TECHNOLOGY REVIEW:

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 phase change materials (PCMs), in particular some more recent applications for these versatile thermal management products. There is much activity in this product arena, and these patents show some of the salient features that are the focus of different inventors.

LIQUID COOLANT WITH MICROENCAPSULATED PHASE CHANGE MATERIALS FOR AUTOMOTIVE BATTERIES

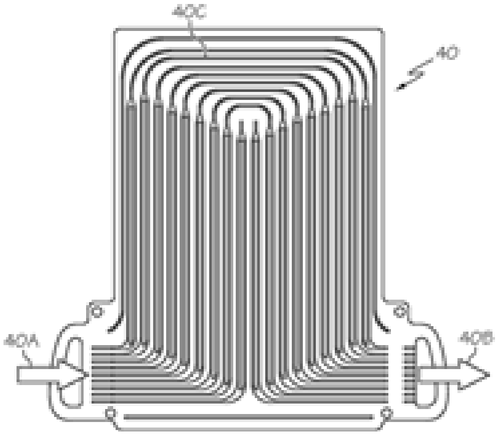
US 8623538 B2, WANG, X.

A microencapsulated phase change material used in conjunction with a cooling fluid as part of a thermal management system for an automotive battery pack assembly. The microencapsulated phase change material is made to have enhanced latent heat transfer properties at lower (colder) temperatures and higher (elevated) temperatures such that a vehicle employing such an automotive battery pack assembly is more resistant to environments where freezing and overheating might otherwise be prevalent. Therefore, there is a need for an improved thermal management of portable and/or wearable electronic devices that take into account other factors and consideration when performing thermal management.

Lithium-ion batteries are being used in automotive applications as a way to supplement, in the case of hybrid

PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
US 8623538 B2	LIQUID COOLANT WITH MICROENCAPSULATED PHASE CHANGE MATERIALS FOR AUTOMOTIVE BATTERIES	Wang, X.	Jan 7, 2014
US 8703271 B2	THERMAL INTERFACE MATERIAL	Razeeb, K. et al	Apr 22, 2014
US 8783894 B2	LED LAMP ASSEMBLY WITH THERMAL MANAGEMENT SYSTEM	Hitchcock, R. et al	Jul 22, 2014

Table 1. Patents Reviewed Featuring Phase Change Material



electric vehicles (HEVs), or supplant, in the case of plug-in electric vehicles (PEVs), 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 needed to serve as a propulsion system for cars, trucks, buses, motorcycles and related automotive or vehicular platforms.

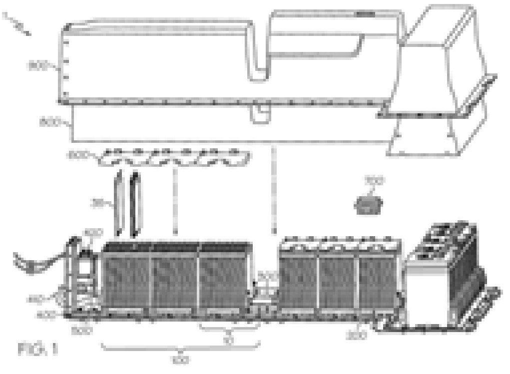


FIG. 1

A battery thermal management system based on a phase change material (PCM) has the potential to limit battery temperature extremes, thus acting to increase temperature uniformity, as well as to reduce heating and cooling requirements. This helps to prolong the life of heat-sensitive components, such as the charge-carrying battery cells that form the building blocks of battery modules and battery packs. PCMs can absorb and release a large amount of latent heat (in some instances up to fifty times higher than sensible heat) during isothermal (i.e., constant temperature) changes of phase, such as from solid-to-liquid or liquid-to-solid. As such, the use of PCMs can help to reduce or eliminate the need for active cooling components such as a fan, blower or pump in forced-air or forced-liquid cooling systems. This is beneficial in that the PCM can provide the ability to maintain the cell temperature in a desired temperature range without drawing power from the battery or another energy source. An example of a PCM-based approach to battery thermal management may be found in a co-pending U.S. patent application Ser. No. 13/175,483 entitled BATTERIES WITH PHASE CHANGE MATERIALS which was filed on the same day as the present application, owned by the Assignee of the present invention and hereby incorporated in its entirety by reference.

