

Passive temperature control of accumulators

The invention relates to a battery with a temperature control. It is today usual to use batteries (accumulators) for the intermediate storage of electricity for cases of need. Typical applications are house batteries, emergency batteries, in particular also hybrid vehicles and electric vehicles, including rail mounted vehicles and aircraft.

Batteries have optimal working temperature ranges and it is well-known that the battery performance decreases at too low temperature strongly and at increased temperatures decomposition of the battery is possible, including fire/oxidation.

In order to thus organize an optimal work temperature range for such batteries, most diverse solutions are suggested.

JP3050051 reveals an air conditioner for electric vehicles, whereas the cooling or heating up of the battery can be made by air cooling.

The JP3733682 teaches a battery temperature controller, which uses the introduction of air of the vehicle's aircondition into the battery casing, that can heat or cool by an introduction channel.

The Japanese patent application (Kokai) No. 10-32021 describes a battery with a heat insulating material, and the use of an auxiliary heating device, like an electrical heating facility, in order to maintain a suitable working temperature of the battery in cold conditions.

The revealed Japanese patent application (Kokai) No. 2006-269426 discloses a battery with several battery units, whereby partitions between the battery units are arranged next to each other, a housing, in which the battery units and the partition are installed and a discharge opening, by which a heat carrier medium flows, and suggests a PTC heating element between the partition and the battery unit

DAIMLER proposes for this task in the DE102010013025 heat transfer plates, which are connected with heat pipes, which out-transport the heat fast from the battery.

Also the DE 102012220873 A1 recommends the use from heat pipes for fast heat transport from the battery. DE 102012200401 A1 of the Zahnradfabrik Friedrichshafen uses for it flat heat pipes or vapor Chambers, which take up the heat of the battery cells in the area and delivers heat at their front surfaces to collectors. It has been already tried to store the waste

heat of batteries for later use in heat accumulators (JP2001236145A and DE102011105366 A1).

The known heat controls of batteries are capable of improvement.

It is the problem of the invention to improve the known heat controls of batteries and in particular to avoid a loss at heat energy within a system, which uses the battery.

The problem is solved according to the invention by a battery assembly with the characteristics of claim 1. Favorable embodiments result from the dependent claims.

A generic battery or accumulator has at least one battery cell and a temperature control for the battery cells, whereas the temperature control comprises: at least a vapor chamber, which is in direct contact with its first battery surface with the surface of that at least one battery cell and has heat pipes, which are arranged on a second heat pipe contact surface of the vapor chamber and run out of the battery to a heat exchanger. If necessary heat can be transported out from the battery very fast and by this passive heat control overheating the same can be avoided while loading or due to leakage current based on material defects. Particularly with the Li-cells this is extremely important, since these can catch fire easily and lead to fires. Some spectacular accidents with these battery types in electric cars and also with laptops and other mobile devices led to severe safety restrictions e.g. in air traffic. Since chemical reactions, that are the reason for the battery fires, are exotherm and need elevated reaction heat security the same can be increased by fast heat transport therefrom.

Furthermore it is well-known that batteries have generally a work temperature range, in which they work optimally. It makes sense to maintain these within the desired temperature range.

According to the invention the heat-uptake-surface of the vapor chamber is arranged between two battery cells of a battery and adapted to these for optimal heat transition. E.g. the heat pipe contact surface of the vapor can have recesses for the insertion of the heat pipe sections to enable a larger heat transfer area between heat pipe and vapor Chamber with better heat transfer.

The selection of the heat pipes is possible for the expert in the technical field according to the objects to be obtained (explosion proof and/or high efficiency and/or legal restrictions and spacial requirements) without inventive activity and they can be selected from thermosiphon, heat pipes, variable conductance heat pipes, loop heat pipes (loop heat pipes), also thermosiphon-loops and and capillary pumped heat pipe loops (capillary pumped loops – CPL), whereby the heat pipe outer section runs in the heat exchanger runs and the heat pipe interior section runs between the battery cells on the vapor Chambers.

In a simple embodiment of the invention, which cools only the battery cells, the heatpipe interior section condensation zone and the heat pipe external section as vaporization zone are in the heat exchanger for warming up the battery cells.

Optionally the vapor chamber is manufactured at least in sections of electrically nonconducting material and preferentially as electrical insulator between the vaporchamber contact area and the Vaporchamber heatpipe contact area to hinder leak currents.

Preferably an external heat exchanger is included to the temperature control system to heat or cool the battery cells for regulation of the battery temperature for optimization of its performance and the heat exchanger medium is selected from: fluid materials, air, cooling agent from the cooling cycle, PCM or a solid heat accumulator material, comprising zeolite, salt hydrates or phase change material, comprising paraffins and fatty acids, and at least one heat pipe, which is thermally connected with the battery at one end by the vapor chamber, works as heating device for the battery and/or as a cooling device, which cools the battery by means of the vapor chamber.

