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(54) COUNTER FLOW MICRO HEAT EXCHANGER FOR OPTIMAL PERFORMANCE

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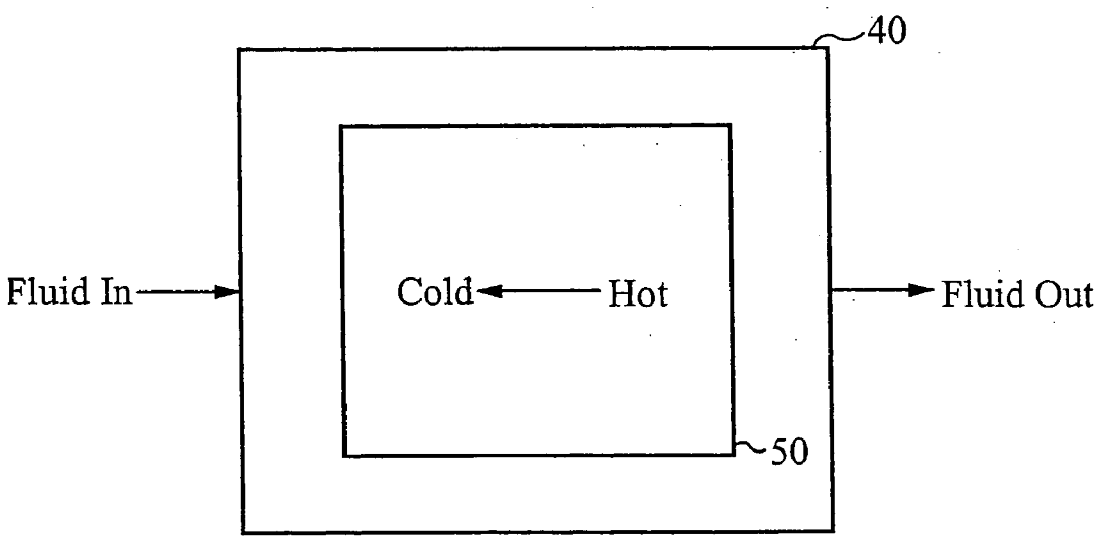
(57) **ABSTRACT**

A micro heat exchanger and an integrated circuit are oriented according to a counter flow orientation. To determine this orientation, a temperature gradient of the integrated circuit is determined. The temperature gradient is used to determine a temperature vector that preferably indicates a directional orientation from a hot portion of the integrated circuit to a cold portion. The micro heat exchanger circulates a cooling fluid to receive heat transferred from the integrated circuit. A directional flow of this cooling liquid is determined. The directional flow is measured as a directional vector from an inlet of the micro heat exchanger to an outlet. The counter flow orientation is defined as the temperature vector oriented opposite that of the directional flow.