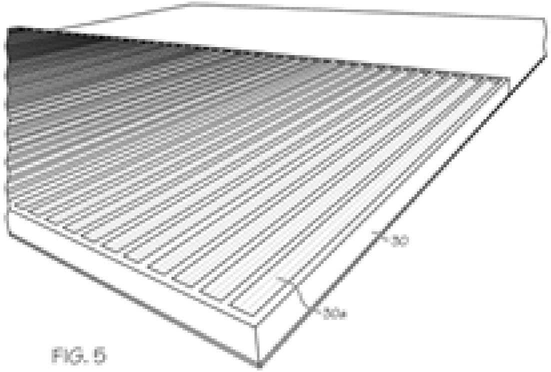


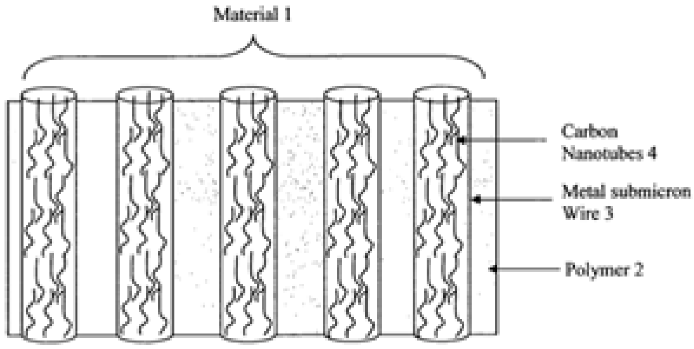
FIG. 5

According to one aspect of the invention, a thermal management system for an automotive battery pack employs a microencapsulated version of a PCM-based thermal management system. This version, known as a microPCM, is made up of very small bi-component particles or capsules that include a core material tailored to latent heat changes within a temperature range typically countered in an automobile battery pack, along with an outer shell or capsule made from a polymer or related material such that together, the core and shell define a generally spherical foam-like material.

THERMAL INTERFACE MATERIAL

US 8703271 B2, RAZEEB, K. ET AL

A thermal interface material (1) comprises a bulk polymer (2) within which is embedded sub-micron (c. 200 to 220 nm) composite material wires (3) having Ag and carbon nanotubes (“CNTs”) 4. The CNTs are embedded in the axial direction and have diameters in the range of 9.5 to 10 nm and have a length of about 0.7 μm. In general the pore diameter can be in the range of 40 to 1200 nm. The material (1) has particularly good thermal conductivity because the wires (3) give excellent directionality to the nanotubes (4)—providing very low resistance heat transfer paths. The TIM is best suited for use between semiconductor devices (e.g. power semiconductor chip)



and any type of thermal management systems for efficient removal of heat from the device.

The invention relates to a thermal interface material (“TIM”) for uses such as high thermal conductivity. One of the main limitations in power semiconductor device cooling is the microscopic unevenness and non-planarity between the mating surfaces (chip and heat sink). Asperities on each of the surfaces prevent the two solids forming a thermally perfect contact. Therefore there have been proposals to move away from TIMs in the form of bulk rigid bodies such as Cu films.

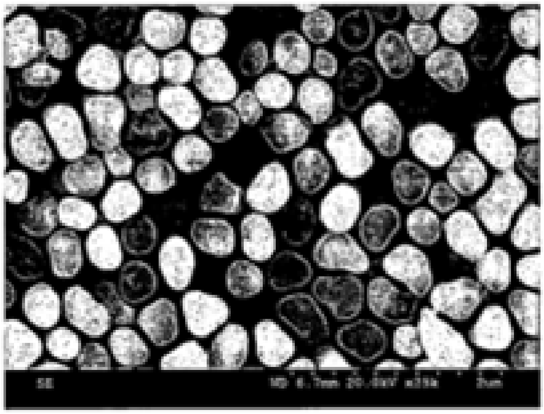
The invention is directed towards providing an improved TIM for applications where there is unevenness, generally where conformity and high thermal conductivity are required.

According to the invention, there is provided a thermal interface material comprising:
- a body having opposed faces, and
- aligned submicron wires in pores in the body and extending between the opposed faces,
- each submicron wire including a metal.

The aligned sub-micron wires give excellent heat transfer paths and the body may be chosen for the required degree of flexibility for conformity with the end-application devices with which it is in contact.

The TIM is best suited for use between semiconductor devices (e.g. power semiconductor chip) and any type of thermal management systems for efficient removal of heat from the device. This material has the potential to achieve thermal conductivity beyond state of the art thermal interface material pads. In the near future, the power level for power semiconductor devices will rise to about 200 W, or about an effective power density of 500 Win−2. In order to remove the heat efficiently, different types of thermal interface material (TIM) are used between packaged semiconductor device and the thermal management system e.g. heat sink. Present TIMs (having thermal conductivity of 10-50 Wm−1K−1) are not sufficient to remove the heat of these power semiconductors. The TIM the invention has a thermal conductivity of >80 Wm−1K−1 and thereby is able to dissipate the heat very efficiently.

The “MWCNT” (multiwall carbon nanotubes) and metal composites are embedded in polymer as high aspect ratio wires and thereby act as a thermal path between two mating surfaces, which can conform to the surface roughness due to their submicron diameters and micron lengths. Because the template within which they are embedded has some flexibility there is excellent conformity with the mating surfaces. As the metal co-deposited with carbon nanotubes have high thermal conductivity (3000 Wm−1K−1), the overall conductivity of the wires is increased. Unlike the prior art, it does not depend on the percolation threshold property of the filler materials of commercial TIM product to constitute a thermal path between two surfaces.

