may be made in one piece. The base of the vapor chamber adjacent to the heat source may be another piece and the two pieces may then be easily bonded together. Depending on the type of the thermally conductive polymer employed in the construction of the chamber, small amounts of working fluid may be absorbed into the polymer material. Similarly, under the low pressure conditions the chemical interactions within the polymer could result in out-gassing of noncondensable gasses that may inhibit or degrade the performance of the device. Both of these phenomena may be overcome by employing a layered construction approach as shown in the embodiment of figure 3.

[0032] Figure 3 is in many aspects of structure and operation similar to figure 2b in both of which only a portion R of the assembly of the vapor chamber, heat sink and the heat source is shown. In figure 3 like elements have been given like reference numerals as those of figure 2b. However, figure 3 further illustrates the presence of a layer 140 which is intended to block the absorption of the fluid as well as the out-gassing of the gasses as described above. According to the embodiment of figure 3, the overall polymer enclosure or at least a part thereof, including the inner walls of the vapor chamber 110 and those of the fins 121, is lined with a thin hermetic layer 140 adapted to act as an impermeable barrier to mass transport to or from the polymer enclosure. This layer may be applied through electroplating or chemical vapor deposition or other known techniques.

[0033] As an alternative solution for providing such blocking effect, use may be made of pure polymer or epoxy layer on either the outside or inside of the vapor chamber to improve its hermeticity.

[0034] In some of the embodiment where the fins of the heat sink also act as condensation walls (*e.g.* figures 2a, 2b), vapor may condense on the fins' inner walls. During the condensation process, liquid droplets may be formed on said inner walls that could potentially bridge the gap between the inner walls in this region and could result in an accumulation of liquid in this space. This situation is schematically illustrated in figure 4a. In figures 4a, 4b and 4c a portion of a fin 121 is shown where the fin 121 has a hollow inner space 115a in accordance with the embodiments described with reference to figures 2a-2b and 3. The fin 121 has walls 122 and 123. As shown in figure 4a, liquid bridges 124 are formed between the inner surfaces of the walls 122 and 123. Such accumulation of droplets may be undesirable as it may block the passage of vapor to other regions of the fins or the return of the liquid back to the liquid base adjacent to the heat source (not shown) or it may increase thermal resistance within the fins 121. To overcome this situation, use may be made of known surface treatments which provide a certain level of hydrophobicity to the regions concerned thereby promoting the flow of liquid droplets from the surface and minimizing the thermal resistance associated with a condensation film on the inner surface of the walls 122, 123. By using such surface treatment, the droplets would not accumulate on the inner surfaces of the walls and may leave such surfaces before an accumulation is produced as shown in figure 4b. Alternatively, depending on the specific design requirements, a hydrophilic surface may be used thereby causing the droplets to adhere along a relatively extended inner surface of the walls 122 and 123, thereby limiting their propensity to form liquid bridges on the opposite wall as illustrated in figure 4c. An example of a hydrophobic material is teflon and one for a hydrophilic material is glass.

[0035] Briefly, Hydrophobicity or Hydrophilicity typically depends on the solid/liquid combination and the surface structure of the solid (i.e. the presence of microstructures to encourage hydrophobicity). Hydrophilic surfaces, more specifically, have the property that water has an affinity for the surface, thus water will readily wet and spread onto a hydrophilic surface. Hydrophobic surfaces, in contrast, are such that water does not have a significant affinity for the surface, and will instead minimize its surface contact area with the surface by forming droplets. Hydrophilicity and hydrophobicity are controlled by the inherent surface energies associated with the interaction of the solid, liquid and vapor phases. Knowledge of the relative magnitudes of the various solid/liquid, solid/vapor and liquid/vapor surface energies allows one to determine if a fluid and solid will interact in a hydrophilic or hydrophobic, e.g., wetting or non-wetting, manner. Surface roughness applied to a hydrophilic/hydrophobic surface will typically enhance its character, e.g., a hydrophilic surface may become super-hydrophilic, and a hydrophobic surface may become super-hydrophobic.

[0036] Since vapor chambers typically operate at pressures different from atmospheric pressure, pillars, ribs or other internal solid structures (hereinafter referred to as support elements) may optionally be incorporated into the internal structure of the vapor chamber or the vapor chamber and the heat sink to ensure that the heat sink and/or the vapor chamber remain rigid and structurally sound while allowing for minimization of the thickness of the enclosure for thermal optimization. Figure 5a shows an exemplary schematic representation of an assembly of a vapor chamber 110, a heat sink 120 and a heat source 130. The embodiment shown in figure 5a is in many structural and operational aspects similar to that of figures 2a-2b or figure 3 and like elements therein have been given like reference numerals as figures 2a-2b and 3. However, figure 5a further illustrates the use of support elements 150 inside the vapor chamber 110 and/or the fins 121 to enhance rigidity as discussed above.

