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(54) COOLING DEVICE FOR COOLING COMPONENTS OF THE POWER ELECTRONICS, SAID DEVICE COMPRISING A MICRO HEAT EXCHANGER

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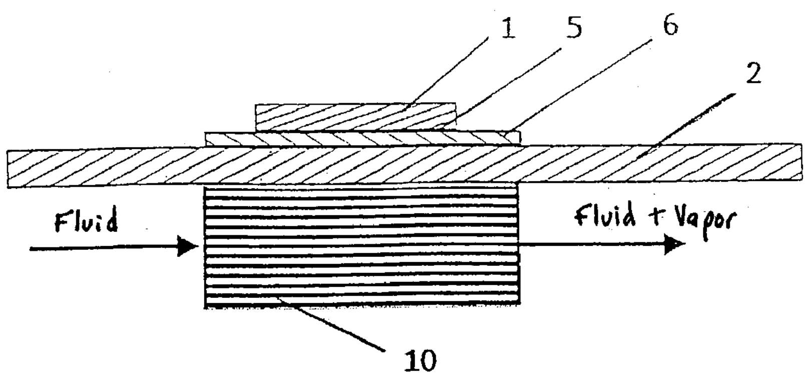
(57) **ABSTRACT**

The present invention relates to a cooling device, in particular for cooling of components of power electronics, using a coolant which flows through a micro heat exchanger **(10)** having a good heat contact with the component **(1)**, and wherein the coolant is selected in such a way that it evaporates in the micro heat exchanger **(10)** at the desired component temperature.



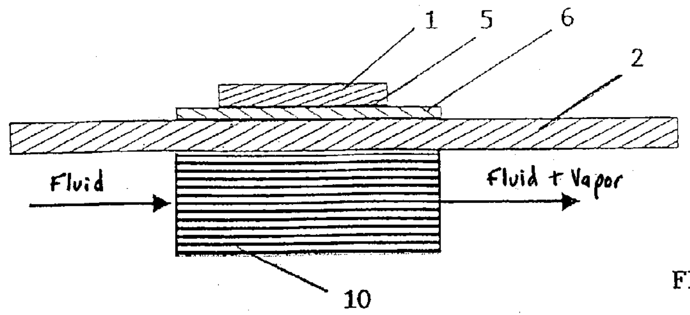


FIG. 1

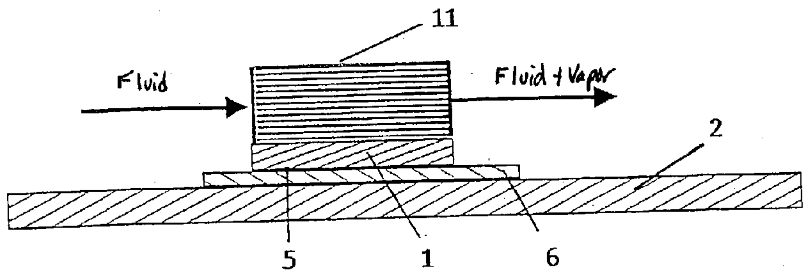


FIG. 2

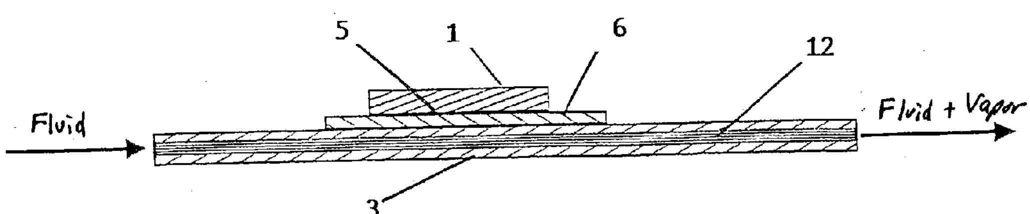


FIG. 3

COOLING DEVICE FOR COOLING COMPONENTS OF THE POWER ELECTRONICS, SAID DEVICE COMPRISING A MICRO HEAT EXCHANGER

BACKGROUND INFORMATION

[0001] The present invention relates to a cooling device, in particular for cooling of components of power electronics, using a coolant which flows through a micro heat exchanger having a good heat contact with the component.

