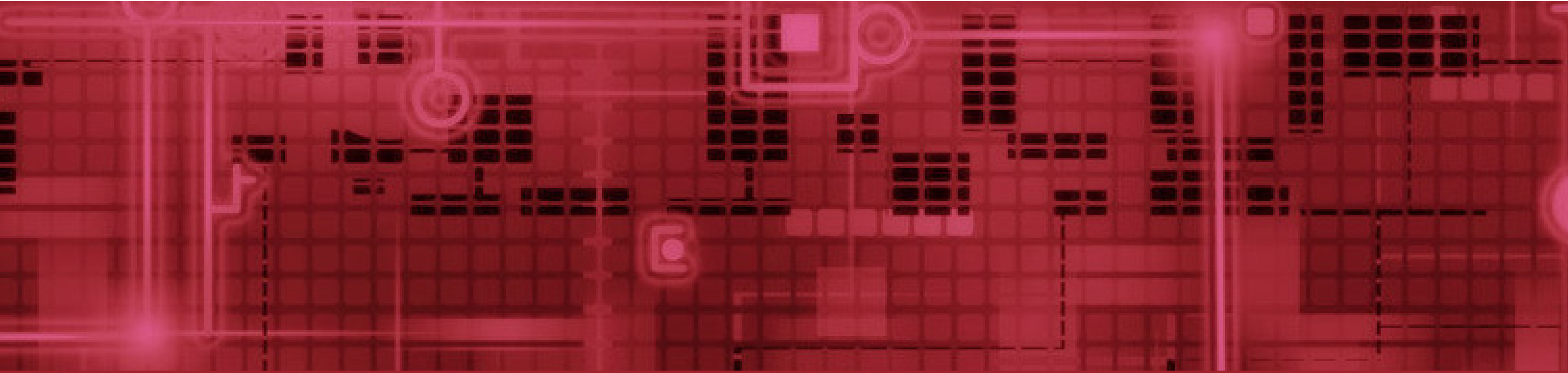


Technology Review:

Cooling Using Phase Change Materials

Qpedia continues its review of technologies developed for electronics cooling applications. We are presenting selected patents that were awarded to developers around the world to address cooling challenges. After reading the series, you will be more aware of both the historic developments and the latest breakthroughs in both product design and applications. We are specifically focusing on patented technologies to show the breadth of development in thermal management product sectors. Please note that there are many patents within these areas. Limited by article space, we are presenting a small number to offer a representation of the entire field. You are encouraged to do your own patent investigation. Further, if you have been awarded a patent and would like to have it included in these reviews, please send us your patent number or patent application.

In this issue our spotlight is on cooling using phase change materials. There is much discussion about its deployment in the electronics industry, and these patents show some of the salient features that are the focus of different inventors.

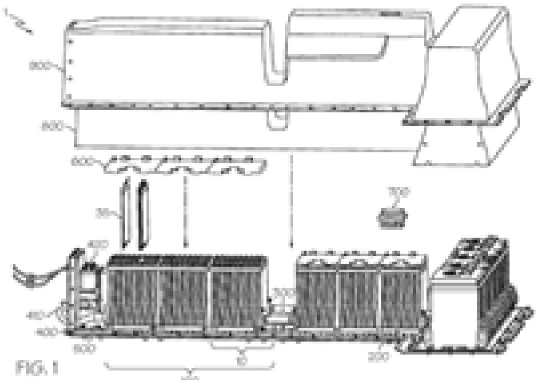
BATTERY THERMAL INTERFACES WITH MICROENCAPSULATED PHASE CHANGE MATERIALS FOR ENHANCED HEAT EXCHANGE PROPERTIES

US 2012/0258337 A1, Wang, X.

This invention relates generally to passive thermal management of batteries and portions thereof, and more particularly to the use of microencapsulated phase change materials in conjunction with automotive battery packs, battery modules or individual battery cells as a way to improve thermal management of such battery components.

