(19) **United States**

(12) **Patent Application Publication**

Schuette

(10) **Pub. No.: US 2014/0041836 A1**

(43) **Pub. Date: Feb. 13, 2014**

(54) **SEALED SELF-CONTAINED FLUIDIC COOLING DEVICE**

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(21) Appl. No.: **14/059,267**

(22) Filed: **Oct. 21, 2013**

Related U.S. Application Data

(62) Division of application No. 11/861,810, filed on Sep. 26, 2007, now Pat. No. 8,561,673.

(60) Provisional application No. 60/826,939, filed on Sep. 26, 2006.

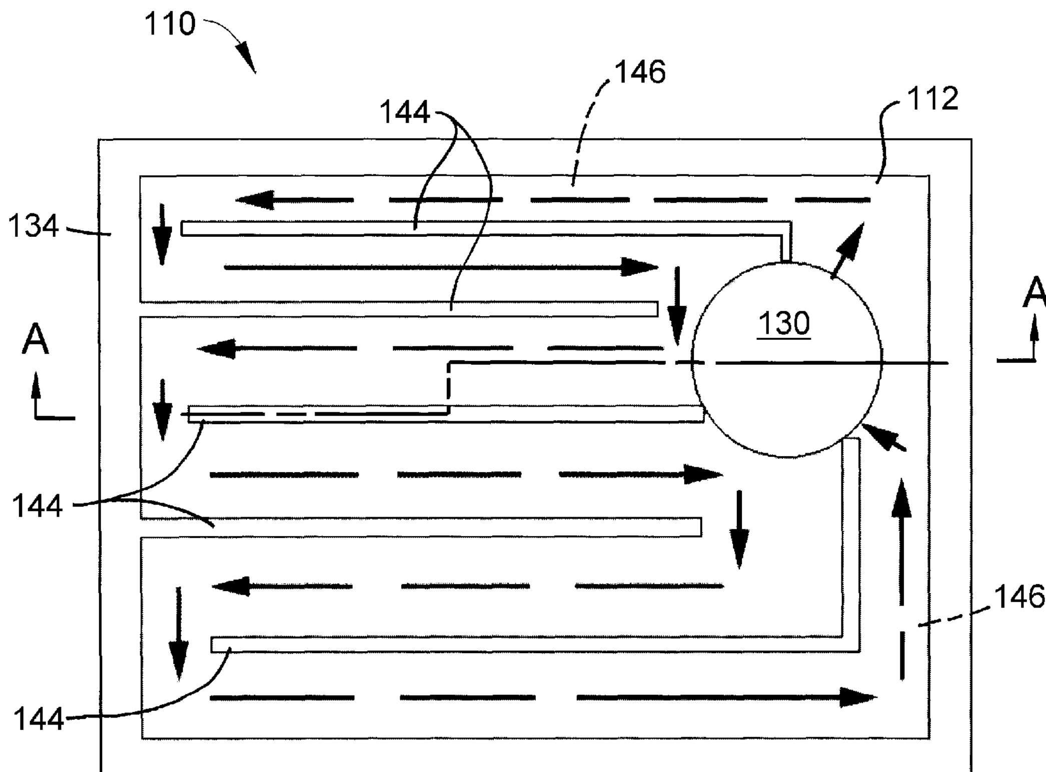
Publication Classification

(51) **Int. Cl.**
F28D 15/00 (2006.01)
B23P 15/26 (2006.01)

(52) **U.S. Cl.**
CPC ***F28D 15/00*** (2013.01); ***B23P 15/26*** (2013.01)
USPC **165/104.19**; 29/890.03

(57) **ABSTRACT**

A cooling system and method for cooling electronic components, including IC dies. The cooling system employs a cooling device that includes a composite structure having first and second plates arranged substantially in parallel and bonded together to define a sealed cavity therebetween. The first plate has a surface that defines an outer surface of the composite structure and is adapted for thermal contact with at least one electronic component. A mesh of interwoven strands is disposed within the cavity and lies in a plane substantially parallel to the first and second plates, with the strands bonded to the first and second plates. A fluid is contained and sealed within the cavity of the composite structure, and flows through interstices defined by and between the strands of the mesh.



