(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 July 2006 (27.07.2006)

PCT

(10) International Publication Number
WO 2006/077519 A1

(51) International Patent Classification:
H01M 10/44 (2006.01) *H01M 10/48* (2006.01)

(21) International Application Number:
PCT/IB2006/050148

(22) International Filing Date: 16 January 2006 (16.01.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
05100335.8 20 January 2005 (20.01.2005) EP

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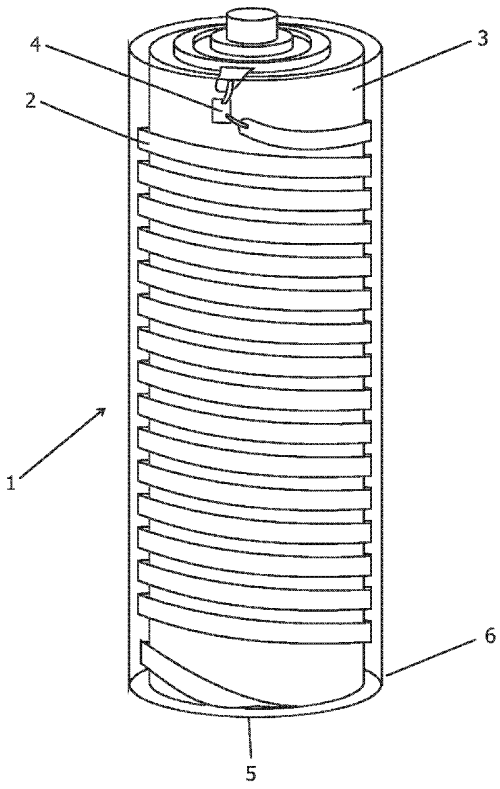
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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH,

[Continued on next page]

(54) Title: ARRANGEMENT AND METHOD FOR MONITORING PRESSURE WITHIN A BATTERY CELL



(57) Abstract: The invention relates to an arrangement for monitoring pressure within a battery cell, comprising: at least one battery cell, and at least one strain gauge for monitoring mechanical deformation of the battery cell. The invention also relates to a method of monitoring internal pressure of a battery cell, preferably by making use of such an arrangement.

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GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

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Arrangement and method for monitoring pressure within a battery cell

The invention relates to an arrangement for monitoring pressure within a battery cell, comprising: at least one battery cell, and at least one strain gauge for monitoring mechanical deformation of the battery cell. The invention also relates to a method of monitoring internal pressure of a battery cell.

In the technical field of batteries efforts are made to improve the technology of measuring battery parameters. Battery monitor systems measure and collect the status of the battery and display results. Battery management systems control the charge phase and partly the discharge phase, based on measurements. The measurement values are often parameters of mathematical models describing the status of the battery. These models form the basis for control programs of microprocessor-based battery monitor and management systems.

Important physical values that should be collected in a battery are current, voltage, temperature and pressure. The latter three are specifically important for the modelling of multi-cell batteries if the physical value can be measured per cell.

In the literature (for example H.J. Bergveld/ W.S. Kruijt/ P.H.L. Notten, Battery Management Systems, Kluwer Academic Publishers 2002, ISBN 1-4020-0832 or P.H.L. Notten Rechargeable nickel-metal hydride batteries: successful new concept, in Interstitial intermetallic alloys, chapter 7, in Nato ASI Series E 281 (1995) 151, Edts. F. Grandjean, G.J. Long and K.H.J. Buschow, ISBN 0-7923-3299-7) the influence of voltage, temperature and pressure on the status of battery cells is described in detail. For example, the generation of gas in a Nickel-Cadmium cell both in the overcharge and over-discharge mode should be mentioned. These modes result in rising gas pressures in gastight cells.

United States Patent US 5,694,018 discloses an assembly of a battery charging compartment and a battery positioned in said compartment, wherein the battery compartment is provided with a strain gauge for unilaterally monitoring the deformation of the battery introduced by elevated pressure within the battery (and partially the temperature introduced expansion) to activate a simple mechanical switch. Thereby the charging current is interrupted. It is also proposed to use a bridge measuring the expansion for the electrical determination of the mechanical deformation. However, this known arrangement has multiple drawbacks. A major drawback of this known arrangement will be elucidated hereinafter.