[0037] In some embodiments, additional structural elements may be provided inside the fins 121 designed to direct or enhance the liquid condensate flow returning back to the liquid base in the vapor chamber (*e.g.* to the wick structure and/or heat source). Advantageously such additional elements may be the same as the support elements as described above. Therefore, in some embodiments, the support elements 150 may be used for both purposes described above, namely that of providing structural rigidity to the overall structure and that of directing the condensed liquid back to the vapor chamber.

[0038] Figure 5b shows a fin 121 in a cross-sectional view along the cross-section represented by broken line A-A in figure 5a. As shown in figure 5b, support elements 150 may be positioned inside the fins 121 to direct the liquid drops 160. Preferably the support elements may be provided in a shape and/or position to assist the flow of the drops 160 back to the vapor chamber 110. For example in figure 5b, the support elements are provided with a certain slope that, when fin is positioned vertically, direct the liquid drops 160 downward as shown by arrows in figure 5b.

[0039] In some embodiments the thermally conductive polymer used in the vapor chamber or the vapor chamber heat sink may include metal inserts incorporated or overmolded into the polymer structure at the location where the heat source is brought into thermal contact with the vapor chamber. This option may help to improve heat transfer from the heat sink into the vapor chamber and the wick structure (if a wick structure is used). Furthermore, such metal insert may allow for more robust heat source attachment options such as the use of threaded holes or studs or the direct soldering or welding of such devices directly to the vapor chamber or heat sink. In addition, a metal wick structure may optionally be soldered directly to such metal inserts to improve heat transfer into the wick inside of the vapor chamber.

[0040] If a wick structure is used, which may often be the case, the wick structure itself may be one of several existing technologies depending on the design requirements and liquid transport needs of the vapor chamber or vapor chamber heat sink. Some non-limiting examples of wick structure include porous sintered metal wicks, layers of woven metal wire screen mesh or a grooved wick. For smaller vapor chambers or heat sinks, grooved wicks may be an attractive option and may be incorporated directly into the heated base of the vapor chamber during the process of molding the plastic.

[0041] In some embodiments a hybrid wick structure may be used. Figure 6 shows an exemplary schematic representation of a portion of a vapor chamber R within which a hybrid wick structure is used. In figure 6, like elements have been given like reference numerals as those of figures 1a and 1b. The hybrid wick structure 119 comprises a first portion made of porous structure 119a which may be made of a sintered metal or a screen mesh wick. The hybrid wick structure further comprises a second portion with grooves 119b such that the groove are embedded in the body of the vapor chamber wall 111 or in the base of the heat sink (not shown).

[0042] According to still a further embodiment, the wick structure itself may be made of sintered plastic material. This option is made possible due to the use of a thermally conductive polymer as material for the vapor chamber as discussed above. Figures 7a and 7b show a schematic representation of a portion of a vapor chamber R within which sintered plastic is used to form the wick structure. In figures 7a and 7b, like elements have been given like reference numerals as those of figures 1a and 1b. According to this embodiment, particles 170a of the thermally conductive polymer are provided inside the vapor chamber 110. The particles 170a are then heated to a temperature below their melting point or glass transition temperature. Atomic diffusion bonds the particles together forming a continuous (sintered) solid porous structure as shown in figure 7b by reference numeral 170b which represents the particles of figure 7a but in porous structure form.

[0043] The initial particle size may be determined based on the required porosity and capillary requirements of the overall vapor chamber or vapor chamber heat sink. The sintered polymer wick 170b may be manufactured in-situ of the vapor chamber heat sink and may further be sintered directly to the inner wall 111 of the vapor chamber (or the vapor chamber and heat sink) to improve heat transfer from the outer heat source 130 into the wick 170b.

[0044] The overall assembly of the vapor chamber or the vapor chamber and heat sink may be made using known processes. For example, in order to create an enclosed chamber of a given design (be it a simple flat vapor chamber design or a more complex extended vapor chamber heat sink) the injection molded conductive polymer may be assembled from a minimum of two separately molded pieces. In order to provide an effective seal between these components, mechanical assembly using fasteners and a gasket material (such as an O-ring or a wet installed sealant or adhesive) may be used. Another alternative approach afforded by the use of a polymeric enclosure may be to use a compatible epoxy or adhesive to chemically bond the components together. Finally, a variety of plastic welding options may also be amenable to joining these components.

[0045] The solution proposed herein provide significant increase in vapor chamber and vapor chamber heat sink effectiveness (performance) and decrease in weight as compared to known designs resulting in increased reliability and functionality for the hardware employing such solution.

[0046] The various embodiments of the present invention may be combined as long as such combination is compatible and/or complimentary.