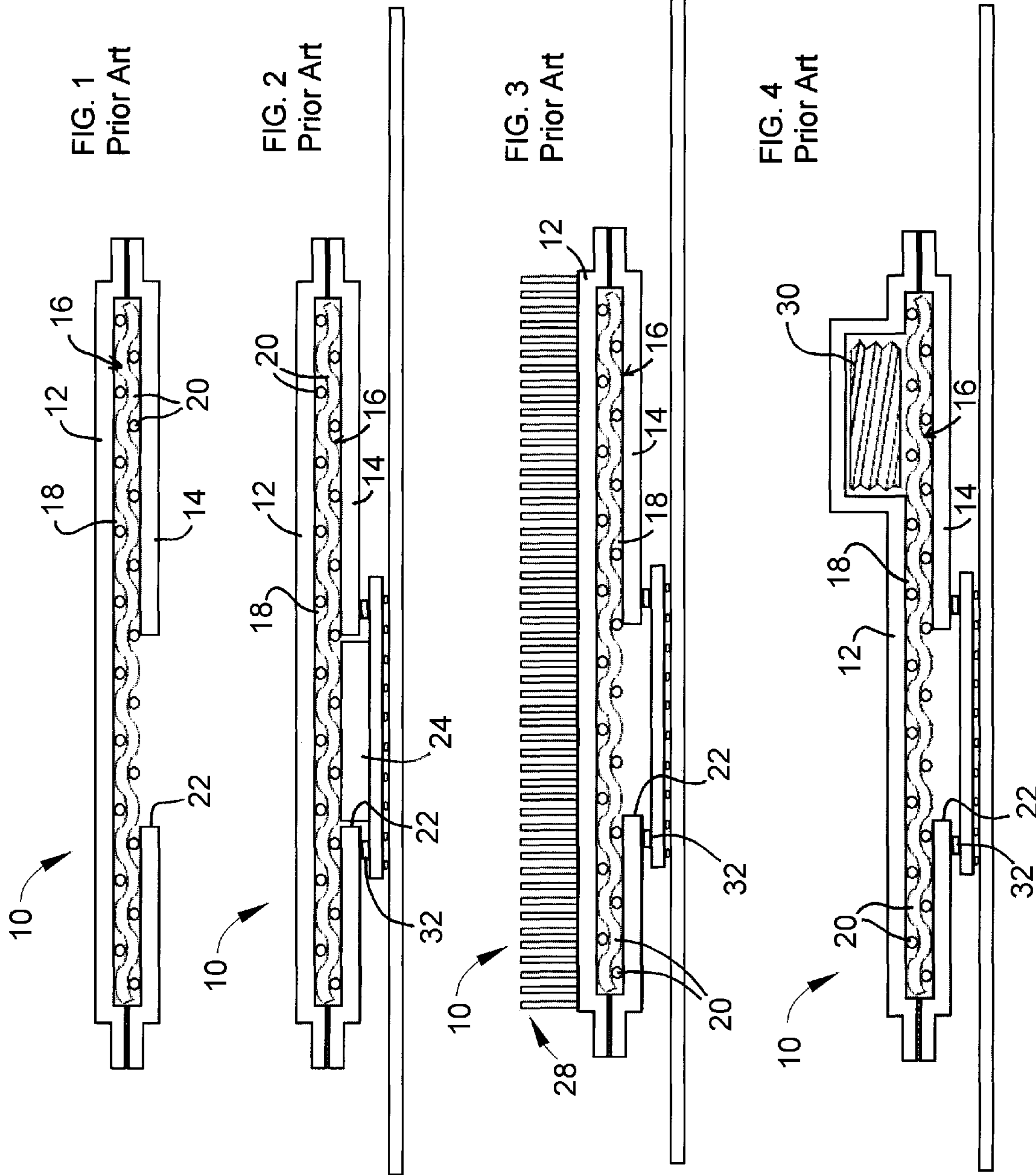


FIG. 1
Prior Art
FIG. 2
Prior Art
FIG. 3
Prior Art
FIG. 4
Prior Art
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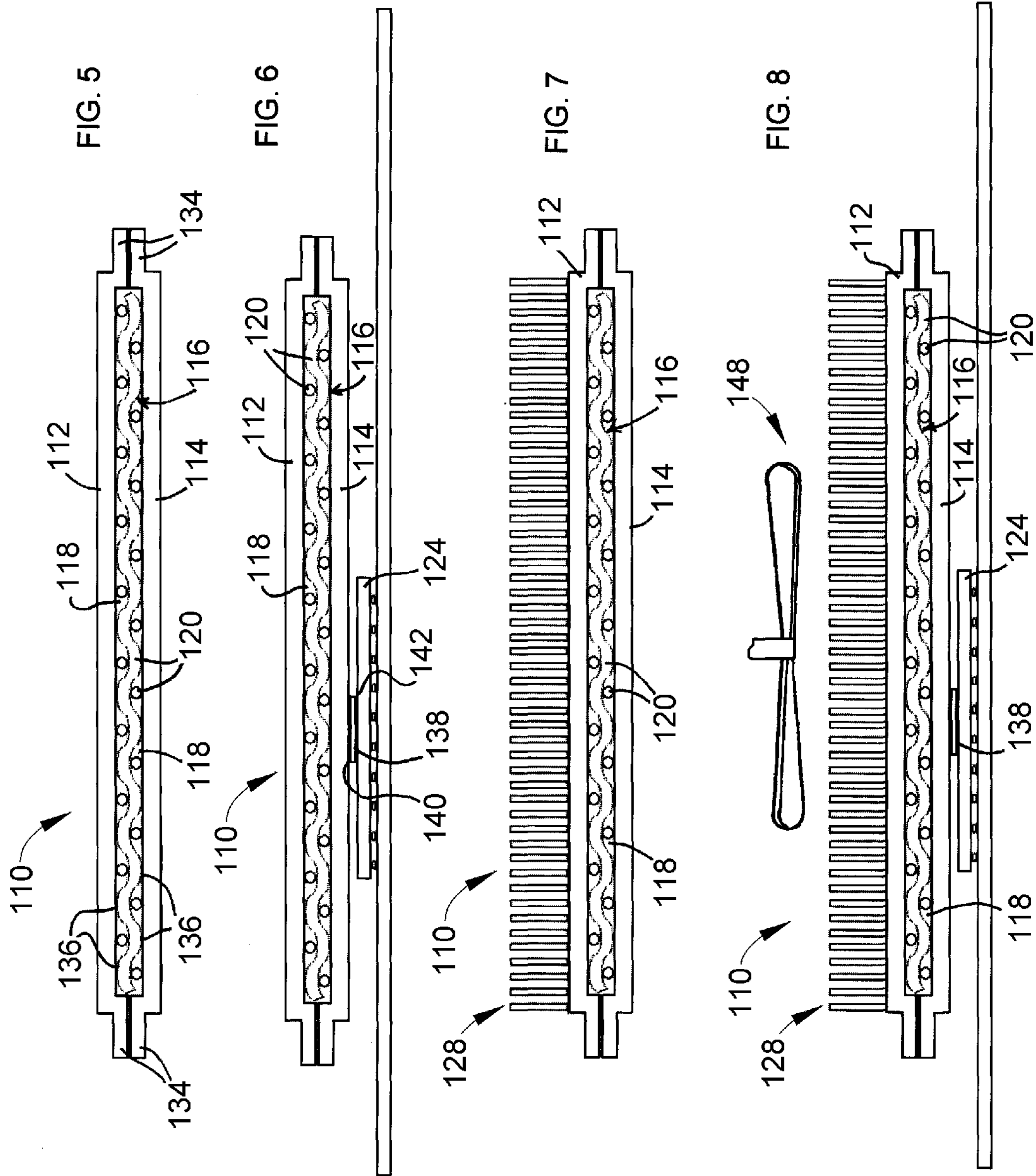
FIG. 5
FIG. 6
FIG. 7
FIG. 8
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148

