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(71) Applicant: **CHRYSLER GROUP LLC** [US/US]; 1000 Chrysler Drive, Auburn Hills, MI 48326-2766 (US).

(72) Inventor: **TIMMONS, Adam**; 1113 North Old Woodward Ave, Birmingham, MI 48009 (US).

(74) Agent: **LACAVA, Richard**; Dickstein Shapiro LLP, 1633 Broadway, New York, NY 10019-6708 (US).

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(54) Title: METHOD AND DEVICE FOR ELECTROCHEMICAL CELL OVERHEATING PROPAGATION AVOIDANCE IN A BATTERY MODULE

(57) Abstract: A method and device for cooling an electrochemical cell is provided. In one embodiment, the cooling element for an electrochemical cell includes a metal element configured to engage with an electrochemical cell and absorb thermal energy from the electrochemical cell. The metal element is configured to melt into a liquid when the electrochemical cell exceeds an eutectic temperature of the metal element.

METHOD AND DEVICE FOR ELECTROCHEMICAL CELL OVERHEATING PROPAGATION AVOIDANCE IN A BATTERY MODULE

FIELD

[0001] The present disclosure relates to energy storage systems, particularly to a device and method for cooling electrochemical cells typically used in a vehicle power source.

BACKGROUND

[0002] Electrochemical cells can experience thermal events resulting in temperature increases for a cell. These temperature increases can damage a cell and in some cases result in propagation of thermal energy to one or more additional cells. Propagation of thermal energy can damage neighboring cells or other elements in proximity to an electrochemical cell. A drawback of current electrochemical cells and methods for cooling electrochemical cells is that thermal energy propagation may be promoted. In addition, conventional methods for cooling electrochemical cells may be volumetrically and thermally inefficient.

[0003] One conventional solution for cooling an electrochemical cell is to include cooling channels within a cooling element, the cooling channels including a fluid exchange to absorb thermal energy. One drawback of this approach can be increased cost for electrochemical cell cooling. Another drawback of conventional devices may be an inability to separate electrochemical cells from other electrochemical cells when a cell has overheated. Further, failure of cooling elements to absorb excessive heat may lead to the return of heat to an electrochemical cell. Cell cooling and detection of faults due to overheating may be necessary to promote safety as overheated cells can ignite or burst. In the particular case of vehicle energy systems, safety of the energy system may be critical, as overheating can lead to loss of vehicle power and potential harm to passengers.

[0004] Accordingly, there is a need and desire for a cooling mechanism for electrical chemical cells.

SUMMARY

[0005] In one form, the present disclosure provides a cooling element for an electrochemical cell. The cooling element comprising a metal element configured to engage with an electrochemical cell and absorb thermal energy from the electrochemical cell. The metal element is configured to melt into a liquid when the electrochemical cell exceeds an eutectic temperature of the metal element.

[0006] The present disclosure also provides an energy storage system comprising an electrochemical cell and a cooling element configured to engage the electrochemical cell and absorb thermal energy from the electrochemical cell. The cooling element is configured to melt into liquid when the electrochemical cell exceeds an eutectic temperature of the cooling element. In one embodiment, the energy storage system is a vehicle power source.

[0007] In another embodiment, a method is provided for detecting a fault in an energy storage system comprising a cooling member.

[0008] Further areas of applicability of the present disclosure will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description, including disclosed embodiments and drawings, are merely exemplary in nature intended for purposes of illustration only and are not intended to limit the scope of the invention, its application or use. Thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1A is a graphical representation of a cooling element in accordance with an embodiment of the present disclosure;

[0010] Figure 1B is a graphical representation of a cooling element in accordance with another embodiment of the present disclosure;

[0011] Figures 2A-2B are graphical representations of electrochemical cells in accordance with embodiments of the present disclosure;

[0012] Figures 3A-3B are graphical representations of energy storage systems in accordance with one or more embodiments of the present disclosure;

[0013] Figure 4 is a graphical representation of a cooling module in accordance with an embodiment of the present disclosure;

[0014] Figure 5 is a process for detecting a fault in accordance with an embodiment of the present disclosure; and