A clear trend in the battery industry is namely to strive for higher energy density. The energy density is primarily described by electrical battery capacity per battery mass (measured in Wh/kg). The ratio battery capacity to volume (Wh/cm3) plays a secondary role. The mass of the cell boundaries is not negligible, since it is most common to use metal cans. Often the can is punched or rolled from metal sheet, for cylindrical cells formed as a beaker or bushing. Besides the requirement of electrical conductivity, metal cans fulfil the specifications for resistance to pressure. In order to reduce mass and material, sheets of reduced thickness are used. Cell boundaries of reduced strength are much more exposed to mechanical deformation, as the inner pressure is increased. Due to the thinner sheet, the maximum tolerable pressure is lower. This leads to an increased necessity to monitor a significant pressure rise earlier and more precisely than is possible by means of the known arrangement as disclosed in United States Patent US 5,694,018 as mentioned above. Only then it is possible to avoid partial damage to thin cans by too high an inner pressure.

The measurement of the cell pressure is difficult because of the nature of the electrolytic material (most common are high viscosity fluids or gels) and/or its chemical aggressiveness. No commonly used means of pressure measurement can be used. Typically used sensors with membranes are not part of the possible solutions; also micro-electromechanical pressure sensors do not fit. Smaller cells are very cost-sensitive due to their high production volumes. They have mature production technologies. For most of the cells, standardized outer boundaries are given. Therefore, it is most advantageous to stick to the existing constructions and add only a few supplementing parts.

It is an object of the invention to provide an improved arrangement for monitoring the actual internal pressure of a battery cell more accurately.

This object can be achieved by providing an arrangement according to the preamble, characterized in that said strain gauge is at least partially wound around a cell casing of said battery cell. In the arrangement according to the invention, the strain gauge, preferably formed by a measurement line, is in intensive contact with the battery cell of which the internal pressure is monitored. In this manner, the pressure built up within the battery cell can be monitored relatively carefully through the (elastic) deformation, in particular stretching or changing of the winding area, of the strain gauge. Moreover, since a cell casing commonly does not have a uniform strength, it is advantageous to wind the strain gauge at least partially around an outer surface of the cell casing, thereby covering a substantial part of the cell casing, which commonly leads to relatively quick and accurate monitoring of deformation of the cell casing and hence of a (significant) pressure rise within

the battery cell. Preferably, said strain gauge is at least partially wound helically around said cell casing. To this end, said strain gauge is preferably at least substantially coil-shaped to be able to cover the cell casing in an optimal way. In this way a slight deformation in a – possibly present – weaker part of the cell casing can be detected relatively quickly and precisely. In fact, stretching of the windings changes the ohmic resistance of the strain gauge. The change of the geometry can be observed relatively precisely, if the recent measurement is compared to the measurement of the non-stretched lines. The strain gauge should preferably be made of appropriate materials, for example materials with a stable specific resistance, independent of temperature variances. Since the strain gauge is applied to an outer surface of the cell casing, there is no direct contact between the strain gauge and the chemical reactants within the cell casing. For this reason, corrosion of the strain gauge will not occur under normal conditions, which gives the arrangement according to the invention an advantageous durability.

In a preferred embodiment, said strain gauge is electronically coupled to a processing unit for processing the mechanical deformation monitored by the strain gauge. Commonly said processing unit is relatively small, and may be formed by a small chip incorporating an electronic circuit. The change of the effective coil area leads to a change of the AC- and RF-parameters of the coil, and in particular to a change of the inductivity. These changes can be observed as complex impedance. It is also proposed to observe the resonance behaviour of the electronic circuit, including the, preferably coil-shaped, strain gauge. This resonance behaviour will change due to the change of the coil dimensions. In a particularly preferred embodiment, said processing unit is adapted to communicate, preferably wirelessly, with an external device, such as a battery management system. Battery management systems control the charge phase and partly the discharge phase, based on measurements as mentioned above. In a further preferred embodiment the processing unit comprises a calibration arrangement. The calibration arrangement can also be part of an external device, such as a microprocessor supporting control unit. In this calibration arrangement the pressure measurement values will be stored of well-defined conditions and states of the battery cells. For example the starting conditions of a non-aged, well-charged or non-loaded cell can be stored as calibration values, assuming non-increased pressure values. Also, calibration values can be related to cell temperature or cell voltage. By storing the calibration values, production tolerances and measurement errors, for example introduced by temperature and voltage, can be widely compensated. In this manner it is possible that only differences from the stored calibration values are used to estimate the deformation.

