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(54) **MINIATURE ACTUATOR INTEGRATION FOR LIQUID COOLING**

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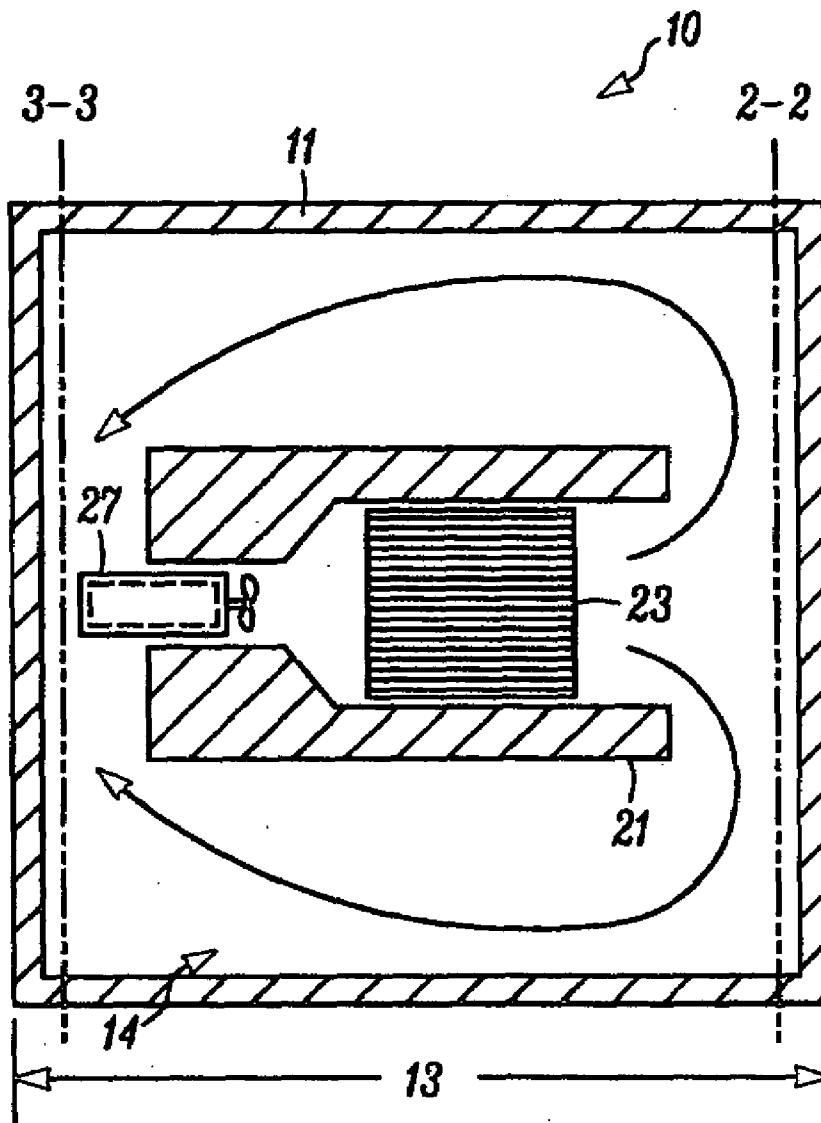
(57) **ABSTRACT**

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A device for cooling integrated circuits on circuit boards. A base placed proximate the element to be cooled contains an actuator that forces a cooling liquid through a plurality of channels that dissipate heat generated by the element. The base with the actuator, liquid and channels is sealed with a top. Preferred actuators are electric motors, and MEMS such as electrostatic actuators and piezoelectric actuators. The base has a large surface area relative to the thickness of the chamber. The ratio of the surface area to thickness may range from about 40:1 to about 5:1.

