ENHANCED ELECTRONIC COOLING BY AN INNER FIN STRUCTURE IN A VAPOR CHAMBER

Inventors: Shiping Yu, San Diego, CA (US); Guoping Xu, San Diego, CA (US)
Assignee: ORACLE INTERNATIONAL CORPORATION, Redwood Shores, CA (US)
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ABSTRACT
A vapor chamber cooling apparatus to cool an electronic component includes a sealed, hollow metal chamber; a working fluid disposed within the metal chamber; a wick structure disposed along an inner surface of the metal chamber; and an inner fin structure disposed within with the metal chamber. An area of the metal chamber is in thermal contact with the electronic component. The inner fin structure is in thermal contact with the metal chamber. A method of manufacturing a vapor chamber cooling apparatus to cool an electronic component includes providing a metal chamber, wherein an area of the metal chamber thermally contacts the electronic component; disposing a wick structure along an inner surface of the metal chamber; disposing a working fluid within the metal chamber; and disposing an inner fin structure within the metal chamber and in thermal contact with the metal chamber.
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FIELD OF DISCLOSURE

[0001] The present invention relates to vapor chamber cooling apparatus to cool one or more electronic components. More specifically, the present invention relates to a vapor chamber cooling apparatus that contains an inner fin structure within the chamber.

BACKGROUND

[0002] Electronic devices, such as a central processing unit (CPU), graphics processing unit (GPU), or application specific integrated circuit (ASIC) are known to generate heat on a limited area. Increasing heat density has made cooling electronic components more and more challenging. Insufficient cooling may result in severe outcomes for electronic devices and the associated systems, for example servers, storage equipment, and high performance computing (HPC) hardware. Such outcomes of over heating may include reduced reliability, shortened life expectancy, or even a significant malfunction of the electronic device.

[0003] Vapor chambers, for example as part of a heatsink, have increasingly been used to spread high density heat generated from electronic devices such as those mentioned above. The electronic device being cooled is typically attached to the vapor chamber. For some high heat density applications, the boiling thermal resistance at the heat source may account for a significant portion of the total thermal resistance of the heatsink.

[0004] A vapor chamber conducts heat from an electronic component within the electronic system by phase change. For example, a vapor chamber is typically a vacuum vessel with a wick structure lining the inside walls. The wick structure is typically saturated with a working fluid. As heat is applied, the fluid in the vapor chamber near the heat source is immediately vaporized and the vapor expands and fills the vacuum. When the vapor contacts a cooler wall surface, it condenses, and releases the latent heat of vaporization. Heat dissipation at the cooler wall is typically aided by a fin structure on the outside of the vapor chamber. The fin structures are used as a means to dissipate heat into the ambient. The condensed fluid then returns to the heat source via capillary action of the wick structure, to be vaporized again. The process then repeats the vaporization/condensation cycle.

[0005] Because vaporization and condensation of the fluid is a phase change process, high power heat may be transported by a relatively small temperature gradient. The high heat transportation capability with a small temperature gradient may be considered equivalent to a super high thermal conductivity. As a comparison, a vapor chamber’s thermal conductivity may be more than 100 times higher than that of metallic copper. The higher thermal conductivity of vapor chambers is one reason vapor chamber cooling has been used in the cooling of electronic devices.

[0006] The total thermal resistance of a vapor chamber assisted heatsink may be accepted, in general, as consisting of two parts. The first part is the air fin thermal resistance, as heat is first spread by the vapor chamber and then dissipated into the ambient by the air fins. The second part is the vapor chamber’s thermal resistance. A vapor chamber’s thermal resistance may be influenced by several factors; one such factor is the vapor chambers boiling thermal resistance.

SUMMARY OF DISCLOSURE

[0007] In general, in one aspect, embodiments of the present invention relate to a vapor chamber cooling apparatus to cool an electronic component, the apparatus comprising: a sealed, hollow metal chamber, wherein an area of the metal chamber is in thermal contact with the electronic component; a working fluid disposed within the metal chamber; a wick structure disposed along an inner surface of the metal chamber; and an inner fin structure disposed within with the metal chamber, wherein the inner fin structure is in thermal contact with the metal chamber.