Lithium-ion batteries are being used in automotive applications as a way to supplement, in the case of hybrid electric vehicles (HEVs), or supplant, in the case of purely electric vehicles (EVs), conventional internal combustion engines (ICEs). In either variant, HEVs or PEVs belong to a larger class of vehicles known as electric vehicles (EVs). The high volumetric heat generation rate and generally passive construction of lithium-ion batteries provides both the durability and functionality

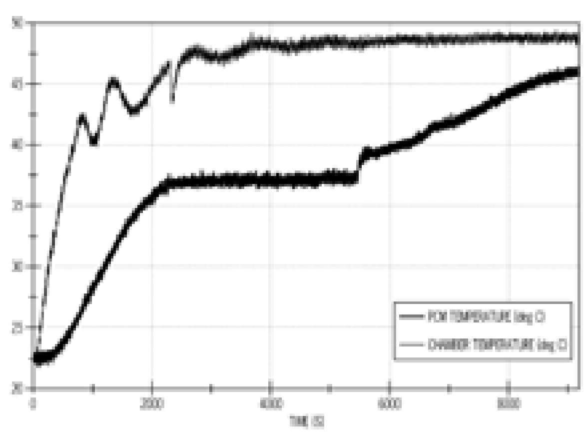
PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
US 2012/0258337 A1	BATTERY THERMAL INTERFACES WITH MICROENCAPSULATED PHASE CHANGE MATERIALS FOR ENHANCED HEAT EXCHANGE PROPERTIES	Wang, X.	Oct 11, 2012
EP 1 264 343 B1	APPARATUS AND METHOD FOR PASSIVE PHASE CHANGE THERMAL MANAGEMENT	Searls, D., et al.	Jan 22, 2014
US 2014/0004394 A1	BATTERY THERMAL MANAGEMENT USING PHASE CHANGE MATERIAL	Kerkamm, I.	Jan 2, 2014

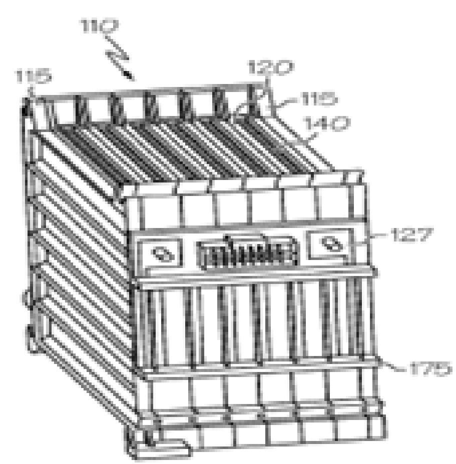


needed to serve as a propulsion system for cars, trucks, buses, motorcycles and related automotive or vehicular platforms.

Temperature is one of the most significant factors impacting both the performance and life of a battery. Extremes (such as those encountered during protracted periods of inactivity in cold or hot environments, or due to extended periods of operation and concomitant heat generation on hot days) can negatively impact the ability of the battery to operate correctly, and in severe cases can destroy the battery entirely. Side effects of prolonged exposure to high temperature may include premature aging and accelerated capacity fade, both of which are undesirable. Conventional heat dissipation methods such as forced air and liquid cooling may prove to be effective at avoiding such side effects, but they add to overall vehicular system weight, complexity and parasitic power requirements.

The nature of the microPCM is that it has high latent heat of absorption and reversible thermal regulation properties. In this way, when used as part of foam isolator sheet 45, cooling plate 30, cooling fin 40 or other structural member within battery module 10 that is in need of augmented heat transfer properties, the microPCM can act as a thermal capacitor which can passively buffer temperature extremes in battery module 10. This promotes a reduction in battery module 10 parasitic losses, thereby allowing optimization of battery module 10 energy usages, as well as reduction of active cooling system use and complexity. In situations where more than one member or component, operating at more than one temperature regime, may require the use of the microPCM of the present invention, it will be appreciated by those skilled in the art that the makeup of both the core and shell may be tailored to such particular temperature regimes. In such circumstance, the cooling fin 40 may be configured to include a layer of material (such as foam, or a related substance) that can contain a microPCM that operates in a different temperature regime than that of a microPCM that may be placed in or on the foam isolator sheet 45 or cooling plate 30. In such tailoring circumstances, blending of various pure materials (such as alkanes) may be performed to have the phase change temperature coincide with the thermal environment of the particular automotive application. One material useful for such tailoring is n-heptadecane, which can be added to eiconsane, octadecane or related phase change





material. Similar blending may be used to adjust the phase change latent heat.