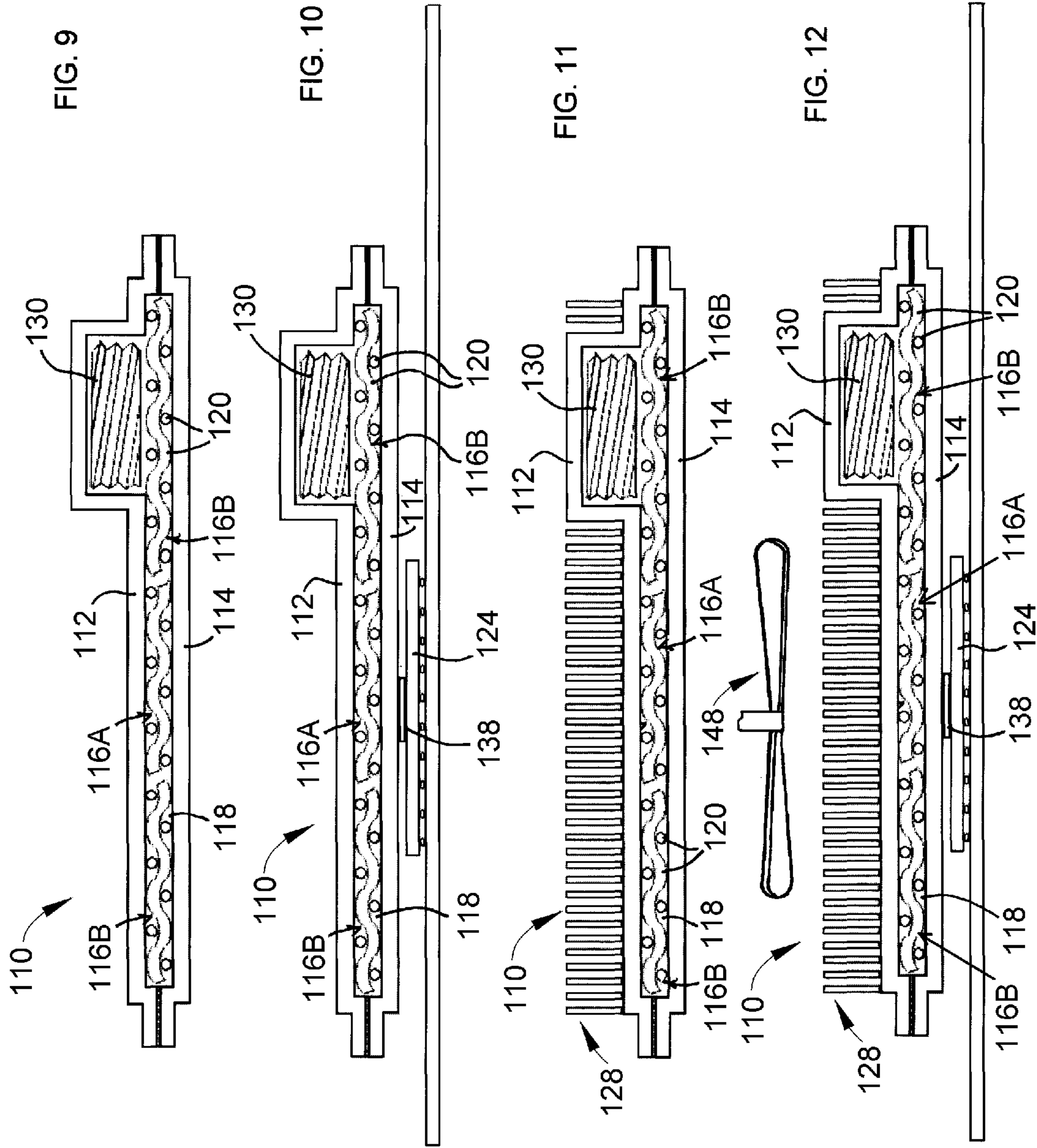
FIG. 9
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116B
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114
116A
118
110
116B
FIG. 10
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120
116B
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116A
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116B
FIG. 11
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116B
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116A
148
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FIG. 12
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116B
128