Depending upon use of the battery – whether mobile in vehicles of all kinds – weight and space requirements – or as stationary battery in permanent or temporary buildings, tent cities, as buffer battery etc. - is to possible, to select suitable heat transfer means.

The at least one battery cell can be selected from rectangular pillared battery cells, laminated battery cells and cylindrical battery cells.

With many applications the heat pipe outer sections are connected with heat transfer sheets, which make more heat dissipation possible from the surface.

According to the requirement also different heat pipes can – both regarding the working medium and the method of construction, can be used.

According to invention flat heat pipes – also called vapor chambers or heat spreader, between are arranged between battery cells, which immediately dissipate locally arising heat points over their surface. Vapor Chambers are substantially faster and more efficient than classical heatsinks, they exceed the heat conductivity of the aforesaid easily hundredfold and thus an extremely fast heat distribution and also – together with the heat pipes – transport from and into the battery is made possible.

On at least one surface of the vapor chambers heat pipes are arranged in intimate thermal contact. The surface texture of the vapor Chamber can be constructed that it surrounds the heat pipes from three sides and thus a good heat transition is enabled.

The heat pipes cross outside of the battery a heat accumulator, preferably a latent heat storage, which takes up the latent heat of the work fluid of the heat pipes. It can be favorable to use in addition loop heat pipes which large heat transport abilities.

A type of heat pipe is selected so that it transports heat starting from a certain initial temperature of the battery cells from the battery and takes up heat at a pre-determined minimum temperature of the battery the heat accumulator to the battery over the Heat Spreader. By both heatpipe-types a battery temperature range can be regulated and overheating and undercooling of the battery avoided. Thus a increased lifetime of the battery is obtained and their capacity is optimally used.

In addition, as latent heat storages solidstate storages, like zeolites, can be used, their heat release is easily controllable. It is also possible to use latent heat storage liquids, which are in a cycle independent of the battery – e.g. a heating cycle. The use of the latent heat storage depends from its capacity and – with mobile employment of the battery – also of its weight. Exemplarily, but not limiting, the following materials are listed, which are used for latent heat storages, so: salt/water eutectics = 0°C – paraffins – 30°C-130°C – salt hydrates 5°C-130°C – sugar alcohols 90°C-180°C – salts and their eutectic mixtures = 180°C and mobile latent heat storage (makroverkapselt) with a phase CHANGE material fusion point of 58°C, introduction temperature of 56°C-180°C

Latent storages are known and are applied already for diverse technical applications, like domestic heatings or also motor vehicles, are used. Regarding the latent heat storages incorporated by reference is the content of the Internet published book: http://www.buch-der-synergie.de/c_neu_html/c_10_07_e_speichern_thermisch.htm - „Buch der Synergie“ by Achmed A.W. Khammas, Rukn Eddin, Al-Buti Bldg., Damascus/Syria P.O.Box 2361.

Known are e.g. the slurries of microencapsulated phase change materials (PCM) as liquid latent storage media (s. „slurry as a heat transfer fluid Yasushi Yamagishi¹, *, Hiromi Takeuchi², Alexander T. Pyatenko², Naoyuki Kayukawa³ AIChE journal volume 45, Issue 4, pages 696-707, April 1999. Such materials are commercially obtainable from BASF S.E. under the trademark MIKRONAL®. The heat can be stored also in hydrated salt crystals - e.g. hydrated Na₂SO₄, chloride, hydrates, fluorides etc.

In mobile systems these are already used in motor vehicles since 1993 (Car Tech) with salts, which already liquefy with 78°C. Further applications in vehicles are the latent heat storage used by Modine Längerer & Reich since 1997, which use salts, which melt at 70°C – through heated water running through pipes that cross the LHS – as in an automobile radiator. When a cold engine is started the cooling water flows through the LHS, the salt crystallizes and freed heat immediately is used for the heating. A further company, the VW subsidiary company Votex, offers such heat accumulators since 1997 also as an addition for the models Golf and Passat. These latent heat storages can be attached problem-free to automotive batteries.

Since heat pipes have the characteristic to be able to transport heat bi-directionally - heat can be back-transferred from the latent heat storage – e.g. in order to maintain a suitable working temperature for the battery.

It is also possible to use loop heat pipes which exhibit a very large heat transfer capacity, run partly outside of the battery and have a great heat transfer capacity.