[0015] Figure 6 is a graphical representation of a state diagram of a cooling element in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0016] Figures 1A-1B illustrate cooling elements according to one or more embodiments of the disclosure. Referring first to Figure 1A, cooling element 100 is illustrated in accordance with a first embodiment of the present disclosure. Cooling element 100 may be configured for thermal management of electrochemical cells. In certain embodiments, cooling element 100 may relate to a cooling fin configured to draw and/or absorb heat from an electrochemical cell typically used in a vehicle power source (as described below). According to another embodiment, cooling element 100 may be designed to undergo a physical transformation (e.g., melt) when thermal energy absorbed from an electrochemical cell exceeds a predetermined temperature. By undergoing a phase change in response to electrochemical cell temperature, the cooling element 100 may absorb heat as it melts and produce an air gap to avoid thermal propagation from one electrochemical cell to another. For example, to avoid thermal propagation from the cell experiencing the thermal event resulting in high temperatures to one or more neighboring cells. One benefit of the cooling elements 110,150 of Figures 1A-1B may be to provide a cooling mechanism for electrochemical cells based on the heat conduction properties of desired element (e.g., metal, plastic, etc.) without the need for coolant running through the cooling element.

[0017] Cooling element 100 may be comprised of one or more metals. In one embodiment, cooling element 100 can be an alloy of tin and bismuth (e.g., Sn-Bn alloy). As will be discussed in more detail with respect to Figure 6, the composition of cooling element 100 may be an eutectic composition with an eutectic point to allow for melting in response to overheating by an electrochemical cell. Although cooling elements are described herein as being metal and/or metal alloy elements, it should be appreciated that the embodiments described herein may employ plastic or non-metal materials with similar characteristics.

[0018] According to one embodiment, cooling element 100 may be configured/designed to melt when a cell is overheating. The heat needed to melt metal of cooling element 100 can be drawn from a cell experiencing a thermal event that has caused high temperature. By way of example, overheating of the electrochemical cell may occur at temperatures of about 150 ºC when cells are designed to operate up to temperatures of about 60 ºC. Thus, the cooling element 100 may be configured and/or designed to maintain a solid form for at least temperatures below 60 ºC.

[0019] Cooling element 100 is depicted as a sheet-like member, however, it should be appreciated that cooling element 100 may take on one or more other forms. For example, the dimensions of cooling element 100 may be based on its use as a spacer between two electrochemical cells, the electrochemical cell shape, and/or the cooling element shape. In addition, one or more dimensions of cooling element 100 may be selected to allow cooling element 100 to deform to the surface of an electrochemical cell. For example, cooling element 100 may be comprised of a soft metal that can conform to any irregularities in electrochemical cell surfaces and promote efficient thermal contact for normal heating and cooling conditions. In addition, cooling element 100 may be dimensioned to conform and/or engage with a cooling plate and allow for a thermal contact between the cooling plate and the cooling element.

[0020] As depicted in Figure 1A, cooling element 100 is depicted as having a width 105, length 110, and thickness 115. In an exemplary embodiment, cooling element 100 may have a width 105 of 15 cm, length 110 of 22 cm, and thickness 115 of 1 mm. Exemplary values for cooling element 100 may include a width 105 within the range of 5 to 25 cm, length 110 within the range of 10 to 44 cm, and thickness 115 of 0.5 to 5 mm. It should be appreciated that the dimensions of cooling element 100 may be different depending upon the application it is being used in.

[0021] Referring now to Figure 1B, another cooling element 150 is depicted in accordance with another embodiment disclosed herein. Cooling element 150 may have similar features to cooling element 100 described above with respect to Figure 1A. Cooling element 150 includes a plurality of spacers 155. Spacers 155 may be employed to provide an air gap between electrochemical cells once the metal of a cooling element melts; the air gap thermally separating an overheating cell from its neighboring cells. According to one embodiment, spacers 155 may be embedded into cooling element 150 to facilitate continued electrochemical cell separation upon melting of the metal and removal of excess stack pressure from the metal while maintaining adequate vertical stack pressure on the stack of electrochemical cells.

[0022] Spacers 155 may be cylindrical plastic elements. In one embodiment, spacers 155 may be thermally non-conducting. Spacers 155 may be comprised of a polyurethane, polyol, pentaerythritol (e.g., stiff white polyol plastic polyurethane) or other material(s) that melt at temperatures greater than 315 °C and exhibit very low heat conductivity. According to one embodiment, spacers 155 may be configured to melt at a temperature greater than roughly the maximum temperature at the surface of a Li-ion cell during a reduction reaction thermal event.

[0023] According to one embodiment, cooling element 150 may include a matrix or pattern of spacers 155. The pattern of spacers in cooling element 150 can provide structural integrity and crush resistance for cooling element 150 without compromising the purpose of the cooling element. Metal of cooling element 150 can melt to prevent thermal propagation and overheating of a neighboring cell. An array of spacers, such as spacer 155, can allow cooling elements to press against and apply pressure to the face of electrochemical cells, which can provide long cell life and good thermal contact between the cooling element and the cell.