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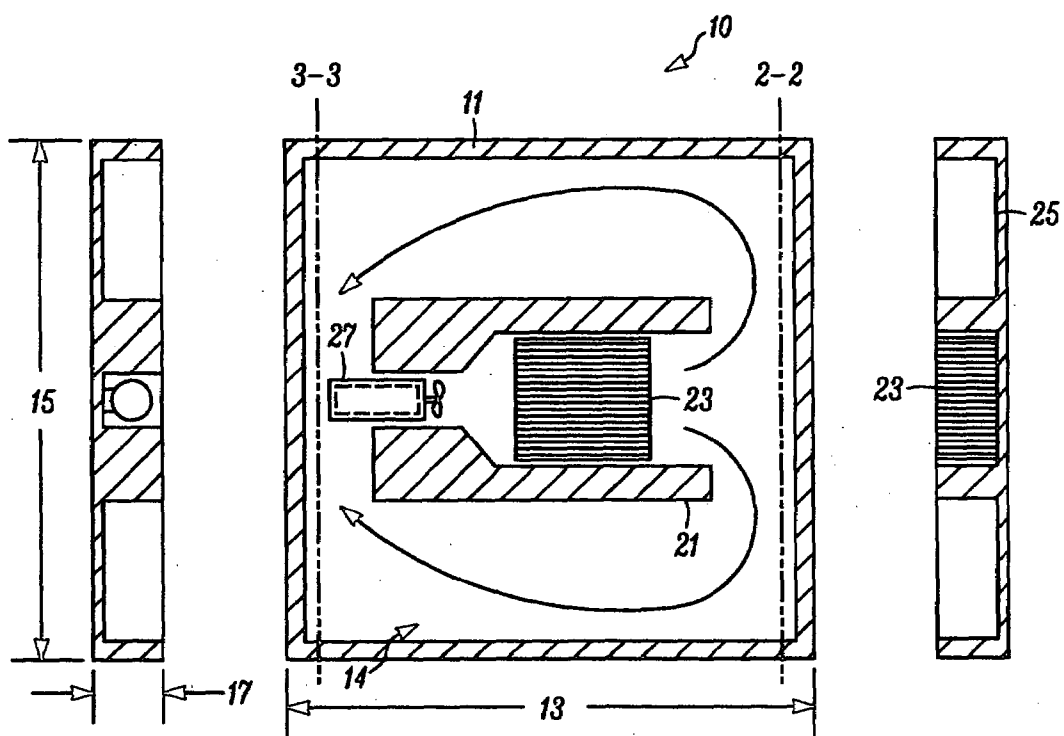


FIG. 3

FIG. 1

FIG. 2

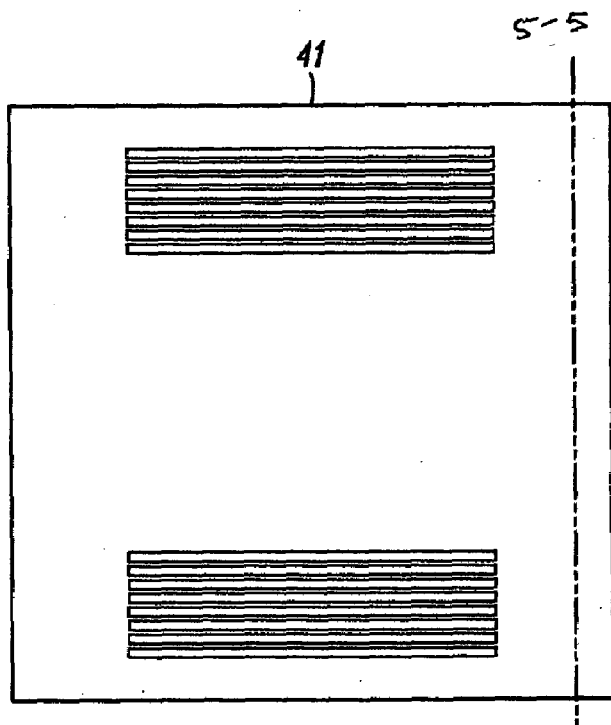


FIG. 4

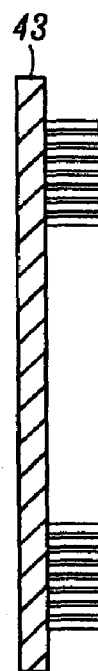


FIG. 5

MINIATURE ACTUATOR INTEGRATION FOR LIQUID COOLING

FIELD OF THE INVENTION

[0001] The present invention relates in general to liquid cooling of integrated circuits and, more particularly, to low cost miniature actuators incorporated directly into the heat spreader or sink.

BACKGROUND OF THE INVENTION

[0002] Liquid cooling is known to have a significantly better heat transfer capability than solid conduction cooling. However, a low cost method of recirculating liquids through a hot region of an integrated circuit (IC) has yet to be successfully accomplished. Also, in CPUs, it is possible to use fans and blowers to move air across those components that generate heat, but it is also not as efficient as liquid heat transfer methods.