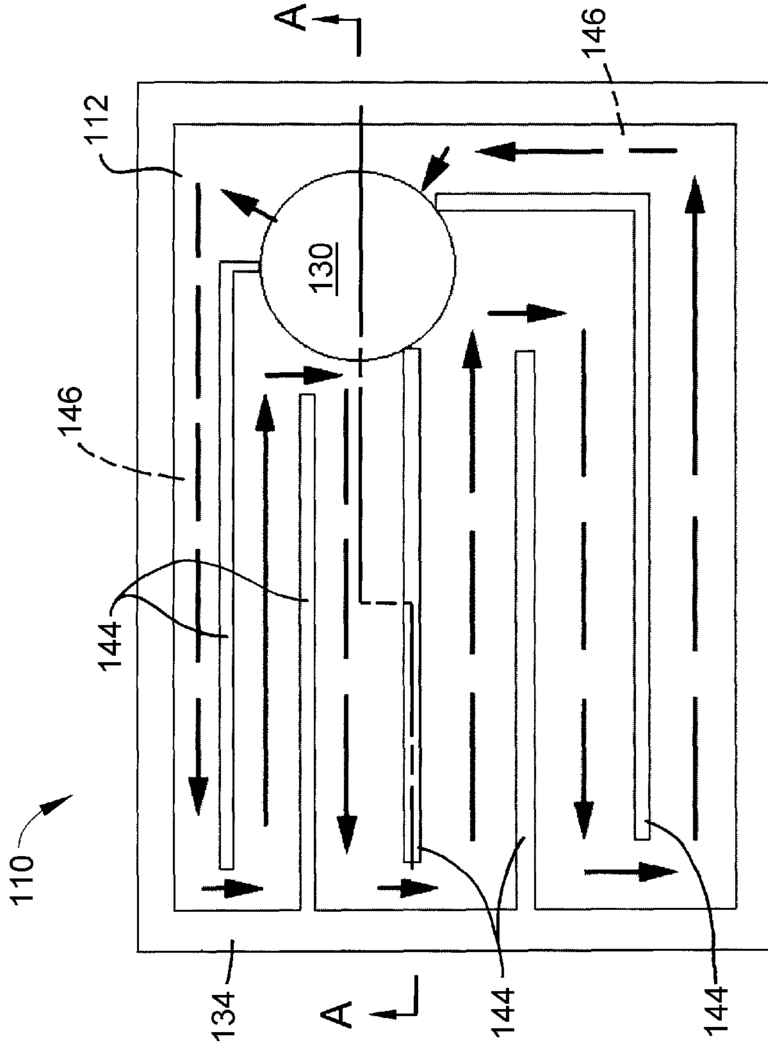

FIG. 13

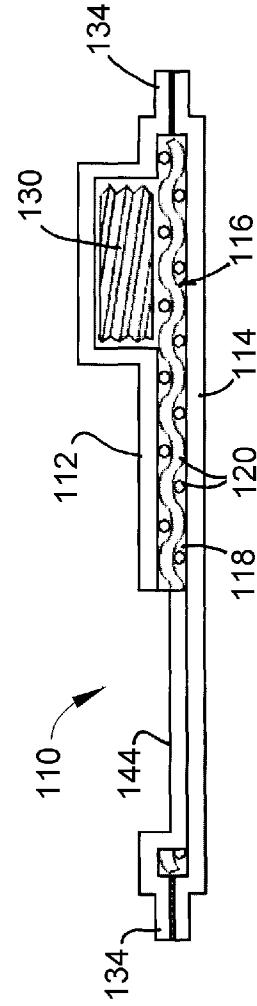

FIG. 14

SEALED SELF-CONTAINED FLUIDIC COOLING DEVICE

INCORPORATION BY REFERENCE TO ANY PRIORITY APPLICATIONS

[0001] Any and all applications for which a foreign or domestic priority claim is made are identified in the Application Data Sheet filed with the present application and are incorporated by reference under 37 CFR 1.57 and made a part of this specification.

BACKGROUND

[0002] 1. Field of the Invention

[0003] The present invention generally relates to cooling systems for electronic components. More particularly, this invention relates to a sealed cooling device that contains a fluid and a mesh material through which the fluid flows to promote heat transfer through the device.

[0004] 2. Description of the Related Art

[0005] Cooling of electronic devices has become increasingly challenging as electronics have evolved. As manufacturing processes are constantly refined, the migration to smaller design processes and the incumbent reduction in operating voltage has not kept pace with the increased complexity of faster integrated circuits (ICs). Increasing number of transistors in combination with increasing operating frequencies has resulted in higher numbers of switching events over time per device. As a result, within the same market space and price range, ICs are becoming more and more sophisticated and power-hungry with every generation.

[0006] Compared to earlier generations, the implementation of smaller design processes has allowed the integration of more electronic building blocks such as transistors and capacitors on the same footprint. Consequently, area power densities have increased, resulting in smaller dies dissipating higher thermal load. As a result, formerly sufficient, passive heat spreaders and coolers often do not provide adequate cooling. While sophisticated fin designs and powerful fans increase the active surface area useable for offloading thermal energy to the environment, even extremely well designed coolers are hitting inherent limitations. In particular, significant limitations stem from the bottleneck of limited heat conductivity of the materials used, and specifically the fact that passive heat transfer throughout a solid structure is limited by the thermal conductance coefficient of the material and the cross sectional area of the structure.

[0007] In a two-dimensional heat spreader of uniform thickness, the amount of heat energy decreases as a square function of the distance from the source, where the thermal conductance coefficient of the material and the cross sectional area define the slope of the decrease. Therefore, even the most highly conductive material will not be able to maintain an even temperature distribution across the entire surface of the cooling device. Any gradient, on the other hand, will cause a decrease in cooling efficiency since the temperature difference (.DELTA.T) between the cooler's surface and the environment is the primary limiting factor for thermal dissipation to the surrounding.

[0008] In view of the above, it is desired that coolers transfer heat from a heat source as quickly and efficiently as possible to provide a uniform temperature distribution or isothermicity at the cooler's surface. In combustion engines, liquid cooling has become the method of choice, using the fact that a liquid (e.g., water) is taking up thermal energy and subsequently being pumped to a remote radiator where it releases the absorbed heat. In electronic devices, liquid cooling is still only marginally accepted for reasons that include the inherent risk of spills, cost overhead, and complexity of the installation, which involves routing of tubing and installation of radiators. Alternatively, some self-contained liquid cooling devices have been proposed and marketed.

[0009] The four primary factors defining the efficacy of a liquid cooling device are the uptake of heat by the cooling fluid at the heat source, the transport rate of the fluid away from the heat source, the offloading of heat to the solid components of the cooler, and finally the dissipation rate of heat into the environment. The exchange of heat between the fluid and the cooling device largely depends on the routing of the flow of the coolant within the device. If the channels are too wide, laminar flow can cause a decrease in efficacy of heat exchange between the fluid and the device. Therefore, it is desirable to have a capillary system to achieve an optimal surface to volume ratio. Such capillary systems have been referred to as microchannel systems.

[0010] Different technologies have been employed to create microchannels, including etching and crosshatching of small grooves into a cooling device and even into the die of an electronic device to be cooled, such technologies have required relatively elaborate steps in their design and manufacturing process. Commonly-assigned U.S. Pat. No. 7,219,715 to Popovich, the contents of which are incorporated herein by reference, describes an alternative approach using a mesh or woven screen that is between and bonded to two foils that define a flow cavity. A generic representation of this type of approach is depicted by a cooling device **10** shown in FIG. **1**, in which a pair of foils **12** and **14** are bonded together, and a mesh **16** is contained within a cavity **18** defined by and between the foils **12** and **14**. The interstices between the warp and weft strands **20** of the mesh **16**, as well as the gaps between the strands **20** and the bordering foils **12** and **14**, allow the passage of a cooling fluid, providing direct contact with the fluid for heat absorption and transfer heat through the bonding contacts with the foils **12** and **14**. As further represented in FIG. **2**, Popovich also provides an opening **22** in one of the foils **14** that provides for direct contact of the cooling fluid within the device **10** with the die **24** of an IC device, which is represented in FIG. **2** as projecting into the cavity **18** through the opening **22**. FIGS. **3** through **4** represent variations of the cooling device **10** of FIG. **1**. In FIG. **3**, the device **10** is modified to include cooling fins **28** that promote heat dissipation to the surrounding environment. In FIG. **4**, the device **10** is modified to include an integrated pump **30** for forcing the flow of the cooling fluid within the device **10**. As would be expected, the fins **28** of FIG. **3** and the pump **30** of FIG. **4** can also be combined in the same cooling device **10**.