If a heat pipe is used will as heat conducting element, the working fluid can be e.g. Water, ammonia, carbon dioxide, ammonia and propane, alcohol or methanol or i-Propanol and/or mixtures thereof, the enumeration is only exemplary and the invention is by any means delimited to it. Considering its efficiency and its effect on the global environment, water and alcohols as well as optionally mixtures thereof are preferred as working fluid of the heat pipes for mobile applications.

The heat pipes can call upon heat from the latent heat storage if necessary and deliver also heat thereto. In a preferred embodiment of the latent heat storage it can be a fluid latent heat storage, like a micro-encapsulated phase change material (PCM = phase CHANGE material), that is applicable in most diverse places of a vehicle and can be pumped there – e.g. for the heating or for warming up a combustion engine, in order to reduce emissions and fuel consumption at cold start, for the support of the heating etc.

Thus a problem-free connection can take place to an existing cooling medium system and/or Temperature fluid system and to use the heat of the PCM, where it is just needed.

Preferrably the geometrical arrangement of the heat pipes takes place in such a way that the gravity supports its function.

The invention becomes more clear on the basis the attached drawings, in which schematically embodiments are shown and explained. The invention is not by any means delimited to these and the examples are purely exemplary to assist in the understanding. In it show:

Fig. 1 is a schematic plan view of on a vapor chamber with applied thermally conducting heat pipes in plan view;

Fig. 2 is a schematic cross sectional view through the vapor chamber of Fig.1;

Fig. 3 a schematic representation of a heat pipe;

Fig. 4 is a schematic crosssectional view of a vapor chamber;

Fig. 5 is a schematic view of a section of an accumulator along the vapor Chamber in accordance with Fig. 1 having heat pipe attached heat guide sheets, which are submerged in a cooling medium;

Fig. 6 is a schematic sectional view of an accumulator along the vapor chamber in accordance with Fig. 1 with attached cooling fluid heat exchanger, that is flushed with cooling fluid; and

Fig. 7 is a schematic view of an arrangement similar to Fig. 6 with attached latent heat storage.

In the following the invention is described in detail with reference to the drawings.

Fig. 1 is schematic view of a heat transfer unit according to the invention, comprising a vapor chamber and on it – as shown in Fig. 2 – run heat pipes in thermal contact (10). One recognizes the vapor chamber (20), which provides for an extraordinarily fast heat distribution over its entire surface. This heat is taken up by the heat pipes (10) thermally connected to the surface of the vapor Chamber (20) and transported to their ends outside of the battery.

On the heat pipe outer section (5) heat guide sheets (so-called fins) can be attached as usually, that are flushed by a heat-storing fluid, as air or other gas and cooled. It is also possible to use this fluid for warming up the battery at cold start conditions, if it is available at a moderate temperature then. Heat pipes work bi-directionally – i.e. the heat transfer direction reverses, if that heat pipe outer section (5) is hotter than the heat pipe interior section (3) on the vapor chamber (2, 2A, 2B) and heats thus the vapor chamber equally due to its high heat distribution capacity. So local overheatings – e.g. while charging the battery, which may lead to battery/accumulator damage up to fire can be avoided.

In Fig. 3 the flow of the working medium in the heat pipe (10) is clearly shown. It is heated at the heat pipe interior section (3), evaporates uptaking latent heat into the gaseous phase and condenses at the upper heat pipe outer section (5) under release of latent heat, which is removed by the heat guide sheets attached at the tube wall and delivered to a heat transfer medium – here schematically represented by thin arrows – and is immediately transported away. So due to the extremely high thermal conduction of the heat pipes (10) amounts of heat can be removed fast from the battery cells (1, 1A, 1B, AC, 1D, 1E) and battery failure can be avoided.

Batteries usually contain several battery cells (1, 1A, 1B, AC, 1D, 1E), which are arranged regularly. These battery cells are interconnected to form a battery or an accumulator.

In Fig.5 such an arrangement is shown on a vapor chamber (2, 2A, 2B). The heat pipe (10) takes up heat from the vapor chamber surface (4), heats up a liquid, which evaporates under absorption of latent heat into the gaseous condition and transports steam to its external end (5) with guide sheets, which are then flushed by a heat transfer fluid, which is gaseous or liquid. With classical heat pipes, so-called thermal syphons, the liquid return takes place only by the gravity. With classical heat conducting pipes the tube contains a wick-like material is – the so-called Wick - usually a sintered compact, fabrics/a mesh or formed channels in the pipe, which transport fluid on basis of the capillary effect and the nucleation effect attraction and nucleation effect back effectively into the hot section of the heat pipes and avoids boiling retardation at the heat pipe surface. Therefore heat pipes with Wicks work very effectively. A further embodiment are loop heatpipes, which transfer back the cooled down gas as liquid as closed loop. Regarding suitable heat pipes/Heatpipes it is

for the avoidance of repetitions referred to the book by David Reay and Peter Kew „Heat Pipes Theory, design and Applications, 5th edition, Butterworth Heinemann – publishing house 2006 which is incorporated by reference.