[0008] In general, in one aspect, embodiments of the present invention relate to a method of manufacturing a vapor chamber cooling apparatus to cool an electronic component, the method comprising: providing a metal chamber, wherein an area of the metal chamber thermally contacts the electronic component; disposing a wick structure along an inner surface of the metal chamber; disposing a working fluid within the metal chamber; and disposing an inner fin structure within the metal chamber and in thermal contact with the metal chamber.

[0009] Other aspects and advantages of the invention will be apparent from the following description, the drawings and the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. 1 is a schematic of the exterior view of a vapor chamber in accordance with one or more embodiments.

[0011] FIG. 2 is a schematic perspective view of a vapor chamber in accordance with one or more embodiments.

[0012] FIG. 3 is a cross-sectional schematic view of a vapor chamber in accordance with one or more embodiments.

[0013] FIG. 4 is a schematic perspective view of a vapor chamber in accordance with one or more embodiments.

[0014] FIG. 5 is a cross-sectional schematic view of a vapor chamber in accordance with one or more embodiments.

[0015] FIG. 6 is a schematic perspective view of a vapor chamber in accordance with one or more embodiments.

[0016] FIGS. 7A-7G are schematic top views of inner fin structures in accordance with one or more embodiments.

DETAILED DESCRIPTION

[0017] Specific embodiments of the present disclosure will now be described in detail with reference to the accompanying Figures. Like elements in the various figures may be denoted by like reference numerals for consistency. Further, in the following detailed description of embodiments of the present disclosure, numerous specific details are set forth in order to provide a more thorough understanding of the invention. However, it will be apparent to one of ordinary skill in the art that the embodiments disclosed herein may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the description.

[0018] Referring to FIG. 1, in one aspect, embodiments disclosed herein generally relate to a vapor chamber cooling apparatus 100 having an inner fin structure (not shown) to cool one or more electronic components. The electronic components are represented by a heat source 110 attached to a sealed metal chamber 120. The metal chamber 120 may be
constructed of high thermal conductivity metal materials such as copper, aluminum, copper and aluminum alloys, or stainless steel. The sealed metal chamber 120 may also have outer fins 130 attached to the outer surface of the metal chamber 120. The outer fins 130 may be constructed of the same material as that of the metal chamber 120. The air flow on the outer fins 130 facilitates the dissipation of heat from the metal chamber 120 to the external ambient.

[0019] One or more embodiments are designed to help reduce the boiling thermal resistance by constructing an inner fin structure inside the vapor chamber. With the addition of the inner fin structure, the boiling heat density may be decreased and, thus, the superheated boiling temperature may be lowered. As a result, the boiling thermal resistance of the vapor chamber will be reduced.

[0020] FIG. 2 shows a perspective schematic view of the vapor chamber 100 according to one or more embodiments of the present invention. The vapor chamber 100 includes an inner fin structure 140 located in the interior of the metal chamber 120. Like the metal chamber 120, the inner fin structure 140 may be constructed of high thermal conductivity metal materials, such as copper, aluminum, copper and aluminum alloys, or stainless steel. The inner fin structure 140 may be positioned anywhere inside the metal chamber 120, however, in one or more embodiments, the inner fin structure 140 is positioned directly adjacent to the heat source 110.

[0021] The inner fin structure 140 may be attached to the inner wall of the metal chamber 120 by welding, soldering, brazing, or the like, to ensure a good thermal contact with the lower surface 150 of the inner fin structure 140. The upper surface 155 of the inner fin structure 140 may or may not fully extend to the top of the metal chamber 120. However, in one or more embodiments the upper surface 155 of the inner fin structure 140 extends to the top of the metal chamber 120. In such embodiments, the upper surface 155 may also be welded, like the lower surface 150, to the metal chamber 120 to ensure a good thermal contact and facilitate heat dissipation. In accordance with one or more embodiments, the inner fin structure 140 may be manufactured separately using methods such as stamping, machining, or casting.