[0011] An advantage of the cooling devices represented in FIGS. **1** through **4** is attributable to the tortuous course of the microchannels through the mesh **16**, meaning that in addition to an X-Y labyrinth of interstices, a Z-plane of tortuousness is created that further increases the internal surface area for heat exchange between the fluid and the solid components of the cooling device **10**.

[0012] Though the approach represented in FIGS. **1** through **4** is thermally efficient, exposure of the IC die **24** to the cooling fluid requires a sealing feature **32** (such as an adhesive seal, O-ring, etc.) around the opening **22** in the cavity **18** to allow direct fluid passage over the die **24**. Aside

from any potential reliability problems, the requirement for a sealing feature **32** can complicate the serviceability of the cooling device **10**, and may render the device **10** ill-suited for aftermarket retrofitting by certain end users with limited technical skills.

[0013] In addition to Popovich, the use of microchannels for coolant fluids has been known for some time, as evidenced by U.S. Pat. No. 4,450,472 to Tuckerman et al. The preferred embodiment featured in this patent integrated microchannels into the die of the microchip to be cooled and coolant chambers. U.S. Pat. No. 5,801,442 also describes a similar approach. Still other approaches have focused on the combined use of coolant phase change (condensation) and microchannels, an example of which is U.S. Pat. No. 6,812,563. U.S. Pat. No. 6,934,154 describes a similar two-phase approach including an enhanced interface between an IC die and a heatspreader based on a flip-chip design and the use of a thermal interface material. U.S. Pat. Nos. 6,991,024, 6,942,018, and 6,785,134 describe electroosmotic pump mechanisms and vertical channels for increased heat transfer efficiencies. Variations of microchannel designs include vertical stacking of different orientational channel blocks as described in U.S. Pat. No. 6,675,875, flexible microchannel designs using patterned polyimide sheets as described in U.S. Pat. No. 6,904,966, and integrated heating/cooling pads for thermal regulation as described in U.S. Pat. No. 6,692,700.

[0014] Additional efforts have been directed to the manufacturing of microchannels. U.S. Pat. Nos. 7,000,684, 6,793,831, 6,672,502, and 6,989,134 are representative examples, and disclose forming microchannels by sawing, stamping, crosscutting, laser drilling, soft lithography, injection molding, electrodeposition, microetching, photoablation chemical micromachining, electrochemical micromachining, through-mask electrochemical micromachining, plasma etching, water jet, abrasive water jet, electrodischarge machining (EDM), pressing, folding, twisting, stretching, shrinking, deforming, and combinations thereof. All of these methods, however, share the drawback of requiring a more or less elaborate and expensive manufacturing process.

SUMMARY OF THE INVENTION

[0015] The present invention is a cooling system and method for cooling electronic components, including IC dies. The cooling system employs a cooling device that includes a composite structure comprising first and second plates arranged substantially in parallel and bonded together to define a sealed cavity therebetween. At least one of the first and second plates has a surface that defines an outer surface of the composite structure and is adapted for thermal contact with at least one electronic component. At least one and preferably multiple separate meshes, each of interwoven strands, are disposed within the cavity and lie in a plane substantially parallel to the first and second plates, with their strands bonded to the first and second plates. A fluid is contained and sealed within the cavity of the composite structure, and flows through interstices defined by and between the strands of the meshes.

[0016] The cooling method entails absorbing heat dissipated by an electronic component with a first plate arranged substantially in parallel and bonded to a second plate so as to define a composite structure and a sealed cavity between the first and second plates. The first plate has a surface that defines an outer surface of the composite structure and is adapted for thermal contact with the electronic component. The absorbed heat is transferred through the cavity and into the second plate via a fluid and at least one mesh contained in the cavity. The mesh lies in a plane substantially parallel to the first and second plates, and comprises interwoven strands that are bonded to the first and second plates and define interstices through which the fluid is able to flow. The fluid acts as a secondary heat absorbent and a thermal transport media that transports thermal energy to the mesh at a distance from the first plate. After traveling through the cavity, the absorbed heat is dissipated to the environment with the second plate.

[0017] In a preferred embodiment, the cooling device has a plate-mesh-plate laminate construction, in which portions of the plates, preferably including their edges, are raised so that by laminating the plates together a channel system is defined between the plates. At least one of the plates is preferably configured to define first order channels or macrochannels within the cooling device in order to direct the general flow of a cooling fluid through the channel system between the plates. Fluid movement through the channel system can be augmented by a pump.

[0018] Within the channel system, a tortuous three-dimensional labyrinth of microchannels is established by interstices between strands of the one or more meshes. The meshes are preferably bonded to each of the plates at substantially every bump of each strand resulting from the strands passing over and under transverse strands of each mesh. Difficulties associated with directly contacting an electronic component with a cooling fluid are overcome by hermetically sealing the cooling device to prevent contact between the cooling fluid and an electronic component cooled by the cooling device, and then thermally contacting the electronic device with one of the plates or a heat-slug formed as part of the plate or as a separate component attached to the plate.