[0047] Further it is to be noted that the list of structures corresponding to the claimed elements is not exhaustive and that one skilled in the art understands that equivalent structures can be substituted for the recited structure without departing from the scope of the invention.

Claims

1. A vapor-based heat transfer apparatus comprising a hollow structure and a working liquid within the hollow structure, wherein the structure is made of a thermally conductive polymer.

2. The apparatus of claim 1, wherein the thermally conductive polymer is a high conductivity plastic.

3. The apparatus of claim 1 or claim 2, wherein the hollow structure of the apparatus comprises inner walls covered, at least in part, with a hermetic layer adapted to block a transport of the working liquid inside the thermally conductive polymer.

4. The apparatus of claim 1 or claim 2, wherein the hollow structure of the apparatus comprises inner walls covered, at least in part, with a pure polymer material or an epoxy layer adapted to block a transport of the working liquid inside the thermally conductive polymer.

5. The apparatus of any one of claims 1 to 4 comprising one or more extended structures configured for dissipating heat from the apparatus to the ambient, said extended structure having a hollow interior space at least in a portion thereof and comprising an inner surface within said interior space, said surface presenting a hydrophobic property.

6. The apparatus of any one of claims 1 to 4 comprising one or more extended structures configured for dissipating heat from the apparatus to the ambient, said extended structure having a hollow interior space at least in a portion thereof and comprising an inner surface within said interior space, said surface presenting a hydrophilic property.

7. The apparatus of any one of the previous claims comprising an internal element configured for providing rigidity to the structure of the apparatus.

8. The apparatus of any one of the previous claims comprising an internal element configured for directing a direction of the flow of the liquid condensate.

9. The apparatus of any one of the previous claims wherein the thermally conductive material comprises one or more metal inserts.

10. The apparatus of claim 9 wherein a wick structure is soldered or bonded to the metal insert or inserts.

11. The apparatus of claim 10 wherein the wick structure comprises a first portion made of a porous structure and a second portion comprising grooves.

12. The apparatus of any one of preceding claims 1 to claim 9 comprising a wick structure made of plastic material particles.

13. The apparatus of any one of claims 1 to 4 or claims 7 to 12 comprising a vapor chamber.

14. The apparatus of any one of claims 1 to 12 comprising a vapor chamber and a heat sink, wherein at least a portion the heat sink comprises a conductive polymer material.

15. The apparatus of any one of claims 1 to 12 comprising a heat pipe,

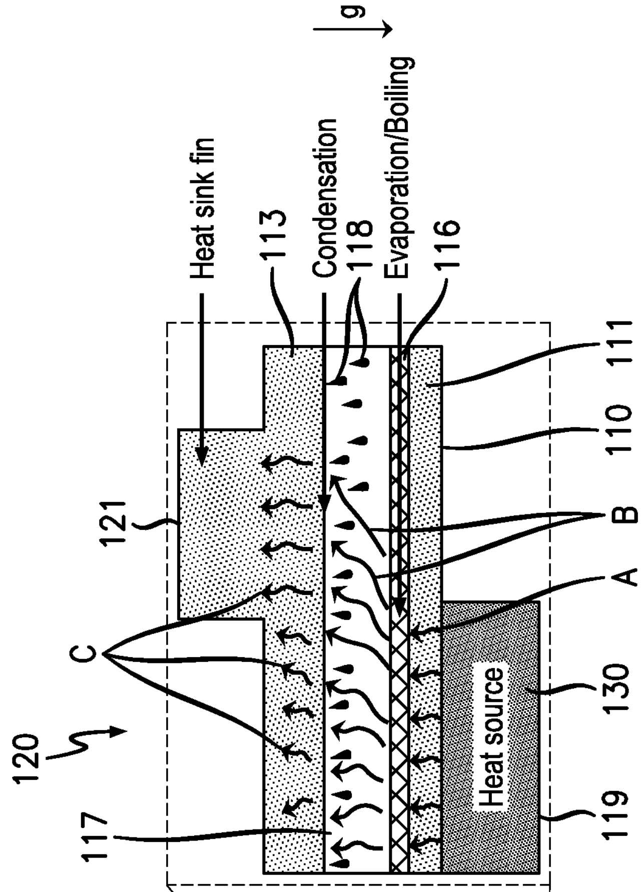
g
Heat sink fin
121
C
120
117
113
Condensation
118
Evaporation/Boiling
116
111
110
B
A
130
Heat source
119

