A micro-channel heat sink comprises an upper cover layer and a cooling layer. The cooling layer comprises at least one inlet fluid tank, a plurality of micro-channels, and at least one outlet fluid tank. The inlet fluid tank can store and deliver the working fluids, and the outlet fluid tank collects the heated working fluid flowing through the plurality of micro-channels. The plurality of micro-channels are disposed between the inlet fluid tank and the outlet fluid tank, wherein the cross sectional area of each of the micro-channels increases along the direction towards the outlet fluid tank.
MICRO-CHANNEL HEAT SINK
BACKGROUND OF THE INVENTION

[0001] Field of the Invention

[0002] The present invention relates to a micro-channel heat sink, and more particularly, to a high performance micro-channel heat sink.

[0003] Description of the Related Art

[0004] With improvements in micro-scaling technologies for electronic components, various electronic products in recent years have been reduced in size to meet the specifications for portable design. The personal computer, digital camera, PDA, and mobile phone have attained the lightweight and compact size required for portability. However, owing to the scaling of the electronic products in design, the issue of cooling for high performance electrical components has also arisen, and the industry has taken notice. Therefore, thermal analysis technologies have become a critical factor affecting how quickly products can be brought to market. According to reports by international electronics magazines, 50% of the causes of malfunctions in electronic products result from inadequately designed cooling systems.

[0005] The continuous demand for increasing the circuit density and power of electrical components has resulted in higher heat dissipation per unit area, with up to 100 W of heat dissipation for a single chip. Even though improvements in the IC manufacturing process lower the heat generated from electrical components, other cooling technologies are still necessary for lowering the temperature of the single chip without degrading its speed and performance. Generally speaking, air-cooling is only applicable to components with thermal dissipation of less than 10⁴ W/m². Cooling fans and cooling fins are not only bulky but also noisy and inefficient. When the thermal load of the electrical component exceeds 10 W/m², better cooling methods are required to dissipate the continuously accumulated heat in order to maintain suitable chip operating temperature.

[0006] However, traditional cooling technologies are limited by their design, so various cooling devices are currently being developed to replace them. Among the different efforts, developments of the micro-channel heat sink fabricated by MEMS (Micro Electrical Mechanical System) processes are more progressive. Not only can such heat sinks be mass produced to reduce costs, but they also have the merits of light weight, miniaturized size, superior spatial utilization, shorter response time, and high heat dissipation rate. Therefore, they have many potential applications in the future.

[0007] Because the two-phase flow and boiling heat transfer within the micro-channels result in high efficiency of thermal dissipation, the micro-channel heat sink is critical for further enhancing the performance of electrical components. Particularly, the silicon micro-channels can be formed on a silicon substrate directly through an etching process. Therefore, the use of high heat transfer cooling fluid within the micro-channels and the large heat transfer areas of the micro-channels can easily remove a large amount of heat, thereby enhancing the performance of the electrical components.

[0008] FIG. 1 is a schematic diagram showing an assembly of a traditional micro-channel heat sink and an electrical component. An electrical component 80 and a micro-channel heat sink 10 are connected to each other by a thermal-conductive adhesive 90, and the heat generated from the electrical component 80 will be promptly transferred to the micro-channel heat sink 10 through the thermal-conductive adhesive 90. The micro-channel heat sink 10 comprises an upper cover layer 11 and a cooling layer 12, wherein the cooling layer 12 comprises a plurality of parallel micro-channels 123. A working fluid 60 fills micro-channels 123 and flows from an inlet pipe 71 to an outlet pipe 72. Meanwhile, the heat generated by the electrical component 80 will be taken away from the cooling layer 12.

[0009] FIG. 2 is a top view of the micro-channel heat sink shown in FIG. 1. The plurality of micro-channels 123 are arranged in parallel and the cross-sectional areas of the micro-channels are consistent along their longitudinal directions. However, various researches and applications show that boiling in the micro-channel 123 is likely to cause instability in the two-phase flow. Such instability issue occurs particularly under conditions of high heat transfer rate and low flow rate. Instability of the heat flow will often result the early reaching of the critical value of the heat transfer rate, resulting in the absence of fluid in the channels and high temperatures on their inner wall surfaces.