[0019] According to a preferred aspect of the invention, the hermetical seal establishes a self-contained, spill-proof, and leak-proof cooling system that can easily be adapted to fit any heat source, while maintaining the advantages of a sealed system. The potential drawback of reduced efficacy of heat uptake compared to a fully immersed IC die can be considered relatively minor compared to the limitations posed by the overall rate of thermal dissipation to the environment that can result in a thermal saturation of the entire cooling apparatus. Additional advantages of the invention include rapid heat distribution throughout the entire cooling device, uncomplicated installation and maintenance, cost-effectiveness, and good scalability that allows for large-scale cooling devices.

[0020] Other objects and advantages of this invention will be better appreciated from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. **1** represents an open cooling device for fluid immersion of an electronic device in accordance with the prior art.

[0022] FIG. **2** shows the cooling device of FIG. **1** mounted and sealed with an electronic device to be cooled.

[0023] FIGS. **3** and **4** show prior art cooling devices mounted and sealed with electronic devices in a manner similar to that shown in FIG. **2**, but further equipped with, respectively, cooling fins to provide increased surface area for promoting heat dissipation and an integrated pump for fluid displacement.

[0024] FIG. **5** represents a first embodiment of a cooling device of the present invention, in which the device defines a

completely sealed enclosure between a pair of bonded plates, and has a mesh material within the enclosure and bonded to the plates.

[0025] FIG. **6** shows the device of FIG. **5** mounted to an electronic device to be cooled.

[0026] FIG. **7** shows a cooling device equipped with cooling fins that provide increased surface area for promoting heat dissipation in accordance with a second embodiment of the invention.

[0027] FIG. **8** shows the cooling device of FIG. **7** mounted to an electronic device in a manner similar to that shown in FIG. **6**.

[0028] FIG. **9** shows a cooling device with an integrated pump for fluid displacement in accordance with a third embodiment of the invention.

[0029] FIG. **10** shows the cooling device of FIG. **9** mounted to an electronic device in a manner similar to that shown in FIG. **6**.

[0030] FIG. **11** shows a cooling device that includes an integrated pump as shown in FIG. **9** and cooling fins as shown in FIG. **7** in accordance with a fourth embodiment of the invention.

[0031] FIG. **12** shows the cooling device of FIG. **11** mounted to an electronic device in a manner similar to that shown in FIG. **6**.

[0032] FIG. **13** shows a top view of a cooling device equipped with a pump, and embossed regions that define partitions within the cooling device to direct fluid flow in macrochannels within the device in accordance with a fifth embodiment of the invention.

[0033] FIG. **14** is a cross-sectional view of FIG. **13** along section line A-A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0034] The present invention provides a self-contained, closed-loop fluid cooling device suitable for cooling a wide variety of electronic components, including those with high power densities such as microprocessors and power conversion devices used in computers. FIG. **5** represents a cooling device **110** of this invention comprising an isothermal plate **111** having a composite construction, in which a relatively pliant mesh **116** is sandwiched between two foils or plates **112** and **114** that are substantially parallel to each other. The mesh **116** is represented as being composed of individual strands **120** that are woven together, generally transverse to each other and conventionally referred to as warp and weft strands **120**. The mesh **116** and plates **112** and **114** are preferably formed of materials having physically and chemically compatible properties, including materials having the same composition, though various material combinations are possible. For example, individual strands **120** of the mesh **116** can be formed by an individual wire, braided wires, bundled wires, etc., of copper, silver, aluminum, carbon, or alloys thereof, and the plates **112** and **114** can be formed of the same or similar materials. As discussed below, heat transfer occurs by conduction through the plates **112** and **114** and mesh **116**, such that preferred materials for these components are thermally conductive, though the use of other materials including polymeric and nonmetallic materials is also foreseeable. Suitable thicknesses for the plates **112** and **114** and mesh **116**, suitable cross-sectional shapes and dimensions for the mesh strands **120**, and suitable weaves (including strands per inch) for the mesh **116** may depend on the particular application and the materials from which these components are formed.

[0035] As evident from FIG. **5**, the peripheral edges **134** of both plates **112** and **114** are preferably raised relative to the remainder of the plates **112** and **114**, such as by embossing, to form a relief in each plate **112** and **114** that promotes the rigidity of the plates **112** and **114** and further defines a continuous peripheral surface at which the plates **112** and **114** can be bonded to each other, such as with a solder alloy, braze alloy, adhesive, etc. With the plates **112** and **114** laminated together, the reliefs define a cavity **118** between the plates **112** and **114**. As will be discussed in reference to FIGS. **13** and **14**, additional embossing can be performed on one or both plates **112** and **114** to define within the cavity **118** a channel system between the plates **112** and **114**, by which particular flow routes can be established within the device **110**. Three-dimensional structures formed by such additional embossing have the further advantage of increasing the mechanical stability of the cooling device **110**.

[0036] As evident from FIG. **5**, the mesh **116** within the cavity **118** of the composite plate **111** may have approximately the same thickness as the height of the cavity **118** (as measured in the direction normal to the plane of the plate **111**). The peaks **136** projecting from both sides of the mesh **116** are preferably bonded, such as by soldering or brazing, to the plates **112** and **114** to establish a highly-conductive thermal contact between the mesh **116** and both plates **112** and **114**. Bonding also serves to cross-link the plates **112** and **114**, which resists any shearing forces to which the plates **112** and **114** are subjected and contributes additional mechanical stability and rigidity to the plate **111**. The warp and weft strands **120** of the mesh **116** form interstices that are more or less freely penetrable by any fluid, yet define tortuous paths that avoid laminar flow conditions within the cavity **118** that would reduce the heat transfer rate between the cooling fluid, the plates **112** and **114**, and the mesh **116**. Assuming the plate **114** is in thermal contact with a heat source, e.g., an electronic component **124** shown in FIG. **6**, heat transfer from the component **124** is through the plate **114**, through the cavity **118** containing the mesh **116** and fluid, and then through the plate **114**, from whose outer surface heat is dissipated by convection. More particularly, heat transfer through the cooling device **110** is by thermal conduction through the plate **114**, the mesh **116**, and then the plate **112**, and by convention between the plate **114** and the cooling fluid and between the cooling fluid and the plate **112**, as well as convection through the cooling fluid from the plate **114** to the mesh **116** and convection through the cooling fluid from the mesh **116** to the plate **112**. Accordingly, heat transfer is generally in a single direction through the thickness of the composite plate **111**, and the fluid acts as a secondary heat absorbent and a thermal transport media capable of transporting thermal energy to the mesh **116** at a distance from the plate **114**.