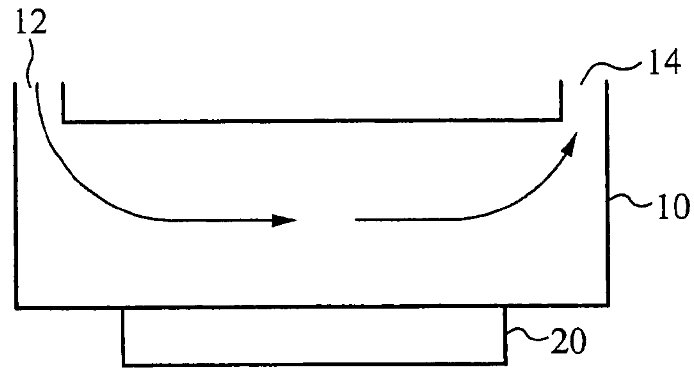


Fig. 1

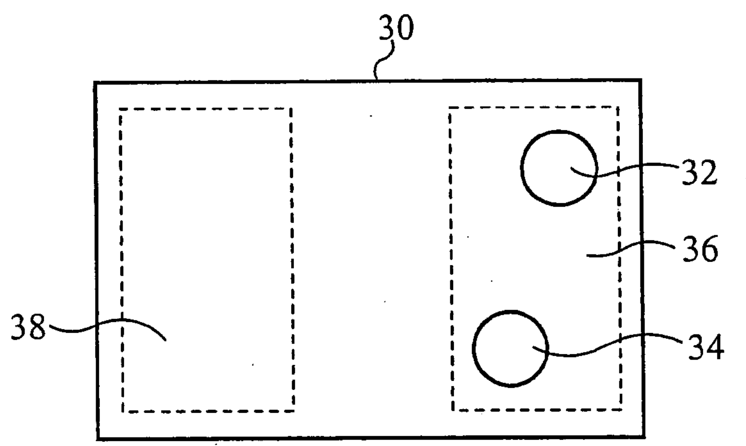


Fig. 2

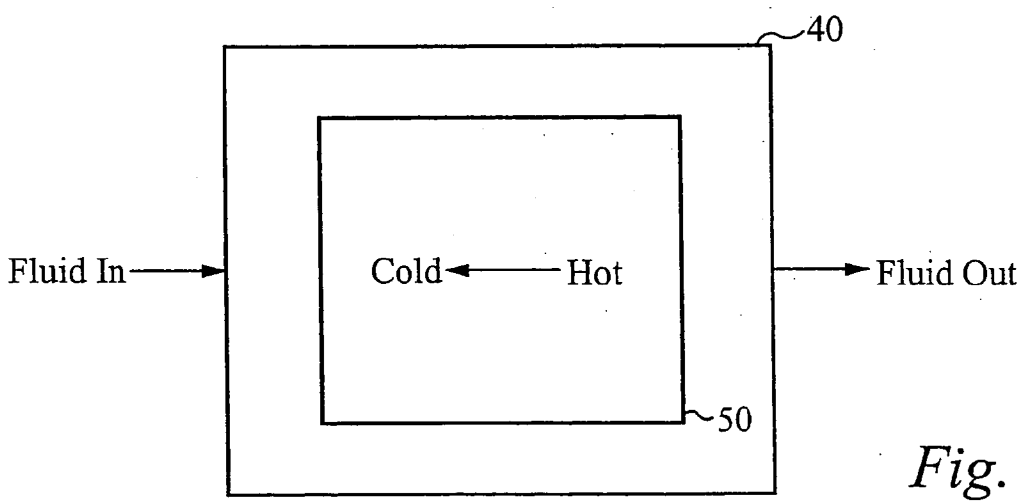


Fig. 3

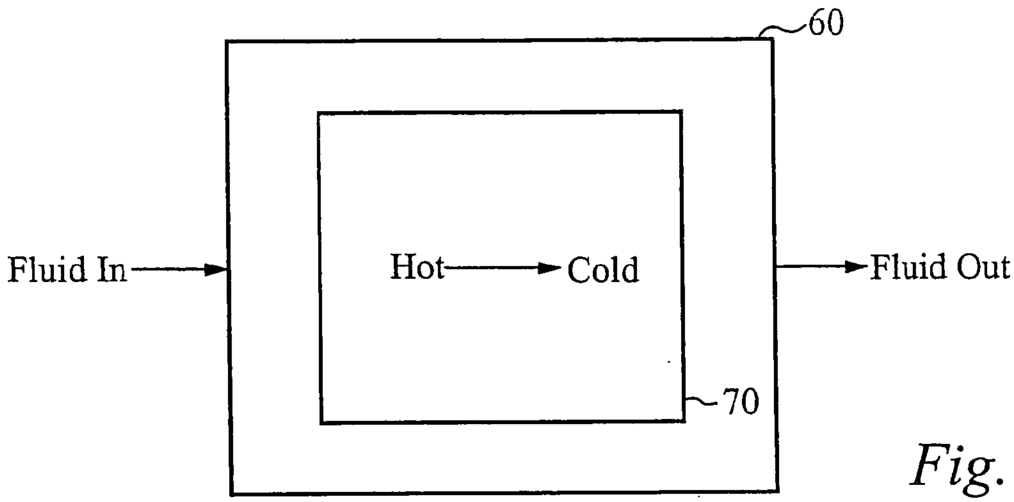


Fig. 4

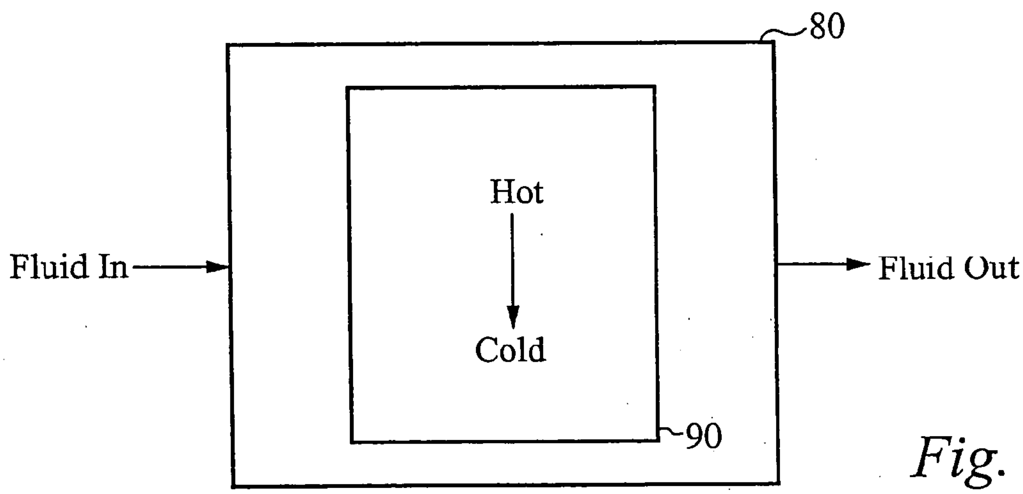


Fig. 5

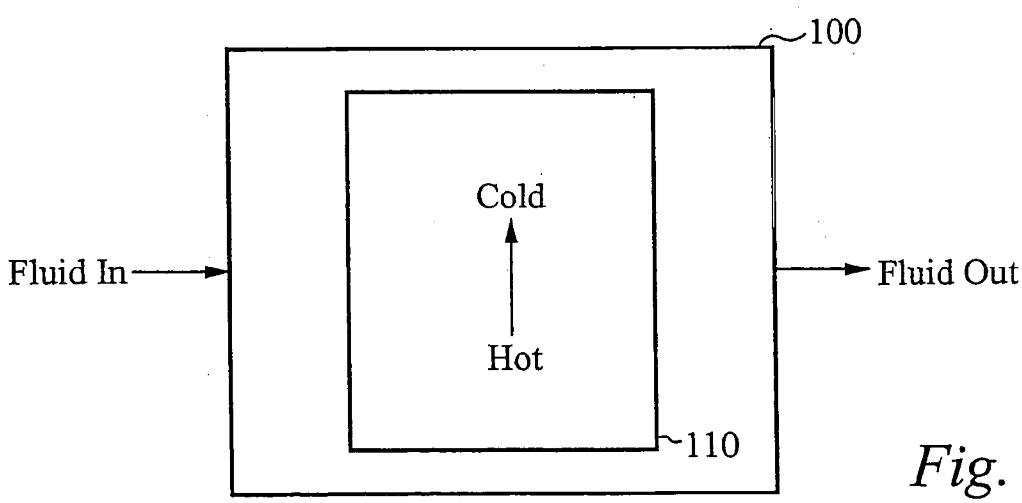


Fig. 6

COUNTER FLOW MICRO HEAT EXCHANGER FOR OPTIMAL PERFORMANCE

RELATED APPLICATION

[0001] This Patent Application claims priority under 35 U.S.C. 119 (e) of the co-pending U.S. Provisional Patent Application Ser. No. 60/577,262 filed Jun. 4, 2004, and entitled "MULTIPLE COOLING TECHNIQUES". The Provisional Patent Application, Ser. 60/577,262 filed Jun. 4, 2004, and entitled "MULTIPLE COOLING TECHNIQUES" is also hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The invention relates to a method and apparatus for cooling a heat source. In particular, the invention relates to a micro heat exchanger using counter flow to optimally cool an integrated circuit.

BACKGROUND OF THE INVENTION

[0003] As integrated circuits increase in complexity, performance, and density, the heat produced by these integrated circuits also increases. Dissipating or otherwise removing this ever increasing heat is critical to further advancement of integrated circuits.

[0004] A heat exchanger is used to transfer heat from a heat source, such as an integrated circuit, to another medium, such as a fluid. Many methods for improving heat transfer from the heat source to the heat exchanger have been developed. Examples of such methods include optimizing the shape and/or configuration of microchannels or fins within a heat exchanger, and improving a thermal interface between the heat source and the heat exchanger by using surface materials with similar thermal conductivity. The performance of a heat exchanger is also dependent on several other factors such as flow rate of a cooling liquid used within the heat exchanger, and the manifold configuration used to provide the cooling liquid to particular areas within the heat exchanger.