Besides the pressure measurement function, the measurement line can be used also as a loop or coil antenna for wireless communication with the cell sensor. Typically, these functions do not interact, since different frequencies are used for communication and pressure measurement. For pressure measurement use can also be made of direct current, provided that no impedance measurement is made. In a preferred embodiment, said processing unit is powered by means of induced electricity. However, it is also conceivable that said processing unit is powered by the battery cell. In a particularly preferred embodiment, said strain gauge is also adapted for use as an antenna to allow the processing unit to communicate with the external device. At high frequencies, the reduction of the number of windings, in the extreme to a single loop, could be suitable. This is especially necessary if the antenna needs to be effective at higher communication frequencies. In a further preferred embodiment, the pressure values, in addition to other parameters like cell voltage and temperature, will be used for electronic switching within the battery. Here the pressure strain gauge can be connected in such a way that it can be used as a bypass line to prevent overcharging of the battery cell by passing a fraction of the charging current around the battery cell.

Preferably, said battery cell comprises an outer hull, wherein the strain gauge is substantially positioned between the cell casing and the outer hull. In this manner the strain gauge is protected by a shielding cover which is formed by the, preferably elastic, hull. In this way, the strain gauge is positioned in a covered manner within the boundaries of the battery cell.

In a preferred embodiment, said arrangement comprises multiple battery cells, wherein the strain gauge is at least partially wound around the cell casing of each battery cell. It is imaginable to apply multiple strain gauges, wherein each strain gauge could be wound around a respective battery cell. If a group of cells is observed with a joint strain gauge, the sensing arrangement should preferably be able to detect an overpressure condition of any individual cell forming part of that group.

The invention also relates to a method of monitoring pressure within a battery cell, preferably by making use of an arrangement according to the invention, comprising the steps of: A) measuring the mechanical deformation of a battery cell by at least one strain gauge attached to an outer surface of a cell casing of said battery, and B) processing the mechanical deformation monitored by the strain gauge by means of a processing unit electronically coupled to said strain gauge to obtain pressure related data, and C) allowing the processing unit to communicate with an external device for wireless transmission of the

pressure related data from the processing unit to said external device. In a preferred embodiment, communication between the processing unit and the external device according to step C) is realized by means of the strain gauge acting as antenna. Further advantages and alternatives have been elucidated above in a comprehensive manner.

The invention can be further illustrated by way of the following non-limitative embodiments, wherein:

Fig. 1 shows a coil-shaped measurement line around the cell jacket of a cylindrical cell,

Fig. 2 shows the deformation of the measurement line shown in Figure 1 due to a pressure rise,

Fig. 3 shows a double coil-shaped measurement line around two cylindrical cells connected to one cell sensor,

Fig. 4 shows the deformation of the arrangement shown in Figure 3 due to a pressure rise,

Fig. 5 shows another arrangement according to the invention in a normal state, and

Fig. 6 shows the arrangement shown in Figure 5 in an expanded state.

Figure 1 shows a coil-shaped measurement line around the cell jacket of a cylindrical cell 1, comprising a cell jacket 3 around which a measurement line 2 is wound in a coil-shaped manner. One end of the measurement line 2 is connected to a cell sensor 4. The other end of the measurement line 2 is connected to a pole 5 of the cell 1. The cell jacket 3 is located within an elastic outer hull 6, for example a sleeve made from soft plastics or foam plastic. The cell 1 should allow expansion of the mechanical dimensions of the cell during pressure generation within the cell 1.

Figure 2 shows the deformation of the measurement line 2 shown in Figure 1 due to a pressure rise in the cell 1. In this Figure, the expanded barrel-shaped cell jacket 3 is shown. It is expanded within the elastic outer hull 6. It should be obvious that the coil 2 has its maximum enlargement of the diameter in the middle of the cell 1. Due to this fact, the circumference (the length of the measurement line) and the effective area of the coil 2 have

been enlarged to a maximum, resulting in changed physical properties of the measurement line 2 which can be monitored by the sensor 4.