[0037] As generally known in the art, suitable coolant fluids include liquids such as water, mineral spirits/oils, alcohols, and fluorocarbonate derivatives, though various other fluids could also be used, including air, vapor, etc., depending on the required temperature range of operation. For example, in extremely cold environments, a fluid with lower viscosity is a better choice than in extremely hot environments. Various other parameters for choosing a cooling fluid exist and are well known, and therefore will not be discussed in any further detail here.

[0038] As evident from FIG. **5**, the composite plate **111** lacks an opening in which the cooling fluid within the cooling device **110** is able to directly contact an electronic component intended to be cooled with the device **110**. Instead, the device **110** is self-contained with the cooling fluid being hermetically sealed within the cavity **118**, such that cooling of an electronic component **124** (FIG. **6**) is achieved by thermally contacting the component **124** with one of the plates **112/114**. This approach greatly simplifies the installation and maintenance of the device **110**.

[0039] Thermal contact between the component **124** and plate **114** is shown in FIG. **6** as being promoted with the use of a heat-slug **138**, which is preferably formed of a high thermally-conductive material that also has high thermal capacitance, a notable but nonlimiting example of which is copper and its alloys. The heat slug **138** can be defined by a portion of the plate **114**, or can be separately formed and then attached to the plate **114**. While a small loss in heat transfer is associated with the interfaces **140** and **142** between the heat slug **138** and the plate **114** and component **124**, the resistance to heat transfer caused by these interfaces **140** and **142** is relatively minor compared to the resistance encountered when dissipating heat from the cooling device **110** to the environment (typically atmospheric air) surrounding the device **110**. Moreover, the heat slug **138** is preferably able to offer sufficient thermal capacitance to buffer transient temperature spikes of the component **124**. The thermal capacitance of the slug **138** also overcomes other problems, such as the potential for localized boiling of the cooling fluid in proximity to hot-spots of the component **124**, the occurrence of which could greatly reduce the cooling efficacy of the device **110**.

[0040] Because the cooling fluid assists the plates **112** and **114** in conducting heat from the component **124**, the coefficient of thermal conductance of the material(s) used to form the plates **112** and **114** is less important than in structures that rely on passive heat transfer. As such, a wider variety of materials could be used to form the composite plate **111** and its individual components. Moreover, because the plate **111** is hollow, the total amount of material used is substantially lower than in a comparable solid structure, resulting in reduced material costs for manufacturing the cooling device **110**. A related issue is the mechanical stability of the cooling device **110**. Hollow structures generally exhibit only a minor reduction in rigidity as compared to a solid body of the same dimensions. The rigidity of the device **10** is promoted as a result of the peripheral edges **134** of the plates **112** and **114** being bonded together, as well as bonding of the mesh **116** to both plates **112** and **114**. Consequently, the cooling device **110** can be much lighter but yet nearly as strong and rigid as a solid heat spreader of comparable size.

[0041] As evident from FIG. **7**, the cooling device **110** may include fins **128** to promote heat transfer to the surrounding environment. While fins **128** are shown on only the upper plate **112**, the lower plate **114** or both plates **112** and **114** could be so equipped. As known in the art, the fins **128** effectively increase the surface area of the cooling device **110** and, thus, facilitate offloading of the heat to the surrounding environment.

[0042] The cooling device **110** may further include a pump **130** as shown in FIG. **9** by which the cooling fluid is recirculated through the cavity **118**, generally in a direction or directions parallel to the mesh **116**. A wide variety of pumps are possible and suitable for use in the device **110**, and the choice of which will be primarily dependent on the specific application since pressure and noise requirements need to be taken into consideration. Notable but nonlimiting examples of suitable pump types include centrifugal, positive displacement, rotary, and osmotic pumps that are commercially available and have been used in prior cooling systems for electronic components. As seen in FIG. **11**, the cooling device **110** may also include a combination of fins **128** and pump **130**.

[0043] FIGS. **9** and **11** depict another aspect of the invention, in which mesh segments **116**A and **116**B are employed in place of the single unitary mesh **116** of FIGS. **5** through **8**. The mesh segment **116**A is a primary mesh juxtaposed and preferably directly aligned and over the electronic component **124** for heat uptake, and one or more mesh segments **116**B located near the periphery of the device **110** and preferably surround the mesh segment **116**A for faster offloading of heat. Heat transfer between the mesh segments **116**A and **116**B is generally via the cooling fluid and via the plates **112** and **114**.

[0044] FIGS. **8**, **10**, and **12** represent, respectively, the use of the devices **110** shown in FIGS. **7**, **9**, and **11** for dissipating heat from an electronic component **124**. In each of FIGS. **8** and **12**, a fan **148** is also shown for promoting heat transfer from the fins **128** through forced convection. Otherwise, the device **110** may rely on natural convection to dissipate heat.

[0045] Notably, with the inclusion of the pump **130**, heat transfer through the cooling fluid is enhanced as a result of the fluid flow becoming turbulent as a result of the fluid being forced to flow through the interstices between the strands **120** of the mesh **116**. More particularly, assuming the plate **114** is in thermal contact with the electronic component **124** as shown in FIGS. **6**, **8**, **10**, and **12**, heat transfer through the cooling device **110** is by thermal conduction through the plate **114**, the mesh **116**, and then the plate **112**, and by turbulent forced convention between the plate **114** and the cooling fluid and between the cooling fluid and the plate **112**, as well as turbulent forced convection through the cooling fluid from the plate **114** to the mesh **116** and turbulent forced convection through the cooling fluid from the mesh **116** to the plate **112**. Even so, because the cooling fluid is recirculated through the cooling device **110**, heat transfer is through the device **110** is generally through the thickness of the composite plate **111**, in other words, from the electronic component **124**, through the plate **114**, through the cavity **118** containing the mesh **116** and fluid, and then through the plate **112**, from whose outer surface heat is dissipated by convection.