FIG. 1B

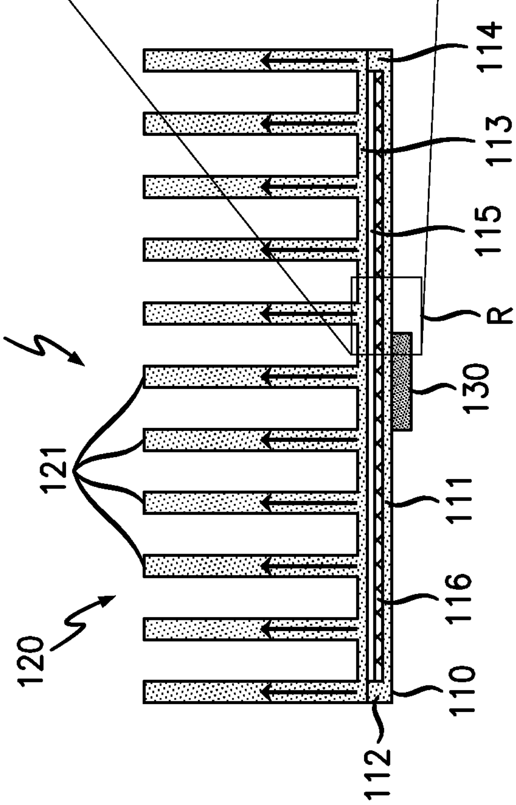
100
121
120
114
113
115
R
130
111
116
110
112

FIG. 1A

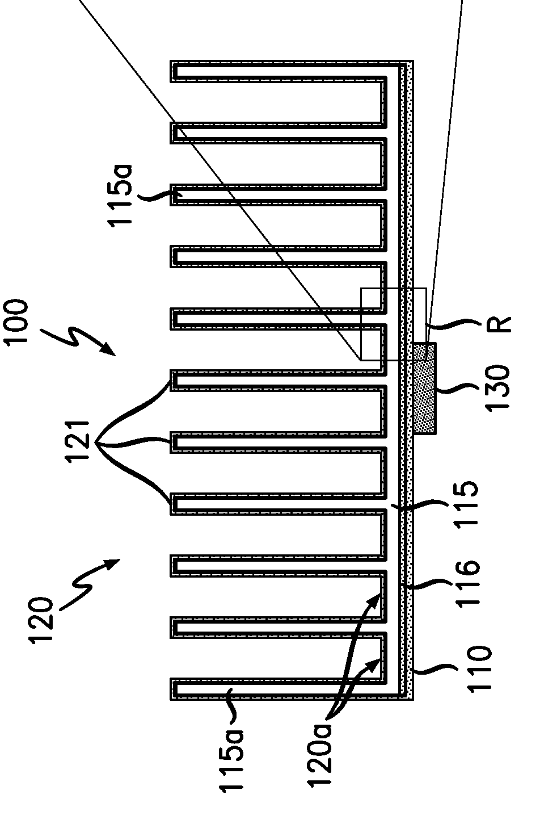
100
121
120
115a
120a
110
116
115
130
R

FIG. 2A

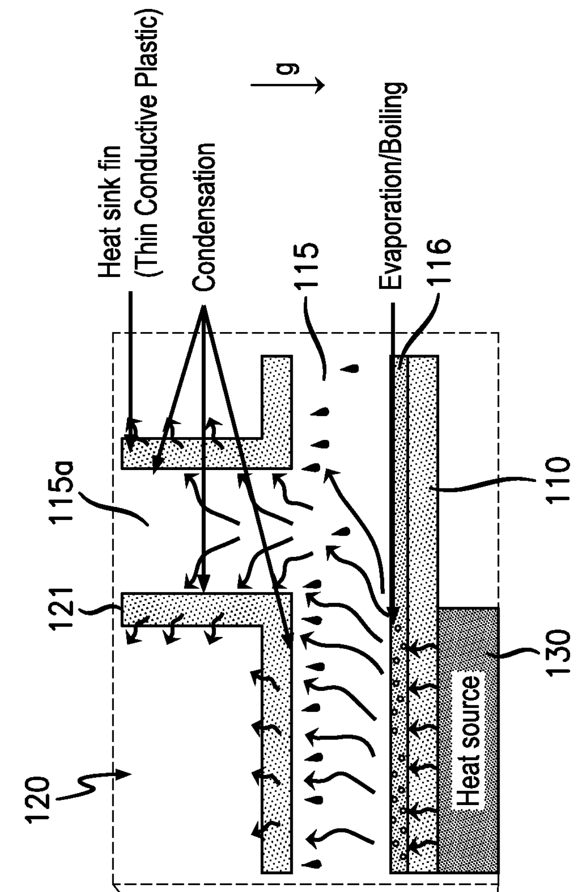
Heat sink fin
(Thin Conductive Plastic)
Condensation
115
Evaporation/Boiling
116
g
115a
121
120
110
130
Heat source