[0002] Such a cooling device has been described in INT. J. Heat Mass Transfer, volume 37, No. 2, pages 321-332, 1994, by M. P. Bowers and I. Mudawar, under the title: "High flux boiling in low flow rate, low pressure drop mini-channel and micro-channel heat sinks."

[0003] Generally, components or modules of power electronics, such as pulse-controlled inverters for example, are presently predominantly cooled using solid heat sinks made of aluminum or copper. Heat is dissipated here via a liquid coolant which flows through bore holes in the heat sinks.

[0004] Alternative heat dissipation via boiling bath cooling is known for power electronics components. Heat is dissipated here by evaporation of an electrically non-conductive fluid, which has direct contact with the components.

[0005] The methods of cooling power electronics components, utilized hitherto, have disadvantages due to the large volumes and weights of the solid heat sinks, which are 30 mm thick, for example. Because of the limited cooling effect of such solid heat sinks, large waste heat flows of the power electronics components result in a significant rise in component temperatures. High component temperatures cause an inferior efficiency of the electronic components and may result in the destruction of the same.

[0006] In boiling bath cooling, the components have direct contact with the heat transfer fluid. Fluorocarbons are generally utilized here. The use of these coolants requires substantial sealing measures, since, along with the temperature change, the vapor pressure of the fluid also varies by several bar. Furthermore, because of high mechanical loads and for improved stability, the components of power electronics in a motor vehicle are embedded in materials such as silicone rubber compound. By utilizing boiling bath cooling, this is only possible to a limited degree.

OBJECTS AND ADVANTAGES OF THE INVENTION

[0007] The object of the present invention is to design a cooling device, in particular for cooling of components of power electronics, in such a way which allows large heat flows to be dissipated on a small surface at low temperatures, and low weight of the heat exchanger utilized by using small amounts of coolants and where there is no contact between the coolant and the electronic components.

[0008] The essence of the present invention is the combination of the phase transition for cooling the power electronics components, e.g., in evaporation cooling, and the utilization of a micro heat exchanger. Micro heat exchangers are patterns featuring channel systems having very small dimensions in the sub-millimeter range.

[0009] The utilization of a micro heat exchanger offers several advantages:

- [0010] small dimensions along with low weight,
- [0011] large heat transfer surface of the channels for the coolant and thus good local cooling of the electronic components.

[0012] Heat dissipation in micro heat exchangers usually takes place by heat transfer to a fluid flowing through.

[0013] Important advantages result from a suitable coolant flowing through the micro heat exchanger, the coolant evaporating at the desired component temperature. Because of a plurality of flow-through channels, micro heat exchangers have a large heat transfer surface and, when a suitable coolant flows through them, are thus in the position to dissipate large heat flows at the desired temperature. In addition, the temperature difference along the cooling channels is smaller than in single-phase convective heat transfer because a large portion of the heat is transferred at the phase transition temperature. Thus, uniform temperature distribution takes place also in the area of the components to be cooled. Because of their small channel diameter micro heat exchangers are suitable for operation under high pressures. Sealing problems may also be solved more easily than in boiling bath cooling.

DRAWING

[0014] A cooling device according to the present invention is described in the following exemplary embodiments with reference to the attached drawing.

[0015] **FIG. 1** shows a schematic section of a first exemplary embodiment of a cooling device according to the present invention;

[0016] **FIG. 2** shows a schematic section of a second exemplary embodiment of a cooling device according to the present invention, and

[0017] **FIG. 3** shows a schematic section of a third exemplary embodiment of a cooling device according to the present invention.

EXEMPLARY EMBODIMENTS

[0018] Three variants of a cooling device according to the present invention for cooling of components of power electronics are illustrated in **FIGS. 1 through 3**.

[0019] In a first exemplary embodiment, shown in **FIG. 1, a** micro heat exchanger **10** is situated on the back of an insulating circuit board substrate **2** opposite a component **1** to be cooled, the component being connected to circuit board substrate **2** on the front of substrate **2** via an electrical and thermal contact **6** and a solder layer **5**. A heat flow is released in power electronics component **1**, the heat flow being transferred to micro heat exchanger **10** via solder **5**, electrical and thermal contact **6**, and circuit board substrate **2** (board for short).

