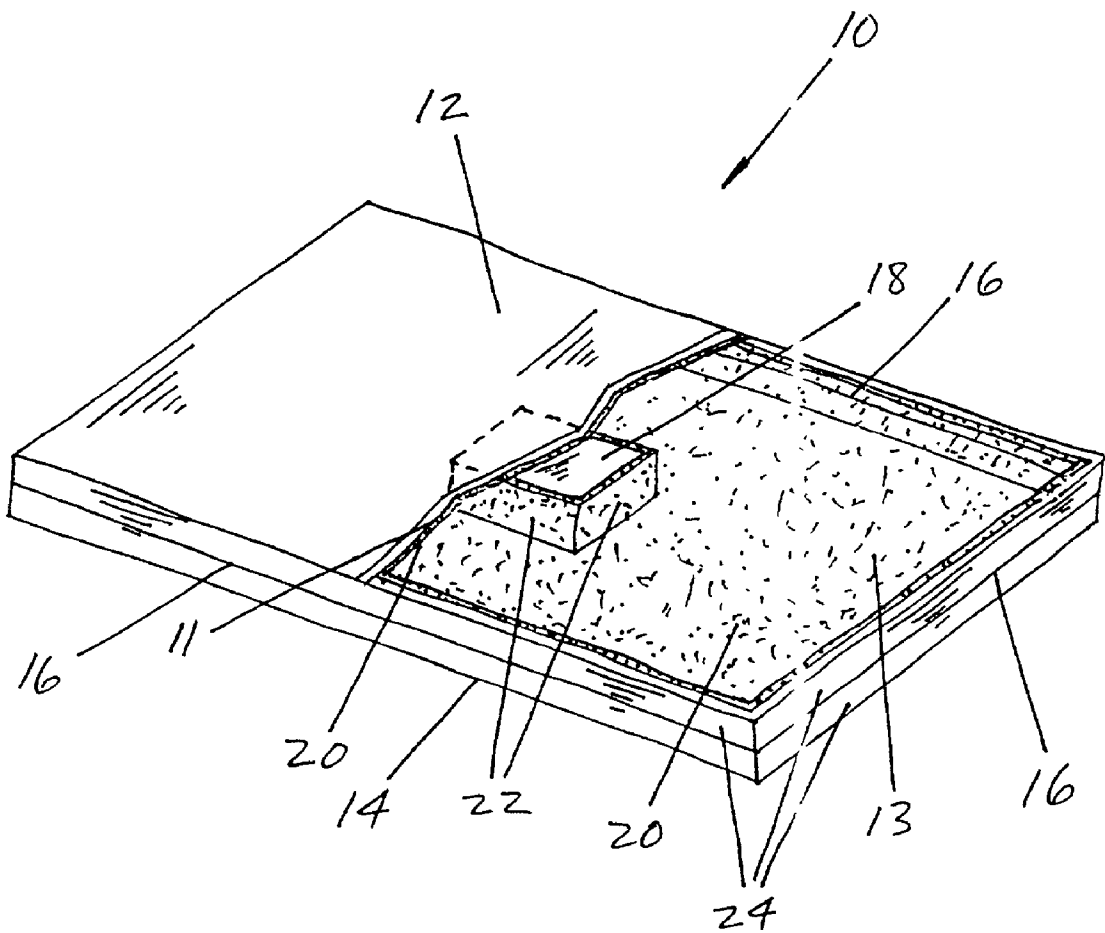




HEAT PIPE HEAT SPREADER WITH INTERNAL SOLID HEAT CONDUCTOR

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to active solid state devices, and more specifically to a flat heat pipe for cooling an integrated circuit chip.

[0002] As integrated circuit chips decrease in size and increase in power, the required heat sinks and heat spreaders have grown to be larger than the chips. Heat sinks are most effective when there is a uniform heat flux applied over the entire heat input surface. When a heat sink with a large heat input surface is attached to a heat source of much smaller contact area, there is significant resistance to the flow of heat along the heat input surface of the heat sink to the other portions of the heat sink surface which are not in direct contact with the contact area of the integrated circuit chip. Higher power and smaller heat sources, or heat sources which are off center from the heat sink, increase the resistance to heat flow to the balance of the heat sink. This phenomenon can cause great differences in the effectiveness of heat transfer from various parts of a heat sink. The effect of this unbalanced heat transfer is reduced performance of the integrated circuit chip and decreased reliability due to high operating temperatures.

[0003] The brute force approach to overcoming the resistance to heat flow within heat sinks which are larger than the device being cooled is to increase the size of the heat sink, increase the thickness of the heat sink surface which contacts the device to be cooled, increase the air flow which cools the heat sink, or reduce the temperature of the cooling air. However, these approaches increase weight, noise, system complexity, and expense.