[0005] Examples of heat exchanger inventions are described in co-pending U.S. patent application Ser. No. 10/439,635, filed on May 16, 2003, and entitled "METHODS FOR FLEXIBLE FLUID DELIVERY AND HOTSPOT COOLING BY MICROCHANNEL HEATSINKS", co-pending U.S. patent application Ser. No. 10/439,912, filed on May 16, 2003, and entitled "INTERWOVEN MANIFOLDS FOR PRESSURE DROP REDUCTION IN MICROCHANNEL HEAT EXCHANGERS", co-pending U.S. patent application Ser. No. (Cool 00303), filed on Jun. 29, 2004, and entitled "INTERWOVEN MANIFOLDS FOR PRESSURE DROP REDUCTION IN MICROCHANNEL HEAT EXCHANGERS", co-pending U.S. patent application Ser. No. (Cool 00304), filed on Jun. 29, 2004, and entitled "METHODS FOR FLEXIBLE FLUID DELIVERY AND HOTSPOT COOLING BY MICROCHANNEL HEATSINKS", co-pending U.S. patent application Ser. No. (Cool 00305), filed on ______, and entitled "APPARATUS FOR EFFICIENT VERTICAL FLUID DELIVERY FOR COOLING A HEAT PRODUCING DEVICE", co-pending U.S. patent application Ser. No. 10/680,584, filed on Oct. 6, 2003, and entitled "METHOD AND APPARATUS FOR EFFICIENT VERTICAL FLUID DELIVERY FOR COOLING A HEAT PRODUCING DEVICE", co-pending U.S. patent application Ser. No. 10/698,179, filed on Oct. 30, 2003, and entitled "METHOD AND APPARATUS FOR EFFICIENT VERTICAL FLUID DELIVERY FOR COOLING A HEAT PRODUCING DEVICE", and co-pending U.S. patent application Ser. No. (Cool 01303), filed on Jun. 29, 2004, and entitled "METHOD AND APPARATUS FOR EFFICIENT VERTICAL FLUID DELIVERY FOR COOLING A HEAT PRODUCING DEVICE", which are hereby incorporated by reference.

[0006] As more and more heat is generated by each successive generation of integrated circuits, there is an ever increasing need to improve the efficiency of transferring heat away from the heat source.

SUMMARY OF THE INVENTION

[0007] In one aspect of the present invention, a method cools an integrated circuit using a micro heat exchanger. The method includes determining a temperature gradient associated with the integrated circuit, determining a first vector beginning at a hot portion of the silicon case temperature profile and ending at a cold portion of the silicon case temperature profile, determining a directional flow of a fluid within the micro heat exchanger, orienting the micro heat exchanger to the integrated circuit such that the first vector of the integrated circuit is aligned counter with the directional flow of the micro heat exchanger, thereby forming a counter flow alignment, and coupling the micro heat exchanger to the integrated circuit according to the counter flow alignment. **FIG. 3** illustrates an example of such an alignment. The directional flow can correspond to the flow of the fluid from an input port of the micro heat exchanger to an output port of the micro heat exchanger. The directional flow can correspond to a second vector beginning at the input port and ending at the output port of the micro heat exchanger. An input temperature of the fluid at the input port can be less than an output temperature of the fluid at the output port. The input port can be positioned at the cold portion of the integrated circuit, and the output port is positioned at the hot portion of the integrated circuit. An actual flow direction of the fluid at a given point in the micro heat exchanger can be different than the directional flow. The hot portion can correspond to a highest temperature on the temperature gradient. The cold portion can correspond to a coldest temperature on the temperature gradient.

[0008] In another aspect of the present invention, a method cools an integrated circuit using a micro heat exchanger. The method includes determining a temperature gradient from hot to cold across the integrated circuit, determining a first vector beginning at a hot portion of the temperature gradient and ending at a cold portion of the temperature gradient, determining a second vector corresponding to a directional flow of a fluid from an inlet to an outlet within the micro heat exchanger, and coupling the micro heat exchanger to the integrated circuit such that the first vector of the integrated circuit is aligned perpendicular to the second vector of the micro heat exchanger. **FIGS. 5 and 6** illustrate examples of such alignments. An input temperature of the fluid at the inlet can be less than an output temperature of the fluid at the outlet. An actual flow direction of the fluid at a given point in the micro heat exchanger can be different than the second vector. The hot portion can correspond to a highest temperature on the temperature gradient. The cold portion can correspond to a coldest temperature on the temperature gradient.

[0009] In yet another aspect of the present invention, a micro heat exchanger and integrated chip assembly includes an integrated chip, wherein the integrated circuit includes an associated temperature gradient, and a first vector begins at a hot portion of the temperature gradient and ends at a cold portion of the temperature gradient, and a micro heat exchanger coupled to the integrated circuit, the micro heat exchanger including an input port to receive a fluid and an output port for expelling the fluid, wherein a second vector begins at the input port and ends at the output port, wherein the micro heat exchanger and the integrated circuit are oriented such that the first vector of the integrated circuit is aligned counter with the second vector of the micro heat exchanger. The second vector preferably defines a directional flow of the fluid. The input temperature of the fluid at the input port can be less than an output temperature of the fluid at the output port. The input port can be positioned at the cold portion of the integrated circuit, and the output port is positioned at the hot portion of the integrated circuit. An actual flow direction of the fluid at a given point in the micro heat exchanger can be different than the second vector. The hot portion can correspond to a highest temperature on the temperature gradient. The cold portion can correspond to a coldest temperature on the temperature gradient.