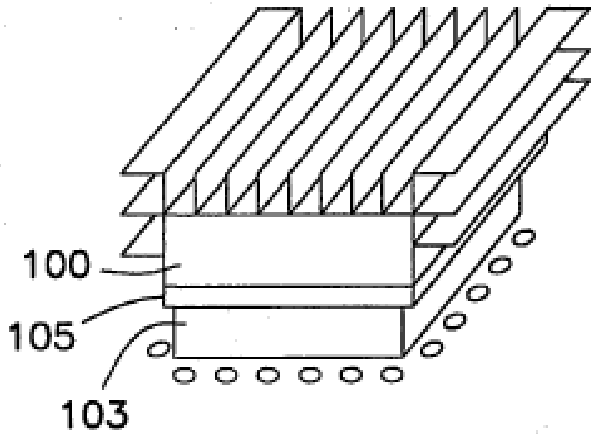
Results from DSC testing are used to determine the phase change properties of bulk laboratory-grade microPCM eicosane. The scan rate used in this test was 5° C per minute, and the temperature range was controlled from −50° C to 80° C. The peaks indicate phase change upon heating (top) and cooling (bottom). The peak on the top curve shows the behavior of the solid-to-liquid phase change transition, while the area under the peak is the latent heat for the solid-to-liquid transition (i.e., the latent heat of fusion); in the present example, the latent heat was found to be 185.6 J/kg. This curve also indicates that liquid starts to appear at 32.28° C and that eicosane is completely liquid at 36.35° C. Likewise, the peaks on the bottom together show the behavior of the liquid-to-solid phase change transition, where the left peak shows the liquid-to-liquid phase change transition associated with eicosane, while the right peak shows the liquid-to-solid phase change transition. The area under these peaks is the latent heat for the solid-to-liquid transition; in the present example, the latent heat was found to be 190.7 J/kg. This curve also indicates that solid eicosane starts to appear at 35.07° C and that it is completely solid at 31.67° C.

APPARATUS AND METHOD FOR PASSIVE PHASE CHANGE THERMAL MANAGEMENT

EP 1 264 343 B1, Searls, D., et al.

A heat sink and a method of fabricating and using the heat sink are described herein. The heat sink is thermally coupled to an integrated circuit die and dissipates heat produced in the integrated circuit die. The heat sink includes a cavity containing a phase change material and a number of particles for enhancing convection in the heat sink during the cooling of an integrated circuit die. The heat sink is highly reliable and exhibits enhanced cooling characteristics when compared with a traditional finned heat sink. Efficient manufacturing of the heat sink is achieved by a symmetrical arrangement of the heat sink structures.

Heat sink 100 thermally coupled to integrated circuit die 103. Heat sink 100 is not limited to operation in connection with a particular type of integrated circuit fabricated on die 103. Digital circuits, such as processors, digital signal processors, and communication circuits are all suitable for use in connection with heat sink 100. Similarly, analog circuits, such as amplifiers, power amplifiers, radio frequency amplifiers, phase-locked loops, and frequency filters are also suitable for use in connection with heat sink 100. Thermally conductive layer 105 is formed on die 103 and fabricated from a thermally conductive gel, paste, tape or other thermally conductive material. When heat sink 100 is affixed to thermally conductive layer 105, thermally conductive layer 105 provides a thermal path to heat sink 100 from integrated circuit die 103. In operation, heat sink 100 dissipates heat produced in integrated circuit die 103.



Example embodiments of the present invention, as described above, are effective in dissipating heat from an integrated circuit directly coupled to heat sink 100. However, the present invention is not limited to such embodiments. The present invention is also effective in dissipating heat from a packaged die. Heat sink 100 thermally coupled to integrated circuit package 107. Heat sink 100 is coupled to package 107 by the same process used to couple heat sink 100 directly to integrated circuit die 103. Thermally conductive layer 105 is formed on package 107 and heat sink 100 is affixed to thermally conductive layer 105. The heat flow

KNOCKOUT

THE COMPETITION

We believe customers who wish to remain competitive should consider a design-to-suit opportunity solution first.

Contrary to common perception, this proves to be less expensive to the customer in the long run, because of the ensuing gain in product efficiency and compatibility.