[0004] It would be a great advantage to have a simple, light weight heat spreader for an integrated circuit chip which furnishes an essentially isothermal surface even though only a part of that surface is in contact with the chip and also includes a simple means for assuring a direct heat transfer path between the chip and a heat sink which dissipates the heat.

SUMMARY OF THE INVENTION

[0005] The present invention is an inexpensive heat pipe heat spreader for integrated circuit chips which is of simple, light weight construction. It is easily manufactured, requires little additional space, and provides additional surface area for cooling the integrated circuit and for attachment to heat transfer devices such as cooling fins for disposing of the heat from the integrated circuit chip. Furthermore, the heat pipe heat spreader of the invention is constructed to maximize heat transfer from the integrated circuit chip to the heat sink.

[0006] The internal structure of the heat pipe is an evacuated vapor chamber with a limited amount of liquid. In the preferred embodiment of the invention two plates form the casing of the heat pipe vapor chamber, thus forming an essentially flat heat pipe. Capillary wick material covers the inside surfaces of at least one plate, the evaporator surface of the heat pipe casing, which is in contact with the integrated circuit chip.

[0007] However, because the heat input area at the integrated circuit chip on the evaporator surface of such a flat

heat pipe is usually much smaller than the fin or other heat removal structure attached to the opposite surface, a considerable amount of the heat must first be transferred throughout the thin plate of the casing before it can be used to evaporate the liquid from the capillary wick which is attached to the thin plate.

[0008] Although a heat pipe transfers heat with less temperature difference than a solid metal conductor, the insertion of the small cross section path along the casing sides to get to the majority of the heat pipe evaporator loses some of this benefit. The present invention therefore adds a parallel heat transfer path which is a solid metal structure spanning the space within the heat pipe between the integrated circuit contact area and the center portion of the fin structure.

[0009] As with any other parallel path, the heat conductive structure reduces the heat flow resistance, even though its heat transfer impedance is not quite as effective as would be a heat pipe of the same dimensions. However, the structure does have a very low thermal impedance because it has a very short length of thermal path, only the small internal height of the heat pipe, and a relatively large cross section. Furthermore, since the sides of the heat conductive structure are covered with capillary wick material, there is very little reduction in the effective area of the evaporator wick.

[0010] The conductive structure also serves other important purposes. It supports the flat plates and prevents them from deflecting inward and distorting to deform the flat surface that is in contact with the integrated circuit chip. This feature is very important for good heat transfer between the heat spreader and the integrated circuit chip. The structure also serves as critical support for the portions of the capillary wick which cover its sides and span the internal space between the plates. The capillary wick on the sides of the structure, along with capillary wick covering the inside surfaces of both of the plates, provides a gravity independent characteristic to the heat spreader, and the structure around which the wick is located assures that the capillary wick on its sides is not subjected to destructive compression forces.

[0011] The present invention thereby provides a heat pipe with heat transfer characteristics superior to those of either a single solid plate or a simple flat heat pipe.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The FIGURE is a perspective view of the preferred embodiment of the flat heat pipe of the invention with part of one plate of the envelope removed to view the interior.

DETAILED DESCRIPTION OF THE INVENTION

[0013] The FIGURE is a perspective view of the preferred embodiment of flat heat pipe **10** of the invention with part of one plate **12** of the envelope removed to view the interior.

[0014] Heat pipe **10** is constructed with a casing formed by sealing together two formed plates, contact plate **14** and cover plate **12**. Contact plate **14** and cover plate **12** are formed as shallow pans so that there is a space between their interior surfaces when they are joined together at seal **16** on their peripheral lips by conventional means, such as soldering or brazing, to form heat pipe **10**. Heat pipe **10** is then evacuated to remove all non-condensable gases and a suitable quantity of heat transfer fluid is placed within it. This

is the conventional method of constructing a heat pipe, and is well understood in the art of heat pipes.

[0015] The interior of heat pipe 10 is, however, constructed unconventionally in that solid structure 18 made of a heat conductive material such as copper spans the interior space between contact plate 14 and cover plate 12 and is attached to each plate with a heat conductive bond. Such bonds are typically either soldered or brazed. The location and size of solid structure 18 is determined by the location and size of the integrated circuit chip or other heat source from which heat pipe 10 is spreading heat. Ideally, solid structure 18 is constructed so that it is aligned with the heat source being cooled, is of the same cross section as the size of the contact area of the heat source, and is located on the opposite surface of contact plate 14 from the heat source.

[0016] Heat pipe 10 also includes internal sintered metal capillary wick 20 which covers the entire inside surfaces 11 of cover plate 12 and 13 of contact plate 14, including their sides. As is well understood in the art of heat pipes, a capillary wick provides the mechanism by which liquid condensed at the cooler condenser of a heat pipe is transported back to the hotter evaporator where it is evaporated. The vapor produced at the evaporator then moves to the condenser where it again condenses. The two changes of state, evaporation at the hotter locale and condensation at the cooler site, are what transport heat from the evaporator to the condenser. In a well designed heat pipe this transfer of heat occurs with virtually the same temperature at the evaporator as at the condenser.