[0010] In still yet another aspect of the present invention, a method cools an integrated circuit using a micro heat exchanger. The method includes determining a temperature gradient from hot to cold across the integrated circuit, determining a first vector beginning at a hot portion of the temperature gradient and ending at a cold portion of the temperature gradient, determining a second vector corresponding to a directional flow of a fluid from an inlet to an outlet within the micro heat exchanger, and coupling the micro heat exchanger to the integrated circuit such that the first vector of the integrated circuit is aligned with the second vector of the micro heat exchanger. **FIG. 4** illustrates an example of such an alignment. An input temperature of the fluid at the inlet can be less than an output temperature of the fluid at the outlet. The inlet can be positioned at the hot portion of the integrated circuit, and the outlet is positioned at the cold portion of the integrated circuit. An actual flow direction of the fluid at a given point in the micro heat exchanger can be different than the second vector. The hot portion can correspond to a highest temperature on the temperature gradient. The cold portion can correspond to a coldest temperature on the temperature gradient.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** illustrates a side view of an exemplary integrated circuit coupled to an exemplary micro heat exchanger.

[0012] **FIG. 2** illustrates a plan view of an exemplary integrated chip.

[0013] **FIG. 3** illustrates a plan view of an exemplary micro heat exchanger superimposed over an exemplary integrated circuit, where the micro heat exchanger and the integrated circuit are configured according to a preferred counter flow orientation.

[0014] **FIG. 4** illustrates a plan view of an exemplary micro heat exchanger superimposed over an exemplary integrated circuit, where the micro heat exchanger and the integrated circuit are configured according to a first alternative orientation.

[0015] **FIG. 5** illustrates a plan view of an exemplary micro heat exchanger superimposed over an exemplary integrated circuit, where the micro heat exchanger and the integrated circuit are configured according to a second alternative orientation.

[0016] **FIG. 6** illustrates a plan view of an exemplary micro heat exchanger superimposed over an exemplary integrated circuit, where the micro heat exchanger and the integrated circuit are configured according to a third alternative orientation.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

[0017] Embodiments of the present invention are directed to improving the thermal performance of a micro heat exchanger and/or a cold plate. Thermal performance is dependent on several factors, such as flow rate of the cooling fluid through the micro heat exchanger, dimensions of the thermally conductive elements within the micro heat exchanger, and the configuration of the manifold through which the fluid is delivered to the thermally conductive elements. It is understood that other factors contribute to the thermal performance of a micro heat exchanger.

[0018] Within the embodiments of the present invention, a micro heat exchanger is preferably used to remove heat from an integrated circuit, such as a microprocessor. It is understood that the micro heat exchanger can be used to remove heat from other types of heat sources. In the case where the integrated circuit has a non-uniform heat flux, a temperature gradient of the integrated circuit is determined. In most such cases, one portion, or side, of the integrated circuit is hotter than a remaining portion or side of the integrated circuit. The temperature gradient is a measure of the varying temperature across the integrated circuit. The temperature is preferably measured at a top surface of the integrated circuit, where the top surface is the surface of the integrated circuit that comes in contact with the micro heat exchanger. The temperature gradient of the integrated circuit can be described as either rising from the cold portion of the integrated circuit to the hot portion, or falling from the hot portion to the cold portion. It is understood that the terms "hot" and "cold" are used in a relative sense. That is, the "hot" portion of the integrated circuit is that portion that is hotter than the remaining integrated circuit. Similarly, the "cold" portion of the integrated circuit is that portion that is colder than the remaining integrated circuit. The "cold" portion can just as easily be referred to as a "warmer" or "less hot" portion. The relative use of the term "cold" refers to that portion of the integrated circuit that is colder than the "hot" portion of the integrated circuit.

[0019] Once the temperature gradient of the integrated circuit is determined, a temperature vector is determined. The temperature vector is a measure of a general heat "flow" across the integrated circuit. In the preferred embodiment, the temperature vector is measured as a directional vector that points from the hot portion of the integrated circuit to the cold portion of the integrated circuit. It is understood that there can be numerous hot spots scattered across the integrated circuit. However, in most cases, a compilation of all temperature variances across the integrated circuit yields a general temperature vector. That is, when the temperature gradient is measured across the entire integrated circuit, in any non-uniform heat flux application, one portion of the integrated circuit is found to be hotter than another portion of the integrated circuit. The temperature vector is a directional vector that preferably points from the hot portion to the cold portion of the integrated circuit.

[0020] The temperature vector of the integrated circuit is then used to properly orient the micro heat exchanger on top of the integrated circuit. To determine the proper orientation, a directional flow of the fluid through the micro heat exchanger is determined. In a preferred micro heat exchanger, the cooling fluid enters the micro heat exchanger at one inlet or a plurality of inlets. The cooling fluid exits the micro heat exchanger at one outlet or a plurality of outlets. Although the cooling fluid can flow in various directions within the micro heat exchanger, the directional flow is preferably determined as a directional vector generally pointing from the inlet to the outlet, or as the combined vector from one or more inlets to one or more outlets.