[0024] Figures 2A-2B are graphical representations of electrochemical cells in accordance with an embodiment of the present disclosure. Figure 2A illustrates an electrochemical cell module 200 including electrochemical cell 205, electrochemical cell 210, and cooling fin 215. Electrochemical cells 205 and 210 may be individual cells of an energy storage system, such as a battery pack, power supply, or vehicle battery source. Cooling fin 215 may be one of the cooling elements 100, 150 described above in reference to Figures 1A and 1B. Cooling fin 215 may be configured to absorb heat and cool electrochemical cell 205 and/or electrochemical cell 210.

[0025] In one embodiment, an increase in temperature of electrochemical cell 205 or electrochemical cell 210, due to a thermal event or overheating, can result in cooling fin 215 undergoing a change from solid phase to liquid phase. In such a case, the metal of cooling fin 215 will melt. As such, an air gap will be created between electrochemical cells 205 and 210. A thermal event may be caused by overheating by one or more of electrochemical cell 205 and/or cell 210. Electrochemical cells may overheat under various abuse conditions. For example, thermal events may be due to a field short (e.g., a short circuit in the cell), an external short (e.g., short is exerted up on a cell), overcharging of a cell and/or over-discharging of a cell. Thermal events may similarly be caused by cell damage, such as the deformation of the cell causing an internal short. Thermal events or faults may also be due to cells spontaneously exhibiting higher internal resistance resulting in a field failure (e.g., current from cells in series will causing a cell to overheat).

[0026] In one exemplary embodiment, if the heat cannot be extracted fast enough at an elevated temperature, such as 90 ºC, then a cell, such as a Li-ion cell with a graphite negative electrode, will begin to create heat as chemicals within the cell begin to deteriorate exothermically. This can cause a fairly rapid rise of temperatures in the cell to above 150 ºC and up to greater than 300 ºC, potentially faster than the energy storage system can react. According to one embodiment, the energy storage system may open contactors (e.g., switches) to the storage system, thus causing the flow of current in the electrochemical cells to stop, in response to such an elevated temperature. Once the temperature of a cell is above 150 ºC for particular periods of time, heat given off to neighboring cells can initiate a similar overheating state and/or propagation to one or more other cells. For energy storage systems in a vehicle, when the vehicle and battery are on and a thermal event is detected in time, the thermal system can try to remove the heat from the overheating cells as fast as possible to prevent propagation. However, when the vehicle is off, an energy storage system and possibly vehicle may be severely damaged if the thermal event is not avoided in time. Cooling elements and fins, as described herein, can be less expensive, more efficient and more reliable to deal with thermal events relative to conventional methods.

[0027] Figure 2B depicts electrochemical cell module 250 after cooling fin 215 of Figure 2A has undergone a phase change. In particular, Figure 2B depicts electrochemical cell 250 including electrochemical cell 205, electrochemical cell 210, and spacers 220a and 220b. Spacers 220a and 220b may exert a force on electrochemical cell 205 and electrochemical cell 210. Spacers 220a and 220b may additionally provide an air gap between the electrochemical cells for heat to dissipate when a cooling element has melted.

[0028] According to another embodiment, the cooling elements described herein may be employed in energy storage systems, such as battery modules typically used in vehicles. Figures 3A-3B are graphical representations of energy storage systems in accordance with an embodiment of the present disclosure.

[0029] Figure 3A depicts energy storage system 300, which may be a multi-celled battery pack, including electrochemical cells 305_1, 305_2, ... 305_n and cooling fins 310_1, 310_2, ...310_n. Electrochemical cells 305_1, 305_2, ... 305_n may each include terminals (e.g., positive and negative terminals), such as terminal 315, to provide electrical power from the electrochemical cells. According to one embodiment, electrical storage system 300 may include cooling plate 320 to absorb and/or remove heat from one or more cooling elements, such as cooling fins 310_1, 310_2, ...310_n. Cooling plate 320 may be beneath cells 305_1, 305_2, ...305_n and cooling fins 310_1, 310_2, ...310_n. In one embodiment, cooling fins 310_1, 310_2, ...310_n are attached to cooling plate 320. Cells 305_1, 305_2, ...305_n may be in contact with cooling fins 310_1, 310_2, ...310_n.