[0017] It should be appreciated that in typical use contact plate 14 is held in thermally conductive contact with a heat source such as an integrated circuit chip (not shown), and cover plate 12 is attached to a cooling device such as an assembly of cooling fins (not shown). Thus, the function of heat pipe 10 is to spread the heat generated at the small area of an integrated circuit chip, from which it is more difficult to dissipate any significant quantity of heat, to a much larger surface area such as an assembly of cooling fins. The larger area facilitates heat removal without requiring an unreasonably high temperature.

[0018] It is also worth recognizing that when capillary wick 20 is attached to the inside surface of both contact plate 14 and cover plate 12, heat pipe 10 actually operates independent of orientation, and it does not matter whether the heat input is at contact plate 14 or cover plate 12.

[0019] In the preferred embodiment of the present invention, heat pipe 10 also has capillary wick on sides 22 of solid structure 18, and that wick is in contact with capillary wick 20 on the inside surfaces of plates 12 and 14. The wick on sides 22 of structure 18 thereby interconnects wick 11 of cover plate 12 and wick 13 of contact plate 14 with continuous capillary wick. This geometry assures that, even if heat pipe 10 is oriented so that the condenser is lower than the evaporator, liquid condensed upon the inner surface of either plate will still be in contact with capillary wick on sides 22 of solid structure 18. The liquid will therefore be moved by capillary force back to the hotter surface which functions as the evaporator. Solid structure 18 also prevents the structurally weaker capillary wick wrapped around it from suffering any damage.

[0020] However, another important function of the wick on sides 22 of solid structure 18 is its function as additional

evaporator surface. At the same time as solid structure 18 is conducting heat directly between contact plate 14 and cover plate 12, heat within solid structure 18 is also evaporating liquid from the wick on sides 22 of solid structure 18 to add to the heat transfer capability of heat pipe 10.

[0021] The preferred embodiment of the invention has been constructed as heat pipe 10 shown in the FIGURE. This heat pipe is approximately 3.0 inches by 3.5 inches with a total thickness of 0.200 inch. Cover plate 12 and contact plate 14 are constructed of OFHC copper 0.035 inch thick, and solid structure 18 spans the 0.130 inch height of the internal volume of heat pipe 10. Capillary wick 22 is constructed of sintered copper powder, averages 0.040 inch thick, and covers essentially all the surfaces inside heat pipe 10, including sides 24. Solid structure 18 is also constructed of OFHC copper and is 0.80 inch by 0.80 inch and 0.130 inch thick.

[0022] The thermal conductivity of solid structure provides additional heat conduction between plates 12 and 14, and thereby reduces the temperature difference within heat pipe 10 between the heat source and the heat sink. This reduction of temperature difference directly affects the operation of heat pipe 10, and essentially results in a similar reduction in the operating temperature of any heat source such as an integrated circuit chip.

[0023] The invention thereby furnishes an efficient means for cooling an integrated circuit and does so without the need for larger heat spreaders which not only add weight but also do not transfer heat away from the integrated circuit as efficiently as does the heat pipe of the invention.

[0024] It is to be understood that the form of this invention as shown is merely a preferred embodiment. Various changes may be made in the function and arrangement of parts; equivalent means may be substituted for those illustrated and described; and certain features may be used independently from others without departing from the spirit and scope of the invention as defined in the following claims. For example, the heat conductive solid structure could be constructed of materials other than copper, and although it is pictured as a rectangular prism, it could be constructed as any other shape.

What is claimed as new and for which Letters Patent of the United States are desired to be secured is:

1. A heat pipe heat spreader comprising:

a first plate and a second plate shaped and sealed together to form an enclosure, with non-condensable gases evacuated from within the enclosure and sufficient liquid loaded into the enclosure to form an operable heat pipe;

a solid heat conductive structure spanning the space within the enclosure between the first and second plates and attached to the two plates with a heat conductive bond, the heat conductive structure being located at that part of the inner surface of one plate where the outer surface of the plate is in contact with a heat source being cooled by the heat pipe; and

capillary wick attached to the inside surface of the plate which is in contact with the heat source cooled.

2. The heat pipe heat spreader of claim 1 wherein the capillary wick is attached to the interior surfaces of both plates.

3. The heat pipe heat spreader of claim 1 wherein the capillary wick is attached to the interior surfaces of both plates and to the surfaces of the solid heat conductive structure which span the space between the two plates, and the capillary wick on the solid heat conductive structure is

continuous with the capillary wick on the interior surfaces of the two plates.

4. The heat pipe heat spreader of claim 1 wherein the cross section of the solid heat conductive structure is the same as the size of the contact surface of a device being cooled by the heat pipe.

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