FIG. 2B

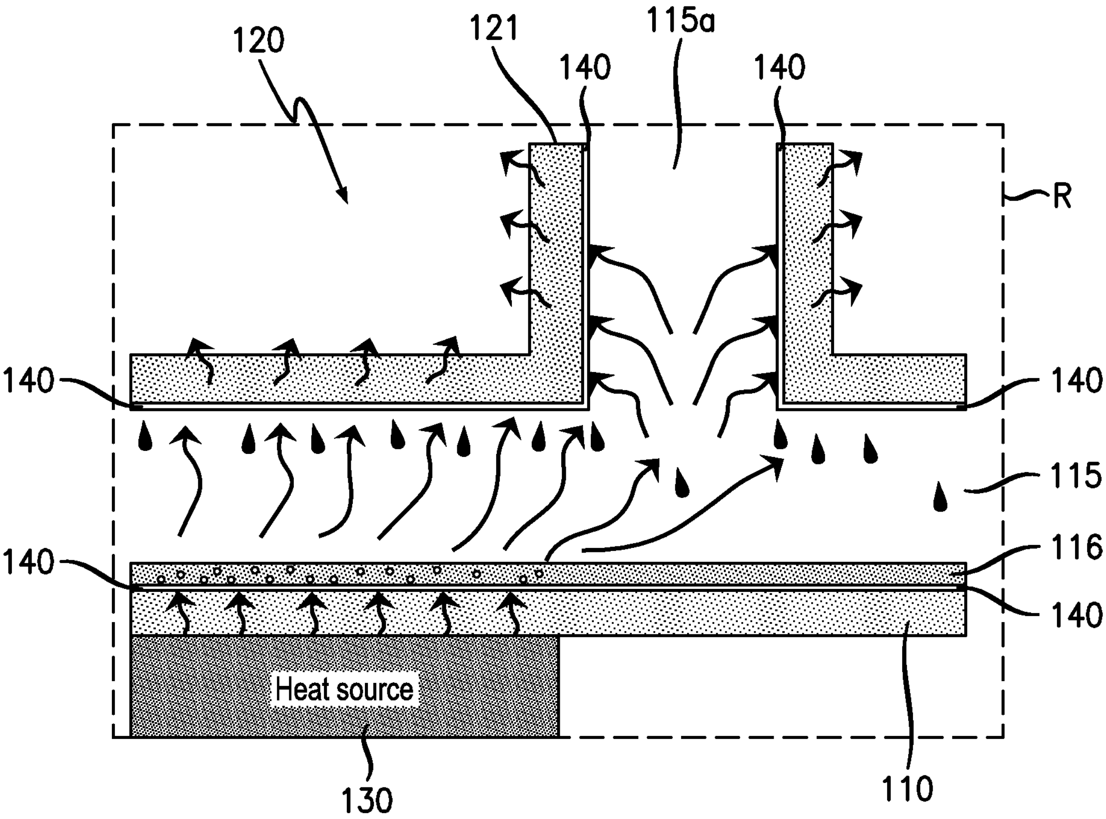
120
121
115a
140
140
R
140
140
115
140
116
140
Heat source
130
110