Fig. 6 shows the use of the heat transfer element according to invention in a battery or an accumulator with connected heat transfer fluid pipe. One recognizes clearly the fact that the heat pipes (10) run vertically and end in a fluid line used as heat exchanger – e.g. for water. The water flows through the heat exchanger (20) with the external heat pipe section, cools them and can be used to heat the vehicle or to dissipate it as usual in the radiator, if it is connected to the fluid cooling system.

Fig.7 shows schematically an embodiment with latent heat storage. The external heat pipe sections (5) deliver their heat to a latent heat storage unit (20) e.g. Zeolite, but also paraffins and other latent heat storages, like acetates and other salts. The heat accumulator thus charged can be also liquid and belong a latent heat storage fluid cycle.

List of reference numerals

1 , 1A , 1B , 1C , 1D , 1E	battery cell
2 , 2A , 2B	vapor chamber
3	inner section of heat pipe
4	section for vapor chamber contact
5	external section of heat-pipe
7	electrically isolating section of the vapor chamber
8	battery or accumulator
10	heat pipe
20	heat exchanger

⇒ flow of heat transfer medium

→ working fluid in vapor chamber

~ heat flow

Claims

1. Battery or accumulator (8), having
 - at least a battery cell (1, 1A, 1B, 1C, 1D, 1E) and
 - a temperature control for the battery cells (1, 1A, 1B, 1C, 1D, 1E), characterized in that the temperature control comprises:
 - at least a vapor chamber (2, 2A, 2B), that is in direct contact with a first battery contact surface (4) with the surface of that at least a battery cell (1, 1A, 1B, 1C, 1D, 1E) and
 - heat pipes (10), that are arranged partially on a second heat pipe contact surface (4) of the vapor Chamber (2, 2A, 2B) and run from the battery (8) to a heat exchanger (20).
2. Battery according to claim 1, characterized in that the heat uptake surface (4) of the vapor chamber (2, 2A, 2B) is arranged between two battery cells (1 - 1A, 1B - 1C, 1D - 1E) of a battery (8) and is adapted to these.
3. Battery according to the preceding claims, characterized therein, that the heat pipe contact surface (4) of the vapor Chamber (2, 2A, 2B) has recesses for the inclusion of the heat pipe interior sections (3).
4. Battery according to one of the preceding claims, characterized in that the heat pipes (10) are selected from thermal siphon, heat pipes, variable conductance heat pipes, loop heat pipe (loop Heatpipes), also thermal siphon loops and capillary pumped heat pipe loops (capillary pumped loops – CPL), whereas the heat pipe external section (5) runs in the heat exchanger (20) and the heat pipe interior section (3) is implemented between the battery cells (1, 1A, 1B, 1C, 1D, 1E runs) on the vapor chambers (2, 2A, 2B).
5. Battery according to one of the claims 1 to 4, characterized therein that the heat pipe interior section (3) is implemented as condensation zone and the heat pipe outer section (5) is implemented as vaporization zone in the heat exchanger (20) for warming up the battery cells (1, 1A, 1B, 1C, 1D, 1E) .
6. Battery according to the preceding claims, characterized therein that at least the vapor chamber (2, 2A, 2B) is manufactured at least partially from electrically non-conducting material and preferably as electrical insulator (7) between the vacuum chamber contact section (4) and the Vacuumchamber heatpipe contact area (5).
7. Battery according to one of the preceding claims, whereas as temperature control system an external heat exchanger (20) is provided for heating or cooling the battery cells (1, 1a...) for regulation of the battery temperature for power optimization thereof and the heat exchanger medium is selected from: fluid materials, air, cooling agent from a coolant circuit, PCKs or a solid heat accumulator material, comprising zeolite, salt hydrates or phase change material, comprising paraffins and fatty acids, at that the at least one heat pipe, which is

thermally connected with the battery at an one end by the vapor chamber, is able to heat as heating device the battery and/or as a cooling device, which cools the battery by means of the vapor chamber.

8. Battery according to claim 1, which is equipped with an individual battery cell or several aligned battery cells, whereby the heat conducting element is arranged between neighbouring battery cells.

9. Battery according to claim 8, whereas the at least one battery cell is selected from rectangular pillar battery cells, laminated battery cells and cylindrical battery cells.

10. Battery according to one of the preceding claims, characterized in that the heat pipe outer sections are connected with heat guide sheets.

11. Battery according to one of the preceding claims, characterized therein that different heat pipes are used.