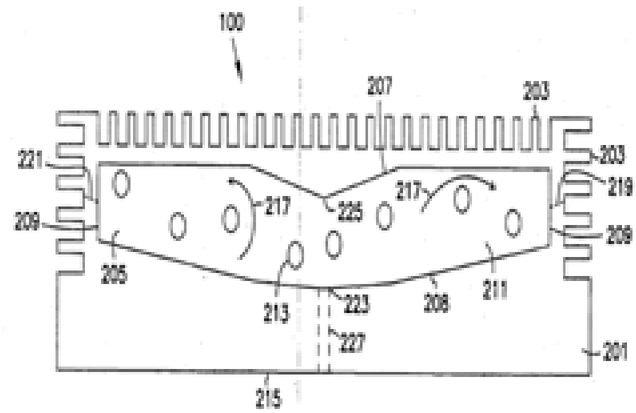
CONSULT THE EXPERTS

ATS ADVANCED THERMAL SOLUTIONS, INC.

Innovations in Thermal Management®

from packaged integrated circuit die 103 is coupled to package 107 by the ambient air surrounding die 103 in package 107 or is directly coupled to package 107 by a heat spreader. Heat sink 100 includes a number of structures and materials that participate in the dissipation of the heat produced by integrated circuit die 103. These structures and materials are described in more detail below. Heat sink 100 comprises body 201 including a number of fins 203 and cavity 205 including cavity surfaces 207-209, phase change material 211 encapsulated in cavity 205, and a number of particles 213 intermixed with phase change material 211.

Body 201 is fabricated from a thermally conductive material, preferably a metal, such as copper or aluminum or an alloy of copper or aluminum. External surface 215 of body 201 is a substantially flat surface suitable for thermally coupling to a surface of integrated circuit die 103 or package 107. The flat surface is formed on heat sink 100 by machining or other material shaping process. External surface 215 has a footprint that is preferably significantly larger than the surface area of integrated circuit die 103 or package 107. The remaining surface area of body 201 preferably provides a large area for transferring heat from body 201 to the surrounding ambient environment. In one embodiment, a number of fins 203 are formed on the remaining surface area of body 201 by machining or other material shaping process. Alternatively, the number of fins 203 are fabricated as a separate unit and attached to the outer surface of heat sink 100 by brazing, soldering or welding. After machining or attachment, fins 203 provide a large surface area for transferring heat to the surrounding ambient environment. The dissipation of heat in phase change material 211 allows the fins 203 of the present invention to have a height that is about 10% to 20% less than the height of fins fabricated on a comparable heat sink intended for use in a forced air cooling system. This creates a lower profile package which is useful in cooling circuits in a variety of devices, such as mobile phones and personal digital assistants. Alternatively, if the height of fins 203 is not reduced, then cooling using heat sink 100 is greater than cooling produced by a standard size package.



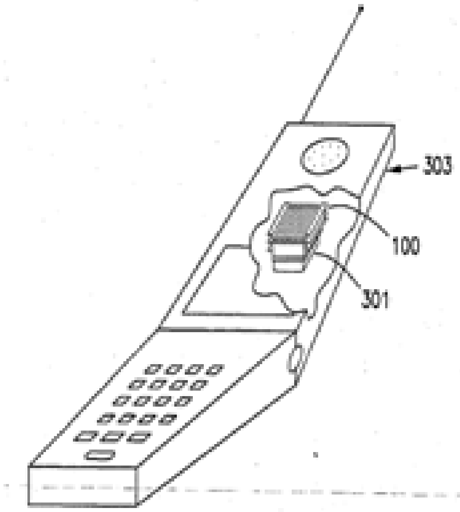
Cavity 205 is included in body 201 to hold phase change material 211. Cavity 205 has a volume that is sufficient to allow convection currents 217 to arise in phase change material 211 during the operation of integrated circuit 103. Convection currents 217 assist in cooling integrated circuit die 103. Cavity 205 is positioned in body 201 to enhance the heat transfer from phase change material 211 to the number of fins 203. Thus, cavity 205 is generally centered with respect to the number of fins 203 located on the side surfaces of body 201. The thickness of the wall between cavity surfaces 207 and 209 and the number of fins 203 is preferably made as thin as possible without compromising the structural integrity of heat sink 100.