[0010] In summary, the market is in urgent need of a cooling device with high stability, high heat transfer capability, and high heat dissipation efficiency so as to stably remove a large amount of heat from the electrical component. Accordingly, the performance of the electrical component is enhanced.

SUMMARY OF THE INVENTION

[0011] The present invention provides a micro-channel heat sink, whose miniaturized structure can prevent the reverse flow of bubbles and pressure oscillations. That is, the bubbles in the boiling fluid cannot easily flow backwards to block the transportation of a working fluid in micro-channels. Therefore, this micro-channel heat sink is a cooling device with high stability, high heat transfer capability, and high power efficiency.

[0012] The present invention provides a micro-channel heat sink, comprising an upper cover layer and a cooling layer. The cooling layer comprises at least one inlet fluid tank, a plurality of micro-channels, and at least one outlet fluid tank. The inlet fluid tank can store and deliver a working fluid. The outlet fluid tank collects the heated working fluid flowing through the plurality of micro-channels. The plurality of micro-channels are disposed between the inlet fluid tank and the outlet fluid tank. The cross-sectional areas of each of the micro-channels increases along the direction from the inlet fluid tank towards the outlet fluid tank.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The objectives and advantages of the present invention will become apparent upon reading the following description and upon reference to the accompanying drawings in which:

[0014] FIG. 1 is a schematic diagram showing an assembly of a traditional micro-channel heat sink and an electrical component;

[0015] FIG. 2 is a top view of the micro-channel heat sink shown in FIG. 1;

[0016] FIG. 3 is a top view of a micro-channel heat sink in accordance with the present invention;

[0017] FIG. 4 is a schematic diagram showing an assembly of a micro-channel heat sink and an electrical component in accordance with the present invention;

[0018] FIG. 5 is a schematic diagram showing an assembly of a micro-channel heat sink and an electrical component in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The following will demonstrate the present invention using the accompanying drawings to clearly present the characteristics of the technology.
FIG. 3 is a top view showing a micro-channel heat sink in accordance with the present invention. The micro-channel heat sink 30 comprises an upper cover layer 31 and a cooling layer 32, wherein the cooling layer 32 comprises at least one inlet fluid tank 321, a plurality of micro-channels 323, and at least one outlet fluid tank 322. The inlet fluid tank 321 can store and deliver the working fluids, and the outlet fluid tank 322 collects the heated working fluids flowing through the plurality of micro-channels. The plurality of micro-channels 323 is disposed between the inlet fluid tank 321 and the outlet fluid tank 322. The cross-sectional area of each of the micro-channels 323 gradually increases along the direction from the inlet fluid tank 321 towards the outlet fluid tank 322, and, conversely, the cross-sectional area of the channel wall 323 between two adjacent micro-channels gradually decreases along the direction from the inlet fluid tank 321 towards the outlet fluid tank 322. The embodiment utilizes such gradually-widening channel width design of the micro-channels 323, and, therefore, can prevent the backflow of bubbles in the fluid. The micro-channels 323 are able to continuously deliver the working fluids without being blocked by the bubbles. That is, the micro-channel heat sink 30 of the present invention can consistently remove a large amount of heat. The width of the channel wall 324 in this figure gradually decreases towards the outlet fluid tank 322. By contrast, another embodiment also maintains the identical cross-sectional area of the channel wall along its longitudinal direction, but the height of the micro-channel 323 gradually increases towards the outlet fluid tank 322. The two embodiments can achieve the same result in the gradually increasing cross-sectional area of the micro-channels 323 towards the outlet fluid tank 322.

In fact, gradually increasing the cross-sectional area of each micro-channel 323 can eliminate the instability phenomenon existing in the two-phase flow of the micro-channels 323. The bubbles resulting from the boiling fluid can smoothly exit the channel, and the early occurrence of the critical value of the heat transfer rate can also be suppressed. So, the micro-channel heat sink 30 can still reliably operate and maintain a high heat transfer capability even under boiling conditions.