FIG. 3

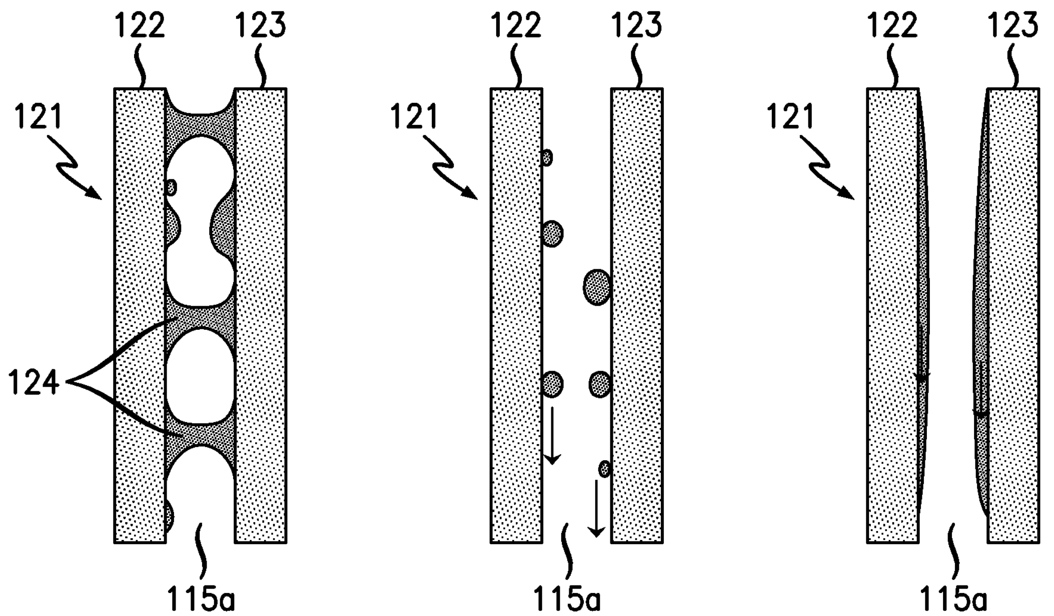

FIG. 4A FIG. 4B FIG. 4C

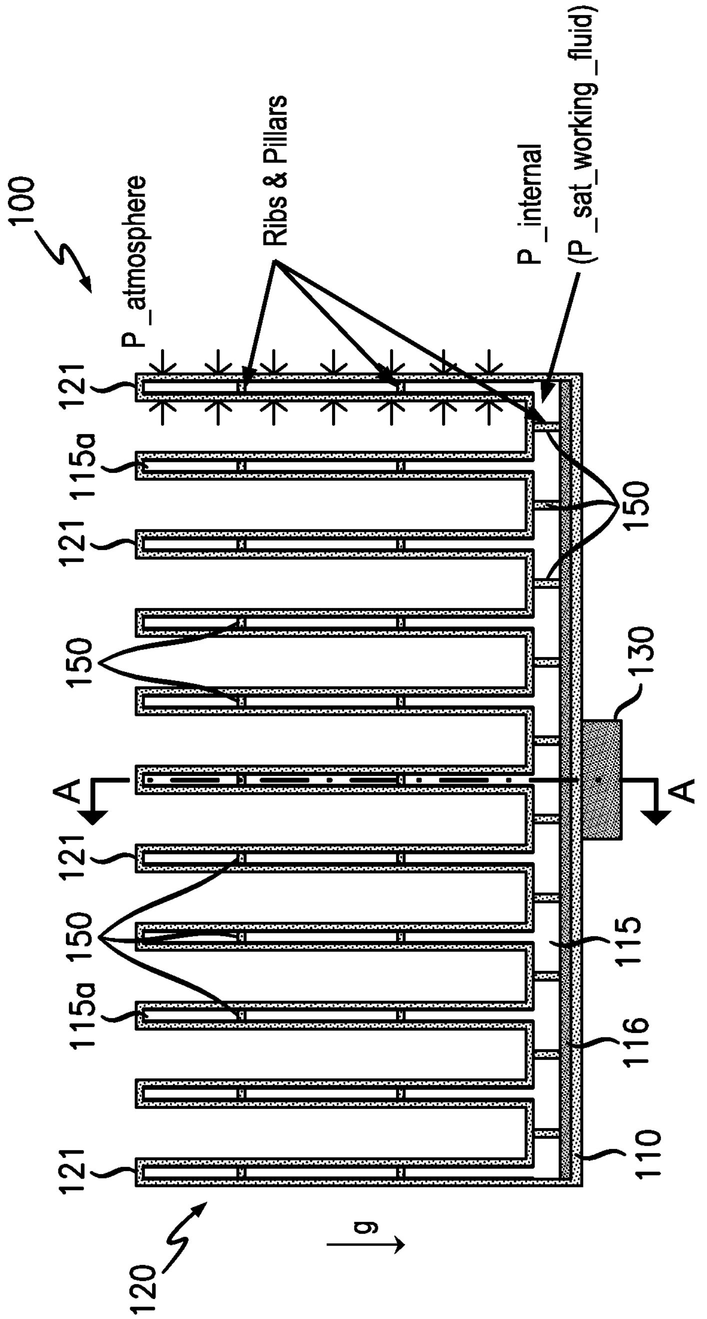
100
P _atmosphere
Ribs & Pillars
P _internal
(P _sat_working _fluid)
121
115a
121
150
130
A
A
121
150
115a
115
116
121
110
120
g
150

FIG. 5A

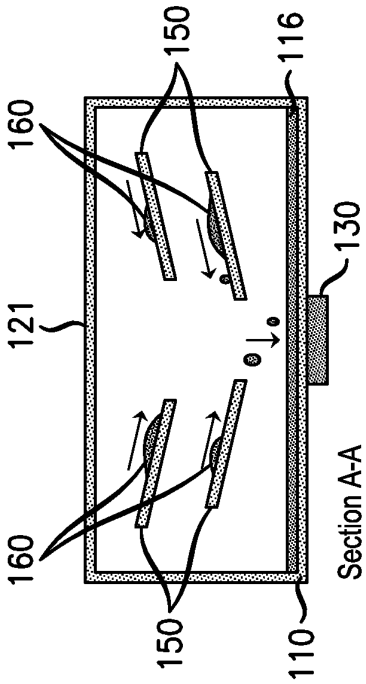
160
150
116
121
130
160
150
110
Section A-A