[0003] The current method for regular desktop CPU cooling is a passive component of air cooled thermal solutions. Located above a silicon chip on a IC board is a heat spreader, such as a flat conductive sheet of, for example, copper or other conductive materials. Above the flat conductive sheet is a heat sink, which comprises a flat surface interfacing the flat conductive sheet and a plurality of outwardly extending elements that contain a heat transfer thermal solution that is air cooled by air passing through and adjacent to the outwardly extending elements.

[0004] It has been proposed to cool ICs using an external pump. However, these pumps are quite expensive compared to the cost of the IC, and do not always seal effectively. None have demonstrated an expectation to meet an IC life requirement of 3 to 7 years or more.

[0005] One of the major costs in using external pump is liquid sealing, to prevent leaks and isolate the pump actuator from the liquid. In addition, some cooling systems have volume constraints, which make large pumps unfeasible. Moreover, small liquid pumps cannot meet the life requirements of most, if not all, IC designs.

[0006] At the present time there is a need for a way to cool ICs and other small sources of a lot of heat. It would be of great advantage if a liquid cooling system could be developed for most, if not all, IC designs.

[0007] Another advantage would be if the cooling system would be low in cost and high in reliability, especially over the life expectancy of the IC design.

[0008] Yet another advantage would be if a cooling system could be developed that would eliminate sealing concerns while having the appropriate capacity for the IC design.

[0009] Other advantages and features will appear hereinafter.

SUMMARY OF THE INVENTION

[0010] The present invention provides a low cost, effective liquid cooling device for cooling IC elements that generate heat when used. In its simplest form the invention includes a base that is to be placed proximate the element to be cooled that defines a chamber. Inside the chamber is an actuator that forces a cooling fluid, preferably a liquid such as water, through a plurality of channels or loops that dissipate heat generated by the element such as an IC chip. The base with the actuator, liquid and channels is sealed with a top.

[0011] Preferred actuators are electric motors, Micro-Electro-Mechanical Systems (MEMS) such as electrostatic actuators and piezoelectric actuators. The base has a large surface area relative to the thickness of the chamber. The ratio of the surface area to thickness may range from about 40:1 to about 5:1.

[0012] It is understood that the device is constructed of conductive materials and that the actuator is capable of operating in the fluid being forced through the microchannels.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] For a more complete understanding of the invention, reference is hereby made to the drawings, in which:

[0014] FIG. 1 is a side elevational view, in section, of one embodiment of the present invention;

[0015] FIG. 2 is a section view taken along the line 2-2 of FIG. 1;

[0016] FIG. 3 is a section view taken along the line 3-3 of FIG. 1;

[0017] FIG. 4 is a plan view of the top used with the device of FIG. 1; and

[0018] FIG. 5 is a section view taken along the line of FIG. 4.

[0019] In the figures, like reference characters designate identical or corresponding components and units throughout the several views.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] Referring to the figures, the device 10 generally includes a base 11, which is formed from a thermally conductive material such as copper or other thermally conductive materials used in the integrated circuit industry. Base 11 has a relatively large surface area. In one embodiment the length 13 and width 15 are about 50 mm each, while the sides 17 are about 7 mm, thus defining a chamber. This gives a ratio of surface area to thickness of about 50:7, or roughly 7:1. Preferred ratios may range from about 40:1 to about 5:1. The essential requirement is that the surface area is sufficient to dissipate all the heat from the element along its bottom. One advantage of this method is that the liquid flow inside can effectively carry and spread heat to large surface areas quite uniformly.

[0021] Inside the chamber defined by base 11 and sides 17 is a cooling fluid 19. Fluid 19 is preferably a liquid, and most preferably water. It may be appropriate to use distilled or deionized water to prevent internal reaction between the material of the base 11 and sides 17, as well as other components. Also inside the chamber is a micro channel plate 21, which includes a plurality of channels or loops 23 that define a path for the fluid 19 to flow, to present the fluid to a cooling surface area 25. Motor 27 is used to force the fluid 19 into and through the plurality of channels 23 in micro channel plate 21. Of course top 29 covers the device to form a sealed chamber that is not affected by any external contact. Top 29 may also be made of copper or other conductive materials and in a preferred embodiment is made of the same material as base 11 and sides 17.