FIG. 4 is a schematic diagram showing an assembly of a micro-channel heat sink and an electrical component in accordance with the present invention. An electrical component 80, e.g., a device with a ball grid array package and the micro-channel heat sink 30 are combined with each other by a thermal adhesive 90, and the heat generated from the electrical component 80 is transferred to the micro-channel heat sink 30 through the thermal grease 90. The upper cover layer 31 and the cooling layer 32 of the micro-channel heat sink 30 enclose the closed micro-channels 323 that are arranged in parallel and connect to the inlet fluid tank 321 and the outlet fluid tank 322 opposite each other. The micro-channels 323, inlet fluid tank 321, and outlet fluid tank 322 are filled with the working fluid 60 that cycles from the inlet pipe 71 to the outlet pipe 72, and, meanwhile, the heat generated from the electrical component 80 is quickly and steadily removed by the cooling layer 32.

FIG. 5 is a schematic diagram showing an assembly of a micro-channel heat sink and an electrical component in accordance with another embodiment of the present invention. The chip of the heat-generating electrical component 80 in FIG. 4 cannot directly contact the micro-channel heat sink 30. The heat is transferred through the molding compound of the electrical component with a low heat transfer coefficient. However, the molding compound limits the heat dissipation efficiency of the micro-channel heat sink 30. The micro-channel heat sink 30 in FIG. 5 is integrated with the IC chip 31', and the IC chip 31' replaces the upper cover layer 31 of the micro-channel heat sink 30 shown in FIG. 4. Therefore, the working fluid 60 can directly remove the heat generated by the chip 31'. Furthermore, the chip 31' is connected to a substrate 53 with high temperature tin balls 51 through a flip chip process. The high temperature tin balls 51 are protected from external force by filling an underfill adhesive 52 therebetween, such as epoxy resin. A plurality of eutectic tin balls 54 are provided on the lower surface of the substrate 53, and act as contacts between the electrical component 50 and an external printed circuit board.

The above-described embodiments of the present invention are intended to be illustrative only. Those skilled in the art may devise numerous alternative embodiments without departing from the scope of the following claims.

What is claimed is:
1. A micro-channel heat sink, comprising:
a cooling layer, comprising:
- at least one inlet fluid tank storing and delivering a working fluid;
- at least one outlet fluid tank collecting and draining the working fluid; and
-a plurality of micro-channels disposed between the inlet fluid tank and the outlet fluid tank, wherein the cross-sectional area of each of the micro-channels increases along a direction towards the outlet fluid tank; and
-an upper cover layer covering the plurality of micro-channels.
2. The micro-channel heat sink of claim 1, wherein the upper cover layer is an IC chip.
3. The micro-channel heat sink of claim 1, wherein the cross-sectional area of the micro-channel gradually increases along the direction towards the outlet fluid tank.
4. The micro-channel heat sink of claim 3, wherein the width of the micro-channel gradually increases along the direction towards the outlet fluid tank.
5. The micro-channel heat sink of claim 3, wherein the depth of the micro-channel gradually increases along the direction towards the outlet fluid tank.
6. The micro-channel heat sink of claim 1, further comprising a plurality of channel walls separating the plurality of micro-channels, wherein the cross-sectional area of the channel wall gradually decreases along the direction towards the outlet fluid tank.
7. The micro-channel heat sink of claim 1, wherein the cooling layer comprises a silicon material.
8. The micro-channel heat sink of claim 1, wherein the plurality of micro-channels are arranged in parallel.
9. The micro-channel heat sink of claim 1, wherein the upper cover layer can be joined to an electrical component using a thermal adhesive.
10. The micro-channel heat sink of claim 1, wherein the micro-channel can prevent backflow of bubbles in the boiling working fluid and instability of a two-phase flow resulting from the backflow.