[0020] Fluid coolant which is slightly undercooled is fed to micro heat exchanger **10**. Initially the coolant heats up to boiling and then starts boiling in the channels of micro heat exchanger **10**. This is also called flow boiling of a saturated fluid.

[0021] Flow boiling of an undercooled fluid serving as coolant represents an alternative. In this case, the undercooled fluid enters micro heat exchanger **10** and forms bubbles which, however, in contrast to flow boiling of saturated fluids, collapse already at the wall or in the immediate proximity of the wall. The improved heat transfer occurs here due to simultaneous evaporation and condensation, as well as an added turbulence in the fluid close to the wall downstream from the point of bubble formation.

[0022] **FIG. 2** shows a second exemplary embodiment of the cooling device according to the present invention, in which a micro heat exchanger **11** is situated directly on and above component **1** to be cooled (e.g., chip). This component **1** is also connected to an insulating board **2** via a solder layer **5** and an electrical and thermal contact **6**.

[0023] **FIG. 3** shows an additional exemplary embodiment. A micro heat exchanger **12** is directly integrated in circuit board substrate **3** in such a way that the micro channels of micro heat exchanger **3** run in the substrate plane and adjacent to component **1** to be cooled and its electrical and thermal contact **6**.

[0024] It should be expressly noted that combinations of the exemplary embodiments illustrated in **FIGS. 1 through 3** may be possible and reasonable, i.e., the micro heat exchanger may be divided into individual sections which may have the configuration and position illustrated in **FIGS. 1 through 3**.

[0025] The coolant and the system pressure at which the appropriate evaporation function occurs are selected in such a way that the heat flow is dissipated from the electrical components and the maximum allowed temperature in the area of the component or chip is not exceeded. In the case of flow boiling, most of the supplied coolant evaporates, is subsequently condensed and re-enters the micro heat exchanger. A condenser (not shown), used for condensing the evaporated coolant exiting the micro heat exchanger, may be micro-structured or conventionally configured and centrally or decentrally situated. The return transport of the coolant, condensed in the condenser, into the micro heat exchanger may take place actively via a pump (not shown), or passively via gravity, or via capillary ducts.

[0026] Due to the small volume in the channels of the micro heat exchanger only small amounts of coolant are necessary in the case of flow boiling of both a saturated and an undercooled fluid.

What is claimed is:

1. A cooling device, in particular for cooling of components of power electronics, using a coolant which flows through a micro heat exchanger which has a good heat contact with the component,

wherein the coolant is selected in such a way that it evaporates in the micro heat exchanger at the desired component temperature.

2. The cooling device as recited in claim 1,

wherein the micro heat exchanger **(10)** is situated opposite the component on the back of a circuit board substrate **(2)** which carries the power electronic component **(1)** on its front.

3. The cooling device as recited in claim 1,

wherein the micro heat exchanger **(11)** is situated directly on and above the component **(1)**.

4. The cooling device as recited in one of the preceding claims,

wherein the dimensions of the micro heat exchanger **(10, 11)** are adapted to the dimensions of the component **(1)**.

5. The cooling device as recited in claim 1,

wherein the micro heat exchanger **(12)** is situated adjacent to component **(1)** in a circuit board substrate **(3)** carrying the component in such a way that the coolant flows through the substrate **(3)** in the substrate plane.

6. The cooling device as recited in one or several of claims **1** through **5**,

wherein the micro heat exchanger **(10, 11, 12)** is subdivided into several sections which are each situated on the back of the circuit board substrate which carries the component on its front and/or directly on and above the component and/or in the circuit board substrate carrying the component.

7. The cooling device as recited in one of claims **1** through **6**,

wherein the micro heat exchanger is an element of a coolant circuit.

8. The cooling device as recited in claim 7,

wherein a condenser for the coolant, which has evaporated in the micro heat exchanger, is connected in series to the micro heat exchanger in the flow direction within the coolant circuit.

9. The cooling device as recited in claim 7 or **8**,

wherein the return transport of the coolant to the micro heat exchanger takes place actively via a pump which is situated in the coolant circuit.

10. The cooling device as recited in one of the preceding claims,

wherein the structure and the positioning of the micro heat exchanger, the coolant, and the system pressure are selected in such a way that a maximum allowed temperature of the component to be cooled is not exceeded.

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