[0030] Cooling plate 320 can be fastened and/or electrically connected to battery chassis 325, another module and/or battery component subsequently connected to battery chassis 325. When energy storage system 300 relates to a vehicle power source, battery chassis 325 may be fastened to a vehicle chassis, such as optional vehicle chassis 330. The positive and negative terminals of energy storage system 300 are electrically isolated from battery chassis 325 and vehicle chassis 330.

[0031] Energy storage system 300 may be configured to detect an isolation fault. Figure 3B depicts a representation of melting, in one exemplary situation, of a cooling element 335 which contacts cell 305_1 and battery chassis

325. Figure 5 below discusses detection of an isolation fault caused by a melted element, such as element 335, in more detail below. By way of example, if a cooling fin is configured to melt when a cell overheats, then a point on the surface of the edge of the cell (e.g., not on the face where the cooling fin normally makes contact with the cell) could be tied electrically to one of the terminals of the cell. As such, melted or molten metal of a formally solid cooling fin could electrically bridge the metal cooling plate and to one or more cells connected to battery chassis 325 creating an isolation fault.

[0032] Figure 4 is a graphical representation of a cooling module in accordance with an embodiment of the present disclosure. According to one embodiment, the cooling module may include one or more cooling elements or cooling fins as described herein. Figure 4 depicts cooling module 400 including a plurality of cooling fins 405_1, 405_2, ...405_n and cooling plate 410. Cooling module 400 may be arranged to conform to one or more energy storage system arrangements such that cooling fins 405_1, 405_2, ...405_n engage and/or contact electrochemical cells. Cooling fins 405_1, 405_2, ...405_n may also be configured to melt in response to an overheating of an electrochemical cell. According to one embodiment, cooling module 400 may be configured to include one or more elements to retain cooling fins 405_1, 405_2, ...405_n, such as support 415. According to another embodiment, cooling plate 410 may include one or more channels, such as channels 420_1, 420_2, ...420_n, to allow for removal of a melted material from a cooling fin.

[0033] Figure 5 is a process 500 for detecting a fault in accordance with an embodiment of the present disclosure. According to one embodiment, a molten cooling element may electrically tie terminals of an electrochemical cell and a cooling plate to result in a fault condition. The process 500 may be initiated by detecting voltage of the energy storage system such as e.g., the voltage of the electrochemical terminals at block 505. An isolation fault may be detected at block 510 when e.g., a terminal of an electrochemical cell is electrically connected to the vehicle chassis (via the battery chassis). The energy storage system can open energy storage system connections at block 515 based on the detection of the fault connection. The energy storage system may provide an indication to other devices of the isolation fault; in the case of a vehicle power source, battery contactors (e.g., switches that connect the battery to the vehicle's propulsion or charging systems) will open and cause the vehicle to go into a shutdown or limp mode (e.g., low power mode).

[0034] Figure 6 is a graphical representation of a state diagram of a cooling element in accordance with one or more embodiments. Cooling elements may be configured to melt when an electrochemical cell reaches temperatures of about 150 °C, whereas the cells are designed to operate only up to temperatures of about 60 °C. Figure 6 depicts an eutectic composition 605, eutectic temperature 610 and eutectic point 615 for a cooling element comprised of Sn-Bi according to one or more embodiments. It should be appreciated that composition values and characteristics of a composition of a cooling element described in relation to Figure 6 are exemplary, and that other values may be employed without departing from the sprit of the embodiments.

[0035] The cooling elements and energy storage systems described herein can advantageously absorb heat from electrochemical cells and discourage thermal propagation. In addition, volumetric and thermally efficient cooling may be provided for vehicles, and in particular vehicles using a battery pack or electrical energy source for propulsion. Additional benefits of the embodiments described herein include the ability to promote cell cooling, vehicle safety, and fault detection for vehicle energy systems.

CLAIMS

What is claimed is:

1. A vehicle energy storage system comprising:

an electrochemical cell; and

a cooling element configured to engage the electrochemical cell and absorb thermal energy from the electrochemical cell, the cooling element being configured to melt when the electrochemical cell exceeds an eutectic temperate of the cooling element.

2. The energy storage system of claim 1, wherein the cooling element is a metal alloy element comprised of tin (Sn) and bismuth (Bi).

3. The energy storage system of claim 1, wherein the eutectic temperature of the cooling element is between 100 and 150 degrees Celsius.

4. The energy storage system of claim 1, wherein the cooling element comprises at least one plastic spacer embedded in the cooling element.

5. The energy storage system of claim 4, wherein the at least one plastic spacer is one of a polyol plastic, pentaerythritol, and polyurethane.

6. The energy storage system of claim 1, wherein melting of the cooling element creates an air gap to absorb thermal energy for the electrochemical cell.