[0022] In one or more embodiments, the inner fin structure 140 may be manufactured as an integral part of the metal chamber 120. Like the metal chamber 120, the integrated structure may be constructed by a variety of methods such as machining or casting. In such embodiments, the overall heat dissipation effects may be improved by the integrated manufacturing of the metal chamber 120 and inner fin structure 140. Furthermore, the integrated manufacturing may alleviate any issues that may arise in establishing a good thermal contact between the metal chamber 120 and the inner fin structure 140.

[0023] The inner fin structure 140 shown in FIG. 2 is shown as a four prong radiating structure. However, the shape of the inner fin structure 140 is not limited to such a four prong radiating structure as will be discussed with regard to FIG. 7.

[0024] FIG. 3 is a cross-sectional schematic view of the vapor chamber 100 in accordance with one or more embodiments of the present invention. The sealed metal chamber 120 has the inner fin structure 140 thermally attached at the upper surface 155 and the lower surface 150. In addition, the inner surface of the metal chamber 120 is lined with a wick structure 175.

[0025] The wick structure 175 may be a porous structure that can generate capillary effects, which may drive flow of a fluid within the wick structure 175. The wick structure 175 may be disposed in the metal chamber 120 by several methods such as sintering, screening, and growing. Sintering is a method that coats a metal power onto the inner surfaces of the metal chamber 120. Screening may be accomplished by attaching layers of screens onto the inner surfaces of the metal chamber 120. Growing may be accomplished by making mechanical grooves onto the inner surfaces of the metal chamber 120.

[0026] The wick structure 175 is disposed along the inner surfaces of the metal chamber 120. In addition, the wick structure 175 may also be disposed along the surfaces of the inner fin structure 140. In one or more embodiments, the inner fin structure 140 may partially or completely comprise the same material as the wick structure 175.

[0027] In one or more embodiments, the metal chamber 120 is a sealed hollow structure that may be charged by a working fluid. Examples of working fluids are well known in the art, and include water, ethanol, acetone, mercury, etc. The heat from the heat source 110 causes the working fluid to vaporize inside the metal chamber near the heat source 110. The vapor 180 expands and fills the metal chamber 120. When the vapor 180 contacts a cooler wall surface of the metal chamber 120, it may condense, and thereby release the latent heat of vaporization.

[0028] The heat dissipation at the metal chamber wall may be aided by outer fins 130 on the outer surface of the metal chamber 120. The condensed fluid 185 returns to the heat source via capillary action of the wick structure 175, to be vaporized again. This process then repeats and the cycle of vaporization/condensation assists heat dissipation. The capillary action of the wick structure inside the vapor chamber may enable the vapor chamber to work in any orientation with respect to gravity.

[0029] The boiling thermal resistance may be defined as the superheated temperature rise between the superheated wall and the saturated working fluid, divided by the heating power. Also, the heat density may be defined as the heating power divided by the heating area. From boiling experiments, it is known that the higher the heat density, the higher the superheated temperature may rise. The boiling thermal resistance may be directly proportional to the heat density. As such, a decrease in the heat density may greatly influence the reduction of the boiling thermal resistance.

[0030] The presence of the inner fin structure 140 may reduce the boiling thermal resistance of the vapor chamber 100 by surface extension. As shown in FIGS. 2 and 3, the inner fin structure 140 extends not only in the x and y directions, but also, in the z direction. As such, the inner fin structures are three dimensional by nature. The three dimensional nature of the inner fin structure may facilitate the surface extension, and thereby reduce the boiling thermal resistance of the vapor chamber 100.