Figure 3 shows another preferred embodiment of an arrangement 7 according to the invention. The arrangement 7 comprises two measurement lines 8, 9 which are wound helically around two respective cylindrical cells 10, 11. The measurement lines 8, 9 are mutually connected by means of a single cell sensor 12. The upper cell 10 and the lower cell 11 are connected in series. The respective measurement lines 8, 9 are connected to opposite poles 13, 14 of the cells 10, 11. The cell sensor 12 observes the group of cells 10, 11. The upper measurement line 8 leads from the upper pole 13 of the upper cell 10 to the sensor 12. A further measurement line 9 leads from the opposite pole 14 of the lower cell 11 to the cell sensor 12. Both measurement lines 8, 9 are coil-shaped and surround the jackets of both cells 10, 11. Both cells 10, 11 are located in a single, sleeve-shaped, elastic outer hull 15 for the group of cells 10, 11, which allows expansion without remarkable forces. The battery compartment (not shown) in which the arrangement is positioned also should not influence the expansion by remarkable forces.

Figure 4 shows the deformation of the arrangement 7 shown in Figure 3 due to a pressure rise. As can be seen clearly in this Figure, the measurement lines 8, 9 are deformed due to the barrel-shaped expansion of the cells 10, 11, which can be monitored by the cell sensor 12. The monitored deformation gives an indication of the internal pressure and thus of the state of the cells 10, 11.

Figure 5 shows another arrangement 16 according to the invention in a normal state. The arrangement 16 comprises a group of substantially parallel-oriented cylindrical cells 17 bundled together by means of a coil-shaped measurement line 18. The measurement line 18 is connected to a sensor circuit 19 to monitor deformation of the cells 17 due to a pressure rise. The arrangement 16 is encapsulated by an elastically deformable outer hull 20.

Figure 6 shows the arrangement 16 as shown in Figure 5 in an expanded state due to a pressure rise within one or more cells 17. In this illustrative embodiment in the expanded state, the bundle of cells 17 have been subjected to a barrel-shaped deformation. Due to the deformation of the cells 17, the measurement line 18 is stretched. This stretching and the intensity of stretching of the measurement line 18 can be detected by the sensor cell 19. These pressure-related data can subsequently be transmitted wirelessly to a battery management system, which is, for example, incorporated in a battery charger (not shown). Dependent on the (over)pressure detected in the cells 17, appropriate action, for example switching off, can be taken by the battery charger.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

1. Arrangement for monitoring pressure within a battery cell, comprising: at least one battery cell, and

at least one strain gauge for monitoring mechanical deformation of the battery cell,

characterized in that said strain gauge is at least partially wound around a cell casing of said battery cell.

2. Arrangement according to claim 1, characterized in that said strain gauge is at least partially wound helically around said cell casing.

3. Arrangement according to claim 2, characterized in that said strain gauge is at least substantially coil-shaped.

4. Arrangement according to any one of the preceding claims, characterized in that said strain gauge is electronically coupled to a processing unit attached to the cell casing for processing the mechanical deformation monitored by the strain gauge.

5. Arrangement according to claim 4, characterized in that said processing unit is adapted to communicate with an external device.

6. Arrangement according to claim 5, characterized in that said processing unit is adapted to communicate wirelessly with the external device.

7. Arrangement according to any one of claims 4-6, characterized in that said processing unit is powered by means of induced electricity.

8. Arrangement according to any one of claims 4-7, characterized in that said processing unit is powered by the battery cell.

9. Arrangement according to claim 5 or 6, characterized in that said strain gauge is also adapted for use as an antenna to allow the processing unit to communicate with the external device.

10. Arrangement according to any one of the preceding claims, characterized in that said battery cell comprises an outer hull, wherein the strain gauge is substantially positioned between the cell casing and the outer hull.

11. Arrangement according to any one of the preceding claims, characterized in that said arrangement comprises multiple battery cells, wherein the strain gauge is at least partially wound around the cell casing of each battery cell.