In one embodiment, body 201 is fabricated from a pair of symmetrical structures. Each structure includes a cavity having a volume equal to one-half of the volume of cavity 205. Coupling the pair of symmetrical structures together forms heat sink 100 including cavity 205 formed in the interior of heat sink 100. Coupling is accomplished by brazing, welding, soldering, or any other suitable metal fusing process.

In an alternate embodiment, a bottom section of body 201 is formed having cavity 205 including cavity surfaces 208 and 209. A top section of body 201 is formed having surface 207. Finally, the top section of body 201 is coupled along the dashed lines 219 and 221 to the bottom section of body 201 to form heat sink 100 including body 201 having cavity 205. Coupling is accomplished by brazing, welding, soldering, or any other suitable metal fusing process.

Cavity surfaces 207-209 are shaped to enhance the formation of convection currents 217 in phase change material 211 during the operation of integrated circuit 103. Cavity surface 208 slopes upward toward cavity surface 209 from low area 223 located near the center of surface 208. Low area 223 is preferably positioned in body 201 such that when body 201 is coupled to integrated circuit die 103, low area 223 is positioned directly above the hot spot of integrated circuit die 103. Such positioning of low area 223 enhances the flow of convection currents 217 in phase change material 211. For most integrated circuits, the hot spot is located approximately in the center of the die. The shape of low area 223 is not limited to a particular shape. In some embodiments, low area 223 is a point or a small flat rectangular area and surface 208 has the shape of a pyramid or a flat top pyramid. In alternate embodiments, low area 223 is an approximately circular area or a point and surface 208 has the shape of a flat top cone or a cone. In still another alternate embodiment, low area 223 is a wedge running the length of cavity 201.

Phase change material 211 in the solid phase only partially fills cavity 205. The unfilled portion of cavity 205 provides room for expansion of phase change material 211 during the operation of integrated circuit 103. Heat sink 100, including phase change material 211, exhibits superior heat dissipation properties when compared with a heat sink that does not include phase change material 211. Phase change material 211 absorbs heat and provides conductive cooling during the power up cycle of integrated circuit 100. Phase change material 211 is especially effective in cooling local hot spots and thermal transients that occur on die 103 during the power up cycle. In addition, phase change material 211, by circulating in a liquid state, provides convective cooling during the steady state operation of integrated circuit 103. In one embodiment, phase change material 211 comprises TH58. A phase change material designated as TH58 has a melting temperature of about 58 degrees centigrade, an average density of about 1500 kg/m^3, and a latent heat of between about 175 kJ/kg and about 225 kJ/kg. Phase change materials suitable for use in connection with the present invention include hydrated salts, eutectic salts and paraffins. Other phase change materials may also be suitable for use in connection with the present invention.



Heat sink 100 is thermally coupled to integrated circuit 301 included in wireless communication device 303. In one embodiment, wireless communication device 303 is a cell phone, In an alternate embodiment, wireless communication device 303 is a personal digital assistant. Heat sink 100 is capable of cooling integrated circuit 301 in wireless communication device 303 without forced air. Integrated circuit 301, in one embodiment, is a processor. In an alternate embodiment integrated circuit 301 is a digital signal processor. Portable devices, such as wireless communication device 303 produce a significant amount of thermal energy and heat sink 100 is also capable of dissipating the heat without increasing the height of the heat sink, which permits wireless communication device 303 to have a low profile package.

Heat sink 100 is not limited to use in connection with wireless devices. Since heat sink 100 is more efficient at dissipating thermal energy than a standard heat sink, heat sink 100 is especially useful for dissipating thermal energy in integrated circuits used in computing devices, such as laptop computers, servers, and engineering workstations, that generate a large amount of thermal energy.

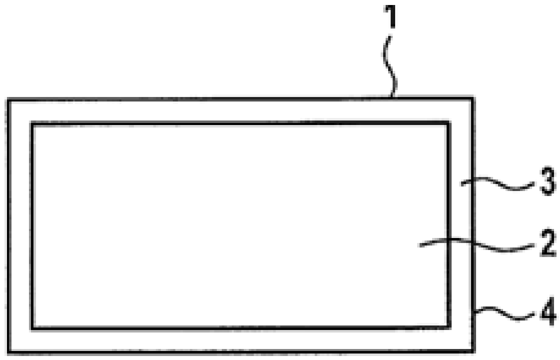
BATTERY THERMAL MANAGEMENT USING PHASE CHANGE MATERIAL
US 2014/0004394 A1, Kerkamm, I.