[0021] In the preferred embodiment of the present invention, when the micro heat exchanger is coupled to the top of the integrated circuit, the micro heat exchanger is oriented such that the directional vector of the fluid flow is opposite that of the temperature vector of the integrated circuit. In other words, the inlet of the micro heat exchanger is positioned proximate the cold portion of the integrated circuit, and the outlet of the micro heat exchanger is positioned proximate the hot portion of the integrated circuit. This preferred orientation is referred to as a counter flow orientation. In the case where the integrated circuit has non-uniform heat flux, thermal performance of the micro heat exchanger is improved by designing a counter flow direction for the liquid flow through the micro heat exchanger. The inlet and the outlet of the micro heat exchanger are in a direction counter to the temperature gradient (hot to cold) of heat flux on the integrated circuit.

[0022] **FIG. 1** illustrates a side sectional view of an exemplary integrated circuit **20** coupled to an exemplary micro heat exchanger **10**. The integrated circuit **20** and the micro heat exchanger **10** are coupled to form a thermal interface there between. A fluid flows through the micro heat exchanger **10** from an inlet **12** to an outlet **14**. A fluid path through the micro heat exchanger **10** generally includes various changes in direction and/or elevation. An overall directional flow of the fluid through the micro heat exchanger **10** is defined as the direction, or vector, from the inlet **12** to the outlet **14**. It will be understood that there can be discrete regions in the heat exchanger that have fluid flow in any direction including opposite that of the general fluid flow direction. The micro heat exchanger **10** can be of any conventional type that uses active liquid cooling. Preferably, the micro heat exchanger **10** is a micro heat exchanger as described in the co-pending U.S. patent application Ser. No. 10/439,635, filed on May 16, 2003, and entitled "METHODS FOR FLEXIBLE FLUID DELIVERY AND HOTSPOT COOLING BY MICROCHANNEL HEATSINKS", co-pending U.S. patent application Ser. No. 10/439,912, filed on May 16, 2003, and entitled "INTERWOVEN MANIFOLDS FOR PRESSURE DROP REDUCTION IN MICROCHANNEL HEAT EXCHANGERS", co-pending U.S. patent application Ser. No. (Cool 00303), filed on Jun. 29, 2004, and entitled "INTERWOVEN MANIFOLDS FOR PRESSURE DROP REDUCTION IN MICROCHANNEL HEAT EXCHANGERS", co-pending U.S. patent application Ser. No. (Cool 00304), filed on Jun. 29, 2004, and entitled "METHODS FOR FLEXIBLE FLUID DELIVERY AND HOTSPOT COOLING BY MICROCHANNEL HEATSINKS", co-pending U.S. patent application Ser. No. (Cool 00305), filed on ______, and entitled "APPARATUS FOR EFFICIENT VERTICAL FLUID DELIVERY FOR COOLING A HEAT PRODUCING DEVICE", co-pending U.S. patent application Ser. No. 10/680,584, filed on Oct. 6, 2003, and entitled "METHOD AND APPARATUS FOR EFFICIENT VERTICAL FLUID DELIVERY FOR COOLING A HEAT PRODUCING DEVICE", co-pending U.S. patent application Ser. No. 10/698,179, filed on Oct. 30, 2003, and entitled "METHOD AND APPARATUS FOR EFFICIENT VERTICAL FLUID DELIVERY FOR COOLING A HEAT PRODUCING DEVICE", or co-pending U.S. patent application Ser. No. (Cool 01303), filed on Jun. 29, 2004, and entitled "METHOD AND APPARATUS FOR EFFICIENT VERTICAL FLUID DELIVERY FOR COOLING A HEAT PRODUCING DEVICE", which are hereby incorporated by reference. As the fluid flows through the micro heat exchanger **10**, heat is transferred from the integrated circuit **20** to the fluid. The heated fluid exits the micro heat exchanger **10** at the outlet **14**. The fluid entering at the inlet **12** is preferably cooler than the fluid exiting at the outlet **14**.

[0023] **FIG. 2** illustrates a plan view of an exemplary integrated chip **30**. Most integrated circuits include a non-uniform heat flux. The integrated circuit **30** shown in **FIG. 2** includes two hot spots, hot spot **32** and hot spot **34**. In general, the integrated circuit **30** can be characterized as having a hot portion **36**, which includes the hot spots **32** and **34**, and a cold portion **38**. As described above, the terms "hot" and "cold" are terms used relative to each other. A temperature gradient is defined as the change in temperature across the integrated circuit, in this case integrated circuit **30**. A temperature vector is preferably defined as the vector from the hot portion **36** of the integrated circuit **30** to the cold portion **38** of the integrated circuit **30**.