7. The energy storage system of claim 1, wherein the eutectic temperature of the cooling element is based on an operating temperature of the electrochemical cell.

8. The energy storage system of claim 1, further comprising a cooling plate configured to support the cooling element.

9. The energy storage system of claim 8, wherein the cooling plate comprises one or more channels for diverting melted material of a cooling element from the electrochemical cell.

10. The energy storage system of claim 1, wherein the energy storage system is a vehicle battery pack comprising a plurality of electrochemical cells, each electrochemical cell associated with a cooling element.

11. A cooling element for an electrochemical cell within a vehicle energy storage system, the cooling element comprising:

a metal element configured to engage with an electrochemical cell and absorb thermal energy from the electrochemical cell, wherein the metal element is configured to melt into a liquid when the electrochemical cell exceeds an eutectic temperature of the metal element.

12. The cooling element of claim 11, wherein the metal element is a metal alloy comprised of tin (Sn) and bismuth (Bi).

13. The cooling element of claim 11, wherein the eutectic temperature of the cooling element is between 100 and 150 degrees Celsius.

14. The cooling element of claim 11, wherein the cooling element comprises at least one plastic spacer embedded in the metal element.

15. The cooling element of claim 14, wherein the at least one plastic spacer is one of a polyol plastic, pentaerythritol, and polyurethane.

16. The cooling element of claim 11, wherein the eutectic temperature of the cooling element is based on an operating temperature of the electrochemical cell.

17. A method of detecting a fault in an energy storage system, the method comprising:

detecting voltage of an electrochemical cell of the energy storage system, the energy storage system comprising a metal element configured to absorb thermal energy from the electrochemical cell melt into a liquid when the electrochemical cell exceeds an eutectic temperature of the metal element; and

determining an isolation fault based on the voltage of the electrochemical cell; and

disabling the energy storage system based on the isolation fault determination.

18. The method of claim 17, wherein the isolation fault is detected based on electrical connection of the electrochemical cell to the energy storage system.