[0031] FIG. 4 is a perspective schematic view of a vapor chamber 200 in accordance with one or more embodiments. The metal chamber 220 has an inner fin structure 240 disposed within, which may be positioned adjacent to a heat source 210. The inner fin structure 240 may be in thermal contact with the metal chamber 220 at the lower surface 250 and the upper surface 255 of the inner fin structure 240. In addition, the inner fin structure 240 may also extend and be in good thermal contact with one or both sides 290 of the metal chamber 220. The shape of inner fin structure 240 is a single rectangular fin structure. The single rectangular fin structure
240 may or may not fully extend in the x direction to the whole width of the metal chamber 220. In addition to help spread heat, this single fin structure, as well as the other inner fin structures described herein, may also serve as a stiffener that improves the mechanical strength of the vapor chamber 200.

[0032] FIG. 5 is a cross-sectional schematic view of the vapor chamber 200 in accordance with one or more embodiments of the present invention. The sealed metal chamber 220 has an inner fin structure 240, which may be thermally attached at the upper surface 255 and the lower surface 250 of the inner fin structure 240. The inner surface of the metal chamber 220 is also lined with a wick structure 275.

[0033] As described in relation to other embodiments, the wick structure 275 is disposed along inner surfaces of the metal chamber 220. The wick structure 275 may also be disposed along one or more surfaces of the inner fin structure 240. The metal chamber 220 may be charged by a working fluid. Similar to previously described embodiments, a process of cycling vaporization/condensation within the vapor chamber 200 assists heat dissipation.

[0034] FIG. 6 is a cross-sectional schematic view of the vapor chamber 300 in accordance with one or more embodiments of the present invention. The sealed metal chamber 320 has an inner fin structure of one or more round post structures 340 disposed within. The round post structures 340 may be thermally attached at the upper and lower surfaces of the metal chamber 320, similar to previously described embodiments. Further, inner surfaces of the metal chamber 320, as well one or more surfaces of the post structures, may be lined with a wick structure, similar to previously described embodiments.

[0035] As can be seen, the round post structures 340 may be positioned at the area of thermal contact between the metal chamber 320 and the heat source 310. Additionally, the round post structures 340 may be positioned at other locations within the metal chamber.

[0036] FIGS. 7A-7G show additional exemplary shapes of inner fin structures according to one or more embodiments. Similar to the inner fin structures described above, the inner fin structures shown in FIGS. 7A-7G may be disposed within the sealed metal chamber of a vapor chamber and may be thermally connected thereto at an upper surface, lower surface, and/or side surface. Those skilled in the art will appreciate that embodiments of the present invention are not limited solely to the particular structures disclosed herein. Rather, many different shapes of the inner fin structures and combination of several different shapes may be employed according to particular applications or manufacturing considerations without departing from the spirit of the invention.

[0037] Referring specifically to the shapes of the exemplary inner fin structures shown in FIGS. 7A-7G, FIG. 7A shows a multiple rectangular structure 341. FIG. 7B shows a branched rectangular structure 342. FIG. 7C shows a multi-pronged radiating structure 343 having, for example, eight radiating prongs. Also, as shown in FIGS. 7D-7G, a plurality of square 344, 345 or round 346, 347 post structures may be used. The plurality of posts may be in ordered 344, 346 or offset 345, 347 arrays.

[0038] One or more embodiments may have one or more of the following advantages. The heat density of the vapor chamber may be decreased by the addition of the inner fin structure. A decrease in heat density by the addition of the three-dimensional fin structure may decrease the boiling thermal resistance, thereby improving the heat dissipation characteristics of the vapor chamber cooling apparatus. In addition, the presence of the inner fin structure may increase the structural integrity of the vapor chamber. The inner fin structure may facilitate the use of the vapor chamber cooling apparatus in any orientations with respect to gravity.

[0039] While the present disclosure has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised which do not depart from the scope of the disclosure as described herein. Accordingly, the scope of the invention should be limited only by the attached claims.