[0024] **FIG. 3** illustrates a plan view of an exemplary micro heat exchanger **40** superimposed over an exemplary integrated circuit **50**, where the micro heat exchanger **40** and the integrated circuit **50** are configured according to a preferred counter flow orientation relative to each other. As shown in **FIG. 3**, the directional flow of the fluid through the micro heat exchanger **40** is from left to right, that is from an inlet of the micro heat exchanger **40** to an outlet. The temperature vector of the integrated circuit **50** is from right to left, that is from a hot portion of the integrated circuit **50** to a cold portion. In the preferred counter flow orientation, the directional flow of the fluid is substantially parallel, but opposite in direction to the temperature vector of the integrated circuit.

[0025] **FIG. 4** illustrates a plan view of an exemplary micro heat exchanger **60** superimposed over an exemplary integrated circuit **70**, where the micro heat exchanger **60** and the integrated circuit **70** are configured according to a first alternative orientation. As shown in **FIG. 4**, the directional flow of the fluid through the micro heat exchanger **60** is from left to right, that is from an inlet of the micro heat exchanger **60** to an outlet. The temperature vector of the integrated circuit **70** is from left to right, that is from a hot portion of the integrated circuit **70** to a cold portion. In this first alternative orientation, the directional flow of the fluid is substantially parallel, and in the same direction to the temperature vector of the integrated circuit **70**. This first alternative orientation of the micro heat exchanger **60** to the integrated circuit **70** is referred to as a parallel flow orientation.

[**0026**] **FIG. 5** illustrates a plan view of an exemplary micro heat exchanger **80** superimposed over an exemplary integrated circuit **90**, where the micro heat exchanger **80** and the integrated circuit **90** are configured according to a second alternative orientation. As shown in **FIG. 5**, the directional flow of the fluid through the micro heat exchanger **80** is from left to right, that is from an inlet of the micro heat exchanger **80** to an outlet. The temperature vector of the integrated circuit **90** is from top to bottom, that is from a hot portion of the integrated circuit **90** to a cold portion. In this second alternative orientation, the directional flow of the fluid is substantially perpendicular to the temperature vector of the integrated circuit **90**. This second alternative orientation of the micro heat exchanger **80** to the integrated circuit **90** is referred to as a cross flow orientation.

[**0027**] **FIG. 6** illustrates a plan view of an exemplary micro heat exchanger **100** superimposed over an exemplary integrated circuit **110**, where the micro heat exchanger **100** and the integrated circuit **110** are configured according to a third alternative orientation. As shown in **FIG. 6**, the directional flow of the fluid through the micro heat exchanger **100** is from left to right, that is from an inlet of the micro heat exchanger **100** to an outlet. The temperature vector of the integrated circuit **110** is from bottom to top, that is from a hot portion of the integrated circuit **110** to a cold portion. In this third alternative orientation, the directional flow of the fluid is substantially perpendicular to the temperature vector of the integrated circuit **110**. This third alternative orientation of the micro heat exchanger **100** to the integrated circuit **110** is also referred to as a cross flow orientation.

[**0028**] To orient a micro heat exchanger to an integrated circuit according to the preferred embodiment of the present invention, a temperature gradient of the integrated circuit is determined. The temperature gradient is used to determine a temperature vector that preferably indicates a directional orientation from a hot portion of the integrated circuit to a cold portion. The micro heat exchanger preferably circulates a cooling fluid to receive heat transferred from the integrated circuit. A directional flow of this cooling liquid is determined. The directional flow is preferably measured as a directional vector from an inlet of the micro heat exchanger to an outlet. Once the temperature vector of the integrated circuit and the directional flow of the micro heat exchanger are determined, the micro heat exchanger and the integrated circuit are preferably oriented according to a counter flow orientation. The counter flow orientation is defined as the temperature vector oriented opposite that of the directional flow. In other words, the micro heat exchanger and the integrated circuit are aligned such that the cooling liquid enters the micro heat exchanger at a point substantially above the cold portion of the integrated circuit, and the cooling liquid exits the micro heat exchanger at a point substantially above the hot portion of the integrated circuit.

[**0029**] The present invention has been described in terms of specific embodiments incorporating details to facilitate the understanding of the principles of construction and operation of the invention. Such reference herein to specific embodiments and details thereof is not intended to limit the scope of the claims appended hereto. It will be apparent to those skilled in the art that modifications may be made in the embodiment chosen for illustration without departing from the spirit and scope of the invention.