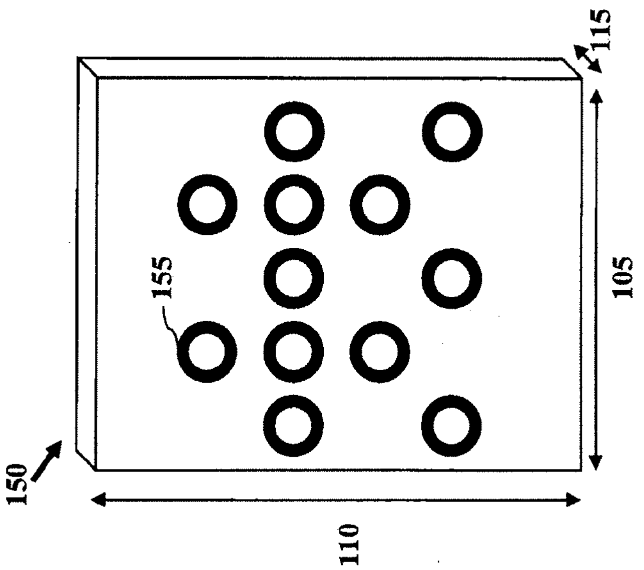

FIG. 1B

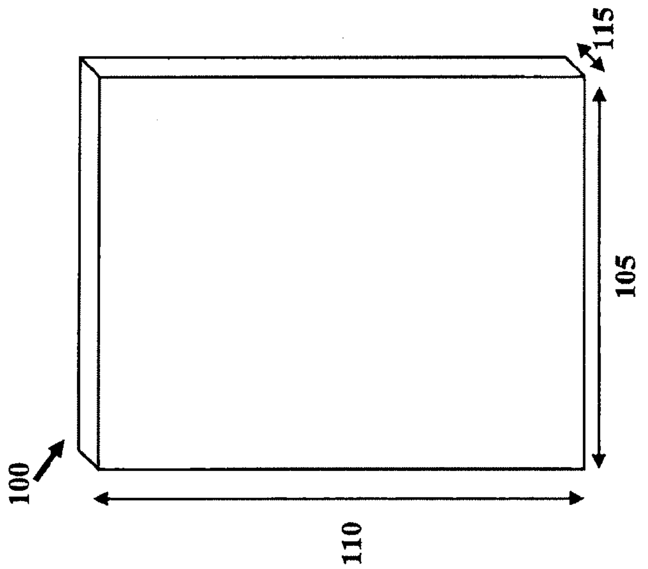

FIG. 1A

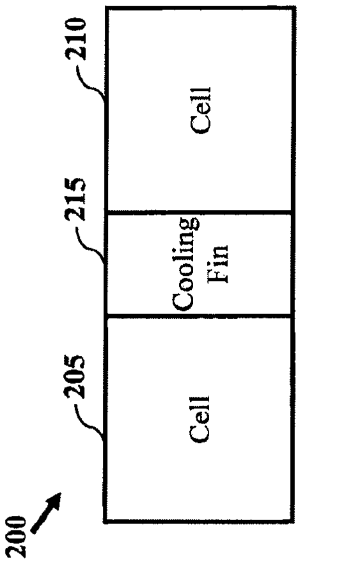
200
205
Cell
215
Cooling Fin
210
Cell

FIG. 2A

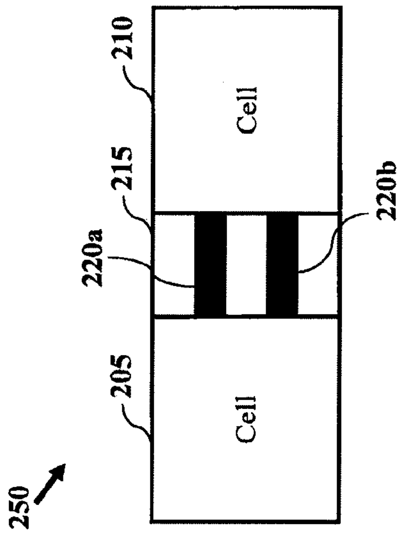
250
205
Cell
220a
215
220b
210
Cell

FIG. 2B

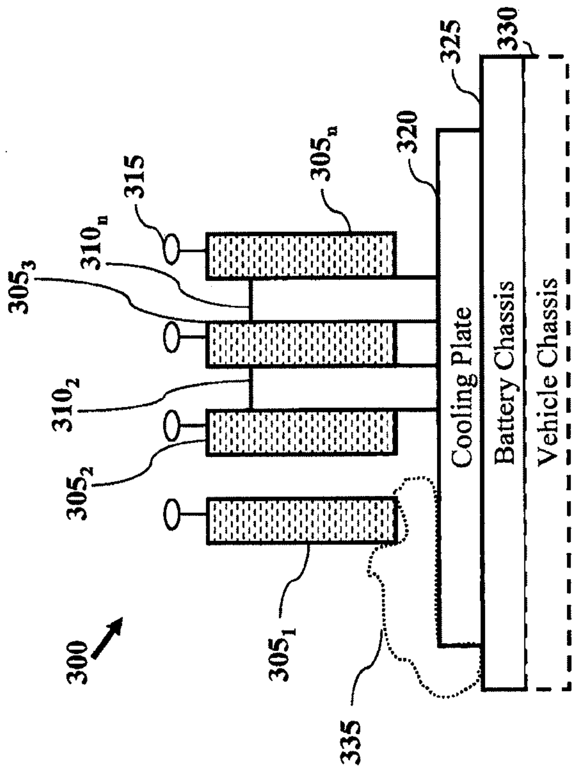
300
305_1
305_2
305_3
305_n
310_2
310_n
315
320
325
330
335
Cooling Plate
Battery Chassis
Vehicle Chassis

FIG. 3B

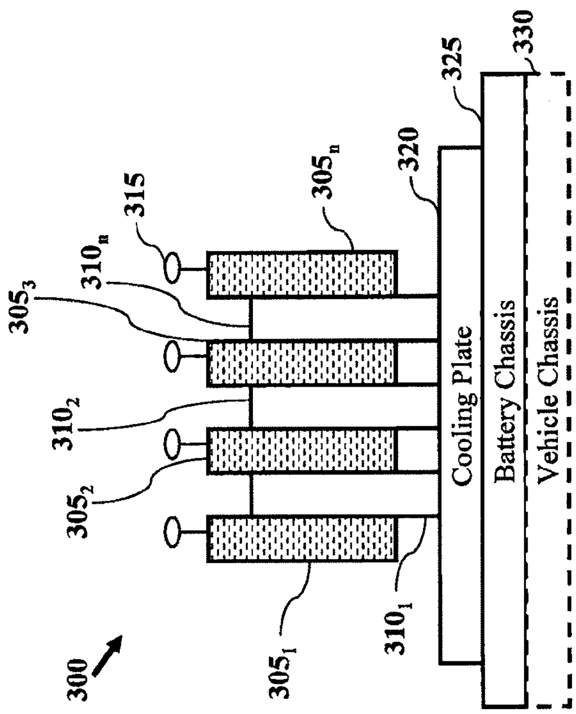
300
305_1
305_2
305_3
305_n
310_1
310_2
310_n
315
320
325
330
Cooling Plate
Battery Chassis
Vehicle Chassis