What is claimed is:

1. A vapor chamber cooling apparatus to cool an electronic component, the apparatus comprising:
   a sealed, hollow metal chamber, wherein an area of the metal chamber is in thermal contact with the electronic component;
   a working fluid disposed within the metal chamber;
   a wick structure disposed along an inner surface of the metal chamber;
   an inner fin structure disposed within the metal chamber, wherein the inner fin structure is in thermal contact with the metal chamber.

2. The apparatus of claim 1, wherein at least a portion of the inner fin structure is positioned at the area of the metal chamber in thermal contact with the electrical component.

3. The apparatus of claim 1, wherein the wick structure is disposed along a surface of the inner fin structure.

4. The apparatus of claim 1, wherein the inner fin structure comprises the same material as the wick structure.

5. The apparatus of claim 1, wherein the inner fin structure traverses the metal chamber and is in thermal contact with at least two sides of the metal chamber.

6. The apparatus of claim 1, wherein the metal chamber comprises copper, aluminum, copper and aluminum alloys, stainless steel, or any combination thereof.

7. The apparatus of claim 1, wherein the inner fin structure comprises copper, aluminum, copper and aluminum alloys, stainless steel, or any combination thereof.

8. The apparatus of claim 1, wherein the inner fin structure comprises a post structure, a radiating structure having a plurality of radial prongs, a branched structure, or any combination thereof.

9. The apparatus of claim 1 further comprising: an outer fin structure disposed on an outside of the metal chamber, wherein the outer fin structure is in thermal contact with the metal chamber.

10. A method of manufacturing a vapor chamber cooling apparatus to cool an electronic component, the method comprising:
   providing a metal chamber, wherein an area of the metal chamber thermally contacts the electronic component; disposing a wick structure along an inner surface of the metal chamber; disposing a working fluid within the metal chamber; and disposing an inner fin structure within the metal chamber and in thermal contact with the metal chamber.

11. The method of claim 10, wherein the inner fin structure and the metal chamber are manufactured separately, the method further comprising: welding the inner fin structure to the metal chamber.
12. The method of claim 10, wherein the inner fin structure is manufactured by stamping, casting, machining, or any combination thereof.

13. The method of claim 10, wherein the inner fin structure is manufactured as part of the metal chamber.

14. The method of claim 10, wherein the wick structure is manufactured by sintering, screening, grooving, or any combination thereof.

15. The method of claim 10, wherein the wick structure is disposed along a surface of the inner fin structure.

16. The method of claim 10 further comprising: positioning at least a portion of the inner fin structure at the area of the metal chamber in thermal contact with the electronic component.

17. The method of claim 10 further comprising: arranging the inner fin structure to traverse the metal chamber and thermally contact at least two sides of the metal chamber.

18. The method of claim 10, wherein the inner fin structure comprises a post structure, a radiating structure having a plurality of radial prongs, a branched structure, or any combination thereof.

19. The method of claim 10 further comprising: disposing an outer fin structure on an outside of the metal chamber, wherein the outer fin structure is in thermal contact with the metal chamber.

20. A vapor chamber cooling apparatus to cool an electronic component, the apparatus comprising:

   - a sealed, hollow metal chamber, wherein an area of the metal chamber is in thermal contact with the electronic component;
   - a working fluid disposed within the metal chamber;
   - an outer fin structure disposed on an outside of the metal chamber, wherein the outer fin structure is in thermal contact with the metal chamber;
   - an inner fin structure disposed within with the metal chamber and positioned at the area of the metal chamber in thermal contact with the electrical component; and
   - a wick structure disposed along an inner surface of the metal chamber and along a surface of the inner fin structure;

   wherein the inner fin structure is arranged to traverse the metal chamber and thermally contact with at least two sides of the metal chamber,

   wherein the metal chamber comprises copper, aluminum, copper and aluminum alloys, stainless steel, or any combination thereof,

   wherein the inner fin structure comprises copper, aluminum, copper and aluminum alloys, stainless steel, or any combination thereof, and

   wherein the inner fin structure comprises a post structure, a radiating structure having a plurality of radial prongs, a branched structure, or any combination thereof.

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