FIG. 5B

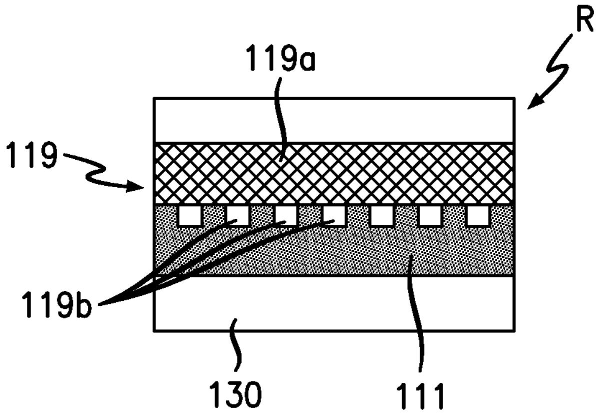

FIG. 6

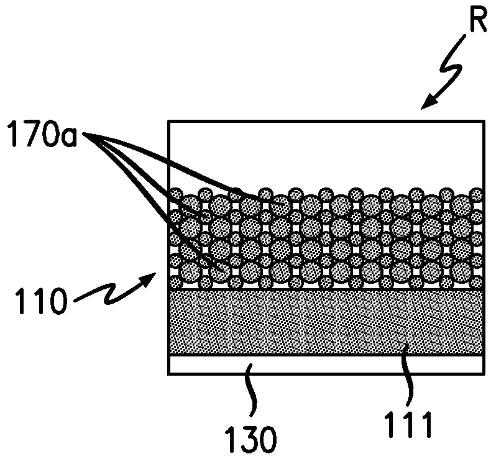

FIG. 7A

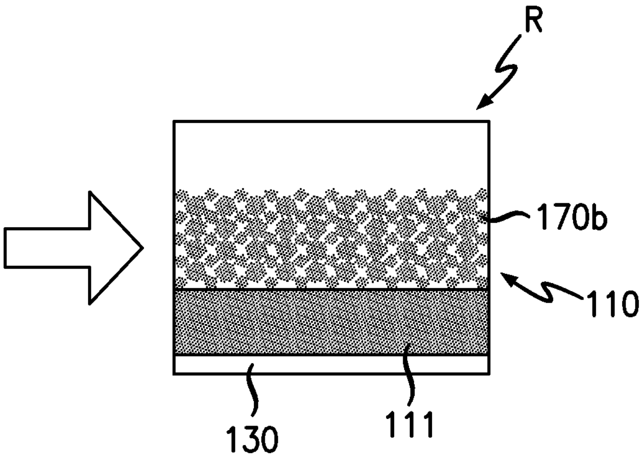

FIG. 7B

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EP 12 30 6167

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 6 237 223 B1 (MCCULLOUGH KEVIN A [US]) 29 May 2001 (2001-05-29) * column 4, line 7 - column 7, line 42; figures 1-10 *	1,2,8, 13-15 5,6,9-12	INV. F28D15/02 F28D15/04 F28F13/04 F28F21/06
Y	DATABASE WPI Section PQ, Week 201210 Thomson Scientific, London, GB; Class Q78, AN 2012-Q63920 XP002694514, -& CN 102 683 307 A (UNIV SOUTHEAST) 19 September 2012 (2012-09-19) * abstract; figure 8 *	5	
Y	US 2002/050344 A1 (KOKUBO AKIHISA [JP] ET AL) 2 May 2002 (2002-05-02) * paragraphs [0019] - [0029], [0041]; figures 1A-2 *	6	
Y	US 2006/016578 A1 (HUANG LUNG-WEI [TW]) 26 January 2006 (2006-01-26) * paragraph [0016] - paragraph [0026]; figures 3-6 *	9,10	TECHNICAL FIELDS SEARCHED (IPC) F28D F28F
Y	EP 2 258 998 A2 (GEN ELECTRIC [US]) 8 December 2010 (2010-12-08) * paragraphs [0029] - [0034], [0069] - [0077], [0094] - [0095]; figures 1-3c *	11,12	
X	WO 03/017365 A2 (HONEYWELL INT INC [US]; FLINT JAMES PATRICK [US]; DEAN NANCY F [US]) 27 February 2003 (2003-02-27) * paragraph [0022] - paragraph [0040]; figures 4-7 *	1-4,7,8, 13-15	

-/--

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	26 March 2013	Beltzung, Francis

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Application Number
EP 12 30 6167