FIG. 3A

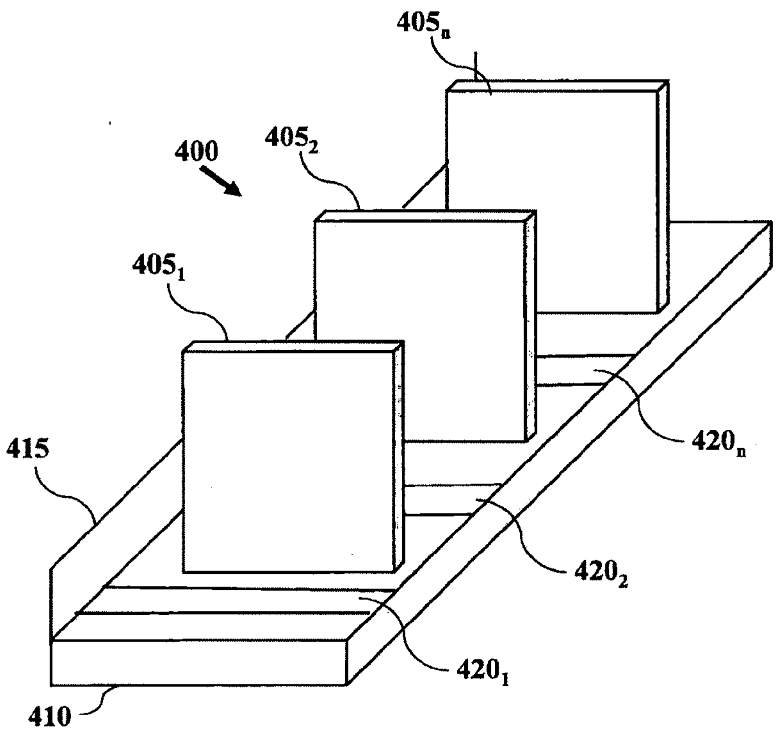
400
405_1
405_2
405_n
415
410
420_1
420_2
420_n

FIG. 4

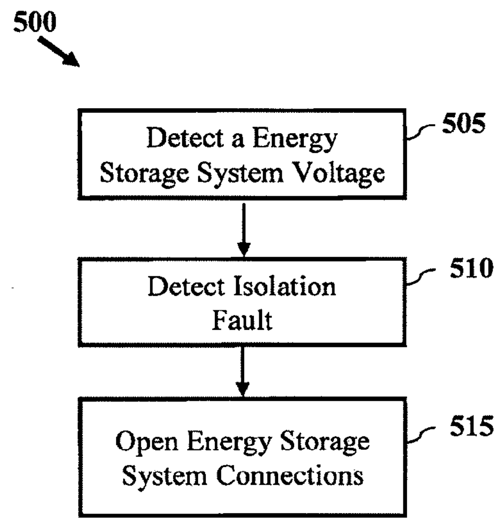
500
Detect a Energy Storage System Voltage
505
Detect Isolation Fault
510
Open Energy Storage System Connections
515