[0022] In the figures, the actuator of this invention is shown as a motor. Any actuator that can apply pressure to a fluid and force it to pass through the micro channels is appropriate for this invention. Other actuators include, but are not limited to, electrostatic actuators and piezoelectric actuators that are

commercially available. All that is required is that the actuator, whether a motor or other device, have the power to force the liquid through the micro channels and operate over the expected life of the device, which should be at least three to seven years and preferably up to ten years or more.

[0023] One advantage of the present invention is that with the actuator, such as motor 27, sealed with the liquid together inside the chamber, the device does not have liquid sealing issues that occur when external pumps are used. Thus the device has a substantially improved actuating reliability.

[0024] The present invention also demonstrates a strong lateral heat spreading capability that makes it admirably suitable for removing heat from a small area, such as an IC chip. The device spreads the heat to a large area, as shown, or carries the heat in the liquid to an external heat sink or heat exchanger. It is also possible to transfer the heat-containing liquid through an outlet to a liquid-air heat exchanger or other heat sink that may or may not be cooled by a fan or blower. In effect the present invention provides a number of ways to dissipate the heat generated by an element, such as but not limited to IC elements. It may operate to transmit the heat containing fluid in the micro channels 23 in contact with the top 29, which in turn dissipates heat outward and away from the element being cooled. Alternatively the liquid may be transmitted while still inside a sealed structure without external pipes or channels. The liquid can thus be sent to a heat sink as noted herein, with or without the fan or blower, and it can be sent through additional micro channels or other channels, not shown, to allow the liquid to be cooled before returning it to the chamber.

[0025] While particular embodiments of the present invention have been illustrated and described, they are merely exemplary and a person skilled in the art may make variations and modifications to the embodiments described herein without departing from the spirit and scope of the present invention. All such equivalent variations and modifications are intended to be included within the scope of this invention, and it is not intended to limit the invention, except as defined by the following claims.

1. A device for cooling elements that generate heat, comprising:

- a base for defining a chamber, said base being adapted to be placed proximate the element to be cooled;
- a coolant fluid in said chamber;
- a micro/mini channel element in said chamber for directing flow of said coolant fluid through a plurality of channels or loops;
- a miniature actuator integrated in said chamber for forcing said cooling fluid through said plurality of channels in said micro/mini channel element having a surface area to thereby dissipate heat generated by said element; and

a top for sealing said chamber and maintaining said coolant fluid inside said base.

2. The device of claim 1, wherein said coolant fluid is a liquid.

3. The device of claim 2, wherein said liquid is water.

4. The device of claim 1, wherein said base is thermally conductive metal.

5. The device of claim 1, wherein said actuator is an electric motor for operating in said fluid.

6. The device of claim 1, wherein said actuator is an electrostatic actuator.

7. The device of claim 1, wherein said actuator is a piezoelectric actuator.

8. The device of claim 1, wherein said element to be cooled is an integrated circuit chip.

9. The device of claim 1, wherein said base has a large surface area relative to the thickness of said chamber.

10. The device of claim 9, wherein the ratio of said surface area to thickness ranges from about 40:1 to about 5:1.

11. A device for cooling elements that generate heat, comprising:

base means for defining a chamber, said base means being adapted to be placed proximate the element to be cooled; a coolant fluid in said chamber;

micro/mini channel element means in said chamber for directing flow of said coolant fluid through a plurality of channels in said micro channel element means;

miniature actuator means integrated in said chamber for forcing said cooling fluid through said plurality of channels in said micro/mini channel element means having a surface area to thereby dissipate heat generated by said element; and

top means for sealing said chamber and maintaining said coolant fluid inside said base means.

12. The device of claim 11, wherein said coolant fluid is a liquid.

13. The device of claim 12, wherein said liquid is water.

14. The device of claim 11, wherein said base means is formed from thermally conductive metal.

15. The device of claim 11, wherein said actuator means is an electric motor for operating in said fluid.

16. The device of claim 11, wherein said actuator means is an electrostatic actuator.

17. The device of claim 11, wherein said actuator means is a piezoelectric actuator.

18. The device of claim 11, wherein said element to be cooled is an integrated circuit chip.

19. The device of claim 11, wherein said base means has a large surface area relative to the thickness of said chamber.

20. The device of claim 19, wherein the ratio of said surface area to thickness ranges from about 40:1 to about 5:1.

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