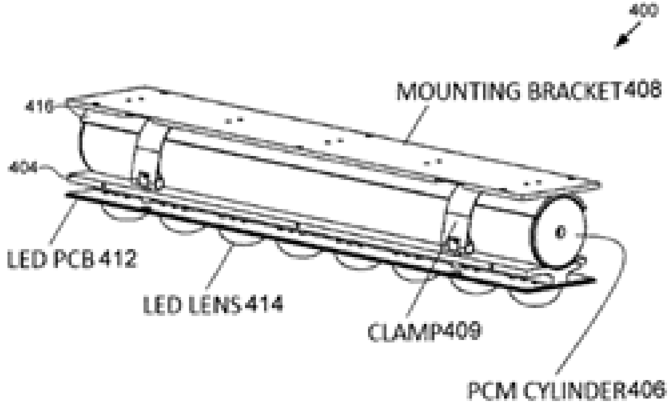


Examples of metal of the submicron wire can be nickel, gold, copper, or silver. Nickel, copper, and silver submicron wires were fabricated having room temperature thermal conductivity of 90.7, 401 and 429 Wm−1K−1 in their bulk form, respectively. Among them silver was the preferred metal of choice as bulk silver has the highest room temperature thermal conductivity of 429 Wm−1K−1. In the present invention a single submicron wire having high aspect ratio will be able to make a thermal path between the device and the heat sink without depending on any percolation and thereby eliminating the inter-particle thermal interface resistance as well found in the commercial TIM products.

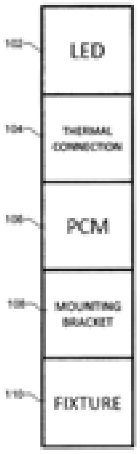
LED LAMP ASSEMBLY WITH THERMAL MANAGEMENT SYSTEM

US 878394 B2, HITCHCOCK, R. ET AL

A lighting system is described. The lighting system includes a lamp and a first container including a first phase change material thermally connected to the lamp. Heat generated by the lamp during operation is conducted to the first phase change material. The system also includes a second container including a second phase change material thermally connected to the lamp. Heat generated by the lamp during operation is also conducted to the second phase change material, and the second phase change material has a transition point temperature lower than the transition point temperature of the first phase change material of the first container to account for a temperature drop between the second container and the first container. The lighting system also includes a temperature sensor for reducing lamp power if the lamp becomes too hot, and a mounting bracket which may also conduct heat away from the lamp.



PCM (“phase change material”) unit 106 includes, in one embodiment, a high heat latency phase change material enclosed in a thermally conductive container. Phase change materials typically have a high latent heat of fusion such that a large amount of heat energy must be applied to change the PCM from, for example, a solid to a liquid, or from a solid having a first characteristic to a solid having a second characteristic. Illustrative PCMs are sodium sulphate, magnesium chloride, and barium hydroxide compositions. At temperatures below and above a PCM's transition point temperature, the PCM temperature rises as the PCM absorbs heat. However, at the PCM's transition point temperature, the PCM absorbs heat without increasing in temperature until a change of state occurs. As such, a PCM can “clamp” the temperature of its surroundings at its transition point temperature.



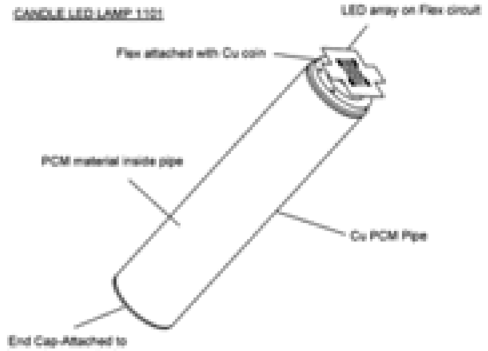


Fig. 11b

PCM unit 106 is effectively clamped at the transition point temperature until a complete PCM change of phase has occurred. LED 102 and PCM unit 106 are coupled via thermal connector 104 so that the heat generated by LED 102 can be transferred to PCM unit 106. Because there is a known temperature drop along thermal connector 104, the clamping temperature of PCM unit 106 effectively clamps the temperature of LED 102 at a slightly higher temperature. During the clamping period, PCM unit 106 absorbs all or at least a portion of the heat or energy released into lighting system 100 while keeping a steady temperature so that lighting system 100 may continue to work within a normal working temperature range.

This clamping effect is especially important for LED-based lighting systems because the available output capacity, efficiency, and life of an LED are highly dependent upon the LED junction temperature, and the LED junction temperature can rise if the temperature of lighting system 100 rises. The clamping effect can provide benefits in several different ways. For example, in one embodiment the clamping effect can be used to drive a configuration of LEDs with a higher current, under ordinary ambient conditions, to provide more light output than would otherwise be possible or sustainable at that current. In another embodiment, the clamping effect can be used to drive a configuration of LEDs with an ordinary current, under extreme ambient conditions (e.g., in a hot desert environment), to provide more light output than would otherwise be possible or sustainable in those conditions.

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