FIG. 5

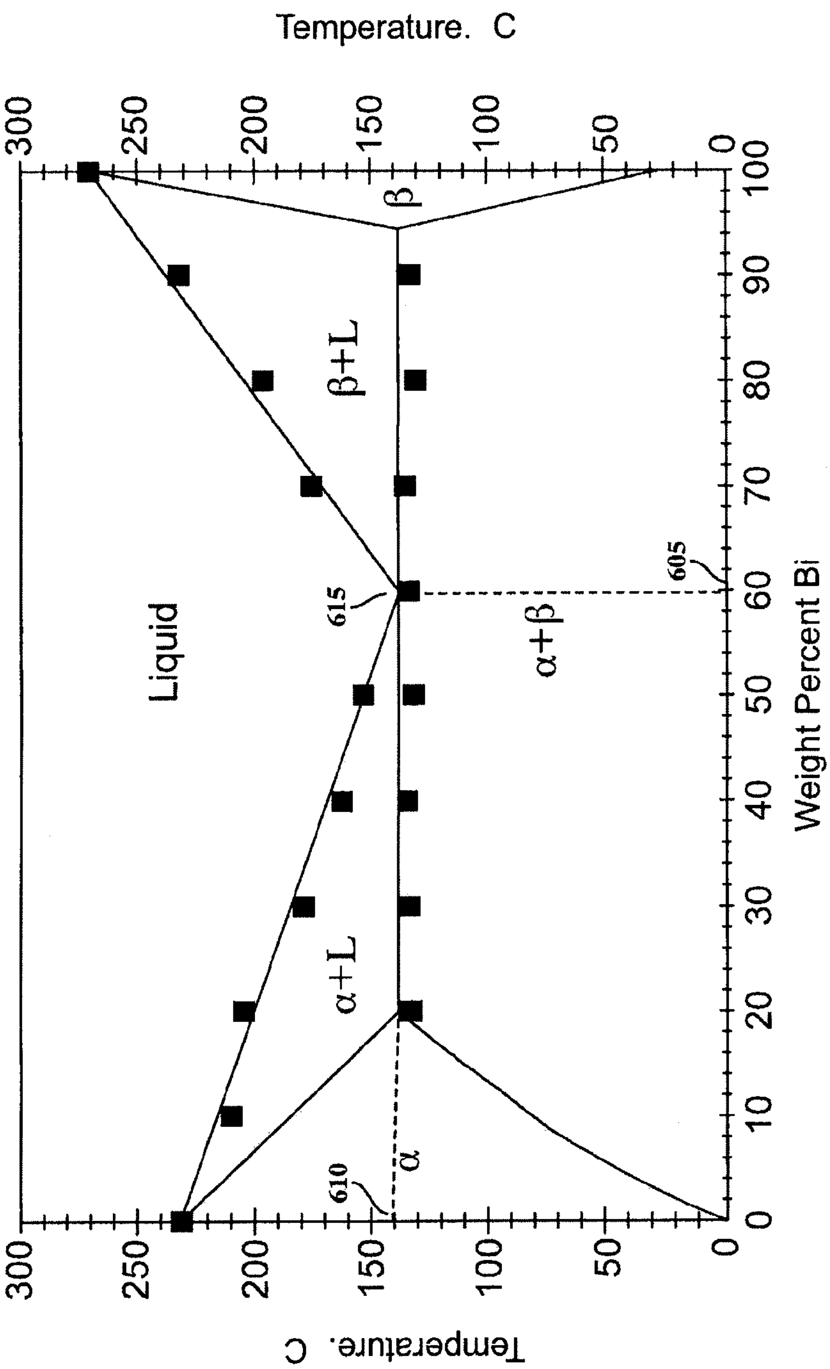
Temperature. C
300
250
200
150
100
50
0
Weight Percent Bi
0
10
20
30
40
50
60
70
80
90
100
Liquid
β+L
α+L
α+β
α
β
605
610
615

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/057012

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M2/10 H01M10/50 H01M10/48 B60L11/18 C09K5/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M B60L C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/151297 A1 (SHIMIZU KEISUKE [JP] ET AL) 23 June 2011 (2011-06-23) abstract; figure 4 paragraphs [0100], [0173], [0199] -----	1,11
X	JP 2011 253747 A (NIPPON TELEGRAPH & TELEPHONE) 15 December 2011 (2011-12-15) abstract; figures 1-4 paragraphs [0020], [0053], [0069], [0070] -----	1-3,7, 11-13,16
A	US 2010/304257 A1 (CHAN ALISTAIR K [US] ET AL) 2 December 2010 (2010-12-02) abstract paragraphs [0052], [0075], [0082] ----- -/--	17,18

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 January 2014	06/02/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Chmela, Emil

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/057012

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP S60 17869 A (HITACHI LTD) 29 January 1985 (1985-01-29) abstract; figure 1	17,18
Y	JP S59 151778 A (HITACHI LTD) 30 August 1984 (1984-08-30) abstract; figures 1-6	17,18

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/057012

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

2, 3, 7, 12, 13, 16-18(completely); 1, 11(partially)

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2013/057012

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 2, 3, 7, 12, 13, 16(completely); 1, 11(partially)

   A cooling element (for a vehicle battery), the element characterised by its melting or eutectic temperature or its chemical composition determining this temperature.

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2. claims: 4-6, 8-10, 14, 15(completely); 1, 11(partially)

   A cooling element (for a vehicle battery pack), the element being characterised by the structure into which it is formed and/or its distribution or location in the battery.

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3. claims: 17, 18

   A method of detecting a fault in an energy storage system comprising a cooling element, characterised by determining an insulation fault of a cell of the system and disabling the system based on the determination

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