What is claimed is:

1. A method of cooling an integrated circuit using a micro heat exchanger, the method comprising:

a. determining a temperature gradient associated with the integrated circuit;

b. determining a first vector beginning at a hot portion of the temperature gradient and ending at a cold portion of the temperature gradient;

c. determining a directional flow of a fluid within the micro heat exchanger;

d. orienting the micro heat exchanger to the integrated circuit such that the first vector of the integrated circuit is aligned counter with the directional flow of the micro heat exchanger, thereby forming a counter flow alignment; and

e. coupling the micro heat exchanger to the integrated circuit according to the counter flow alignment.

2. The method of claim 1 wherein the directional flow corresponds to the flow of the fluid from an input port of the micro heat exchanger to an output port of the micro heat exchanger.

3. The method of claim 2 wherein the directional flow corresponds to a second vector beginning at the input port and ending at the output port of the micro heat exchanger.

4. The method of claim 2 wherein an input temperature of the fluid at the input port is less than an output temperature of the fluid at the output port.

5. The method of claim 4 wherein the input port is positioned at the cold portion of the integrated circuit, and the output port is positioned at the hot portion of the integrated circuit

6. The method of claim 1 wherein an actual flow direction of the fluid at a given point in the micro heat exchanger is different than the directional flow.

7. The method of claim 1 wherein the hot portion corresponds to a highest temperature on the temperature gradient.

8. The method of claim 1 wherein the cold portion corresponds to a coldest temperature on the temperature gradient.

9. A method of cooling an integrated circuit using a micro heat exchanger, the method comprising:

a. determining a temperature gradient from hot to cold across the integrated circuit;

b. determining a first vector beginning at a hot portion of the temperature gradient and ending at a cold portion of the temperature gradient;

c. determining a second vector corresponding to a directional flow of a fluid from an inlet to an outlet within the micro heat exchanger; and

d. coupling the micro heat exchanger to the integrated circuit such that the first vector of the integrated circuit is aligned perpendicular to the second vector of the micro heat exchanger.

10. The method of claim 10 wherein an input temperature of the fluid at the inlet is less than an output temperature of the fluid at the outlet.

11. The method of claim 10 wherein an actual flow direction of the fluid at a given point in the micro heat exchanger is different than the second vector.

12. The method of claim 10 wherein the hot portion corresponds to a highest temperature on the temperature gradient.

13. The method of claim 10 wherein the cold portion corresponds to a coldest temperature on the temperature gradient.

14. A micro heat exchanger and integrated chip assembly comprising:

a. an integrated chip, wherein the integrated circuit includes an associated temperature gradient, and a first vector begins at a hot portion of the temperature gradient and ends at a cold portion of the temperature gradient; and

b. a micro heat exchanger coupled to the integrated circuit, the micro heat exchanger including an input port to receive a fluid and an output port for outputting the fluid, wherein a second vector begins at the input port and ends at the output port,

wherein the micro heat exchanger and the integrated circuit are oriented such that the first vector of the integrated circuit is aligned counter with the second vector of the micro heat exchanger.

15. The assembly of claim 14 wherein the second vector defines a directional flow of the fluid.

16. The assembly of claim 14 wherein an input temperature of the fluid at the input port is less than an output temperature of the fluid at the output port.

17. The assembly of claim 16 wherein the input port is positioned at the cold portion of the integrated circuit, and the output port is positioned at the hot portion of the integrated circuit

18. The assembly of claim 14 wherein an actual flow direction of the fluid at a given point in the micro heat exchanger is different than the second vector.

19. The assembly of claim 14 wherein the hot portion corresponds to a highest temperature on the temperature gradient.

20. The assembly of claim 14 wherein the cold portion corresponds to a coldest temperature on the temperature gradient.

21. A method of cooling an integrated circuit using a micro heat exchanger, the method comprising:

a. determining a temperature gradient from hot to cold across the integrated circuit;

b. determining a first vector beginning at a hot portion of the temperature gradient and ending at a cold portion of the temperature gradient;

c. determining a second vector corresponding to a directional flow of a fluid from an inlet to an outlet within the micro heat exchanger; and

d. coupling the micro heat exchanger to the integrated circuit such that the first vector of the integrated circuit is aligned with the second vector of the micro heat exchanger.

22. The method of claim 21 wherein an input temperature of the fluid at the inlet is less than an output temperature of the fluid at the outlet.

23. The method of claim 22 wherein the inlet is positioned at the hot portion of the integrated circuit, and the outlet is positioned at the cold portion of the integrated circuit

24. The method of claim 21 wherein an actual flow direction of the fluid at a given point in the micro heat exchanger is different than the second vector.

25. The method of claim 21 wherein the hot portion corresponds to a highest temperature on the temperature gradient.

26. The method of claim 21 wherein the cold portion corresponds to a coldest temperature on the temperature gradient.

* * * * *