[0046] FIGS. **13** and **14** depict a variation of the cooling device **110** of FIGS. **5** through **12**, modified to include embossed regions **144** within the interior of the cavity **118**. The embossed regions **144** are represented as forming walls or dividers within the cavity **118** to define a system of channels **146** in fluidic series. As shown in FIG. **13**, the channels **146** define a circuitous route (identified by arrows) for the cooling fluid through the cooling device **110**, with flow through the device **110** being maintained at a desired rate with a pump **130**. Alternatively, flow may occur opposite the direction indicated in FIG. **13**. Another alternative is to use the channel **146** immediately downstream from the pump **130** as a macrochannel or manifold to direct the flow of the cooling fluid in series through the remaining channels **146**, or simultaneously in parallel through two or more of the channels **146**. The mesh **116** can be a single unit having portions clamped between the embossed regions **144** and the opposing interior

surface regions of the plate **114**, or can be made up of mesh segments that are each sized to individually fit within one of the channels **146**.

[0047] While the invention has been described in terms of specific embodiments, it is apparent that other forms could be adopted by one skilled in the art. For example, the functions of the components of the cooling device **110** could be performed by components of different construction but capable of a similar (though not necessarily equivalent) function, the cooling device **110** and its components could differ in appearance and construction from the embodiments shown in the Figures, and appropriate materials could be substituted for those noted. Therefore, the scope of the invention is to be limited only by the following claims.

What is claimed is:

1. A cooling device comprising:

a first plate and a second plate bonded together to define a sealed cavity between the first plate and the second plate, the first plate having an outer surface adapted for thermal contact with an electronic component;

a first mesh disposed within the sealed cavity and lying in a plane substantially parallel to the first and second plates, the first mesh comprising interwoven strands extending between the first plate and the second plate;

a fluid contained and sealed within the sealed cavity; and

interstices defined by and between the interwoven strands of the mesh through which the fluid within the sealed cavity is able to flow.

2. The cooling device of claim **1**, further comprising a heat slug disposed on the outer surface of the first plate and of sufficient size to buffer transient heat spikes of the electronic component.

3. The cooling device of claim **2**, wherein the outer surface of the cooling device is limited to thermal contact with the electronic component through the heat slug.

4. The cooling device of claim **3**, wherein the heat slug physically contacts the electronic component.

5. The cooling device of claim **1**, further comprising a second mesh disposed within the sealed cavity and lying in the plane substantially parallel to the first and second plates, the second mesh spaced apart from the first mesh and comprising interwoven strands extending between the first plate and the second plate.

6. The cooling device of claim **5**, wherein the first mesh is positioned within the sealed cavity to align with a heat slug disposed on the outer surface of the first plate, and wherein the second mesh is positioned at a periphery of the first mesh.

7. The cooling device of claim **5**, wherein the interwoven strands of the first mesh are bonded to the first plate and the second plate, and the interwoven strands of the second mesh are bonded to the first plate and the second plate

8. The cooling device of claim **5**, further comprising a pump mounted within the sealed cavity, the pump configured to circulate the fluid within the sealed cavity in a flow direction generally parallel to the first and second plates so that fluid flow becomes turbulent as the fluid is forced to flow through the interstices.

9. The cooling device of claim **5**, wherein the sealed cavity is configured to convect heat from the first mesh and/or the first plate to the second mesh via the fluid.

10. The cooling device of claim **1**, wherein the sealed cavity is configured so that heat transfer from the electronic component is through the first plate, through the sealed cavity containing the first mesh and the fluid, and through the second plate, from which heat is dissipated by convection to the environment.

11. A method of transferring thermal energy from an electronic component, the method comprising:

absorbing heat dissipated by an electronic component with a first plate arranged substantially in parallel and bonded to a second plate so as to define a sealed cavity between the first and second plates, the first plate having a surface that defines an outer surface of the sealed cavity and adapted for thermal contact with the electronic component, a fluid contained within the sealed cavity;

conducting heat from the first plate and through the sealed cavity and into the second plate via a first mesh contained in the sealed cavity, the first mesh lying in a plane substantially parallel to the first and second plates, the first mesh comprising interwoven strands extending between the first and second plates and defining interstices through which the fluid is able to flow;

convecting heat from the first plate and/or the first mesh to the second plate via the fluid contained within the sealed cavity; and

dissipating the absorbed heat from the second plate.

12. The method of claim **11**, further comprising providing a pump mounted within the sealed cavity.

13. The method of claim **12**, further comprising forcing fluid through the interstices so that the fluid flow through the interstices becomes turbulent.

14. The method of claim **11**, further comprising providing a second mesh, the second mesh spaced from the first mesh, the second mesh lying in the plane substantially parallel to the first and second plates, the second mesh comprising interwoven strands extending between the first and second plates and defining interstices through which the fluid is able to flow.

15. The method of claim **14**, further comprising convecting heat from the first plate and/or the first mesh to the second mesh via the fluid contained within the sealed cavity.

16. The method of claim **11**, wherein the sealed cavity is configured so that heat transfer from the electronic component is primarily through the first plate, through the sealed cavity containing the mesh and the fluid, and through the second plate, from which the heat is dissipated by convection to the environment.

17. A method of manufacturing a cooling device comprising:

positioning a mesh between a first plate having an outer surface adapted for thermal contact with an electronic component and a second plate, the mesh comprising interwoven strands; and

bonding the first plate and the second plate together along bonding edges so as to define a sealed cavity between the first and second plates, wherein the mesh and a fluid is contained and sealed within the sealed cavity.

18. The method of claim **17**, further comprising bonding the interwoven strands of the mesh to the first plate and the second plate.

19. The method of claim **17**, further comprising positioning a second mesh between the first and second plates, the second mesh comprising interwoven strands and spaced apart from the mesh.

20. The method of claim **17**, further comprising aligning the mesh with a heat slug disposed on the outer surface of the first plate.

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