FIG. 1 shows a device 1 for thermal management of a battery, having a battery 2, a latent heat storage material 3 and a housing 4. In the simplest specific embodiment here, latent heat storage material 3 is situated around battery cell 2. The latent heat storage material is a storage material which may change its phase from liquid to solid and vice versa and release or absorb energy in the process. Latent heat storage material 3 may be situated in one or multiple containers, for example, one or multiple housings 4, one or multiple films to retain latent heat storage material 3 in the liquid phase.

The operating mode "device 1 for battery thermal management" is as follows: Device 1 for thermal management of a battery has a cooling function, on the one hand. When the battery is in operation, the battery generates energy. Most of the energy is consumed. Some of the energy is converted into heat. The thermal energy is delivered by the battery to the latent heat storage material which surrounds the battery. The latent heat storage material absorbs the thermal energy. The input of heat causes a phase transition to occur in the latent heat storage material, so that the phase of the latent heat storage material changes. The storage material which was previously solid changes to the liquid phase. Absorbing the excess heat of the battery by the latent heat storage material results in melting of the storage material and the battery is cooled by the release of heat.

On the other hand, device 1 for thermal management of a battery has a heating function.

When battery 2 is not in operation or is turned off, no energy is generated by battery 2. Latent heat storage material 3 is in the liquid phase. Crystallization of latent heat storage material 3 is triggered by a pulse. A phase transition from the liquid phase to the solid phase then takes place in the latent heat storage material. During crystallization, the heat of crystallization is released and is absorbed by battery 2 bordering latent heat storage material 3. This causes the battery to heat up and the device acts as a heating element.



The device and the heat of crystallization released by the latent heat storage material may be used to heat or preheat the battery.

Housing 4 may be configured in such a way that the latent heat storage material is stored in several separate housings. The individual housings may be controlled jointly. In a specific embodiment, the individual housings may be controlled independently of one another. This means that crystallization may be triggered independently in the individual housings.

This means that the pulses may be triggered independently of one another in the individual housings. The quantity of heat released may be adjusted in this way, based on the number of triggered crystallization processes or the number of controlled housings or the number of controlled latent heat memory materials. Regardless of the starting temperature being too low, the optimum operating temperature of the battery may be set in this way. The thermally managed battery may be using a plurality of small housings which contain the latent heat memory materials and surround the battery, and the temperature of the battery may be set exactly, if necessary.

To be able to achieve better heating directly at the battery, the latent heat storage material may also be applied to the battery. The latent heat storage material may be then located in small interspaces in the battery.

Crystallization of the latent heat storage material and thus the heating function of device 1 for thermal management of a battery are not triggered when the ambient temperature is high enough. Latent heat storage material 3 then remains deactivated and does not heat the battery.
Device 1 according to the present invention for thermal management of a battery may be used with all batteries which are used under mobile or stationary conditions, regardless of the chemical composition.

The present invention also includes products which include device 1 for thermal management of a battery, for example, equipment and vehicles.

Device 1 for thermal management of a battery may be used in all equipment in which a battery is to operate at a certain temperature, for example, in motor vehicles, in stationary energy stores (for example, in conjunction with photovoltaic systems or wind power plants) or in power tools.

A particular specific embodiment of the present invention relates to the use of device 1 for thermal management of a battery in vehicles, e.g., automobiles, boats, aircraft, motorcycles.

The advantages of device 1 according to the present invention for thermal management of a battery include the fact that an automobile is able to start at very low temperatures without necessitating an energy-intensive preheating of the battery with the aid of a separate system. This reduces the energy consumption for preheating the battery at low ambient temperatures. With the device, faster heating of the battery may be achieved and the warm-up phase is shortened. With the device, operation of the battery in the optimal temperature range may be ensured. The lifetime of the battery may therefore be increased. An additional battery heater is redundant, as the case may be. This lowers manufacturing and repair costs.

The present invention is verifiable easily and unambiguously by a visual arrangement or by a simple measuring technique on the product through the use of a coolant/heating medium with latent heat storage materials.