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2004/174651 A1 (AISENBREY THOMAS [US]) 9 September 2004 (2004-09-09) * paragraph [0035] - paragraph [0055]; figures 6,11 *	1,2,8, 13-15	
X	US 2004/190253 A1 (PRASHER RAVI [US] ET AL) 30 September 2004 (2004-09-30) * paragraph [0030] - paragraph [0037]; figures 3a-3e *	1,2, 13-15	
X	WO 2005/031238 A1 (LG CABLE LTD [KR]; LEE YONG-DUCK [KR]; HONG YOUNG-HO [KR]; OH MIN-JUNG) 7 April 2005 (2005-04-07) * page 6, line 5 - page 7, line 18; figure 1 *	1,2,8, 13-15	
X	US 2005/199376 A1 (LEE YI-SHENG [TW]) 15 September 2005 (2005-09-15) * paragraph [0025] - paragraph [0033]; figure 1 *	1,7,8, 13-15	
A	US 2007/012429 A1 (SIU WING M [HK]) 18 January 2007 (2007-01-18) * paragraph [0021] - paragraph [0036]; figures 1-10 *	1-15	TECHNICAL FIELDS SEARCHED (IPC)
A	EP 0 910 235 A1 (LUCENT TECHNOLOGIES INC [US]) 21 April 1999 (1999-04-21) * paragraph [0006] - paragraph [0016]; figures 1-7 *	1-15	
A	WO 2008/020295 A1 (ATI TECHNOLOGIES ULC [CA]; ATI INT SRL [BB]; REFAI-AHMED GAMAL [CA]) 21 February 2008 (2008-02-21) * page 22, line 14 - page 24, line 12; figures 9,10 *	1-15	

-/--

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	26 March 2013	Beltzung, Francis

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Application Number
EP 12 30 6167

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2009/040726 A1 (HOFFMAN PAUL [US] ET AL) 12 February 2009 (2009-02-12) * paragraphs [0076] - [0081], [0104] - [0105]; figures 1-5, 27, 28 * -----	1-15	
A	WO 2010/124025 A2 (UNIV DUKE [US]; CHEN CHUAN-HUA [US]; BOREYKO JONATHAN B [US]; ZHAO YUE) 28 October 2010 (2010-10-28) * paragraphs [0041] - [0051], [0064] - [0065]; figures 1,2 * -----	1-15	
A	DE 20 2012 004731 U1 (ASIA VITAL COMPONENTS CO LTD [TW]) 5 June 2012 (2012-06-05) * paragraph [0026]; figure 6 * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	26 March 2013	Beltzung, Francis

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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26-03-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6237223 B1	29-05-2001	NONE	
CN 102683307 A	19-09-2012	NONE	
US 2002050344 A1	02-05-2002	JP 2002141449 A	17-05-2002
		US 2002050344 A1	02-05-2002
US 2006016578 A1	26-01-2006	NONE	
EP 2258998 A2	08-12-2010	EP 2258998 A2	08-12-2010
		US 2010294467 A1	25-11-2010
WO 03017365 A2	27-02-2003	AU 2001285013 A1	03-03-2003
		TW 502102 B	11-09-2002
		WO 03017365 A2	27-02-2003
US 2004174651 A1	09-09-2004	CA 2464280 A1	14-10-2004
		CN 1551339 A	01-12-2004
		EP 1469513 A2	20-10-2004
		JP 2004349685 A	09-12-2004
		KR 20040089590 A	21-10-2004
		US 2004174651 A1	09-09-2004
US 2004190253 A1	30-09-2004	US 2004190253 A1	30-09-2004
		US 2005117299 A1	02-06-2005
		US 2005117300 A1	02-06-2005
		US 2005117301 A1	02-06-2005
WO 2005031238 A1	07-04-2005	CN 1864043 A	15-11-2006
		EP 1676086 A1	05-07-2006
		JP 2007507685 A	29-03-2007
		KR 20050032888 A	08-04-2005
		TW I260388 B	21-08-2006
		US 2007068656 A1	29-03-2007
		WO 2005031238 A1	07-04-2005
US 2005199376 A1	15-09-2005	TW M309091 U	01-04-2007
		US 2005199376 A1	15-09-2005
		US 2006237167 A1	26-10-2006
US 2007012429 A1	18-01-2007	CN 101147038 A	19-03-2008
		EP 1896790 A2	12-03-2008
		KR 20080025365 A	20-03-2008
		US 2007012429 A1	18-01-2007
		WO 2007029125 A2	15-03-2007

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 30 6167

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26-03-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0910235 A1	21-04-1999	BR 9803360 A	03-11-1999
		CA 2247688 A1	30-03-1999
		CN 1213071 A	07-04-1999
		EP 0910235 A1	21-04-1999
		JP H11163237 A	18-06-1999
		US 6062302 A	16-05-2000
WO 2008020295 A1	21-02-2008	CN 101573790 A	04-11-2009
		EP 2057678 A1	13-05-2009
		US 2008043437 A1	21-02-2008
		US 2008043438 A1	21-02-2008
		WO 2008020295 A1	21-02-2008
US 2009040726 A1	12-02-2009	TW 200926953 A	16-06-2009
		US 2009040726 A1	12-02-2009
WO 2010124025 A2	28-10-2010	US 2012012804 A1	19-01-2012
		WO 2010124025 A2	28-10-2010
DE 202012004731 U1	05-06-2012	NONE	

EPO FORM P0459

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