12. Method of monitoring pressure within a battery cell, comprising the steps of:

measuring the mechanical deformation of a battery cell by at least one strain gauge attached to an outer surface of a cell casing of said battery, and

processing the mechanical deformation monitored by the strain gauge by means of a processing unit electronically coupled to said strain gauge to obtain pressure related data, and

allowing the processing unit to communicate with an external device for wireless transmission of the pressure-related data from the processing unit to said external device.

13. Method according to claim 12, characterized in that communication between the processing unit and the external device according to step C) is realized by means of the strain gauge acting as antenna.

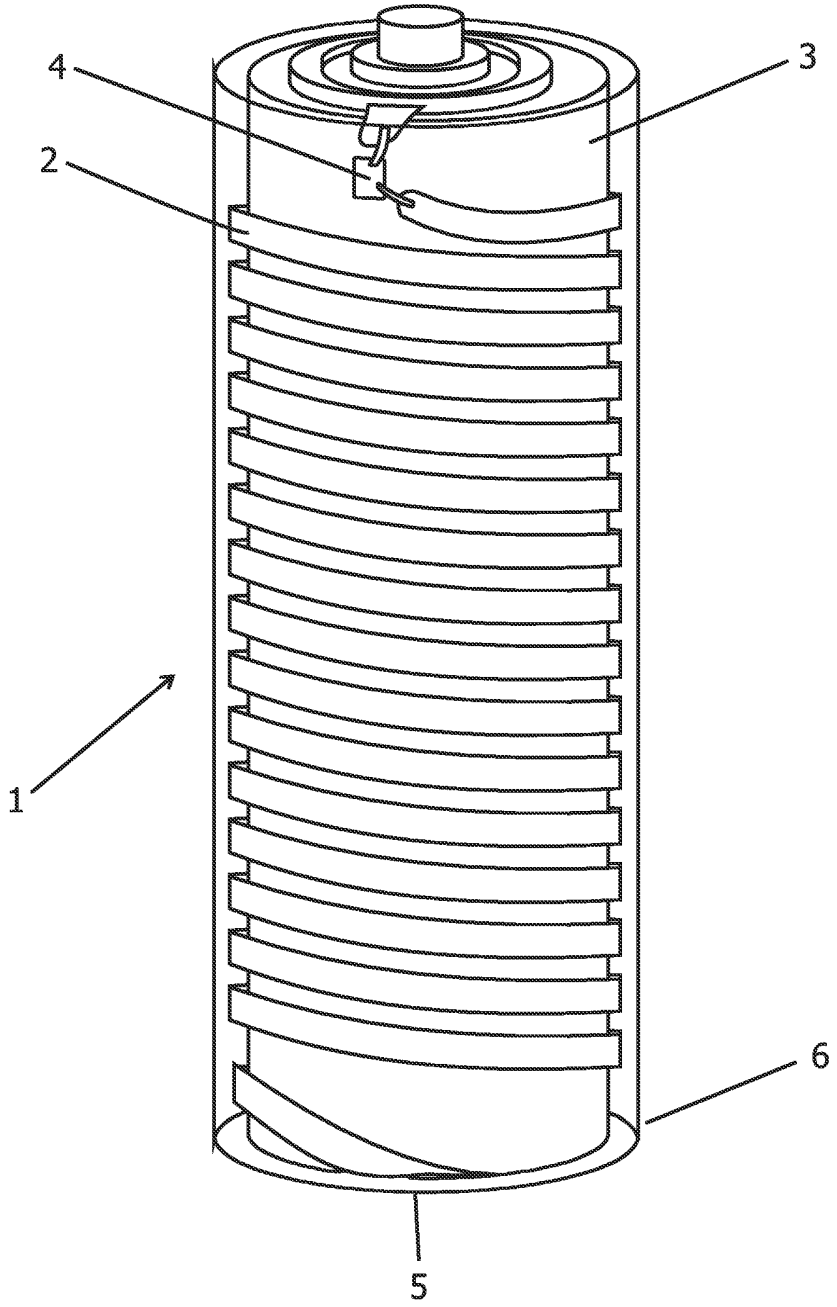


FIG.1

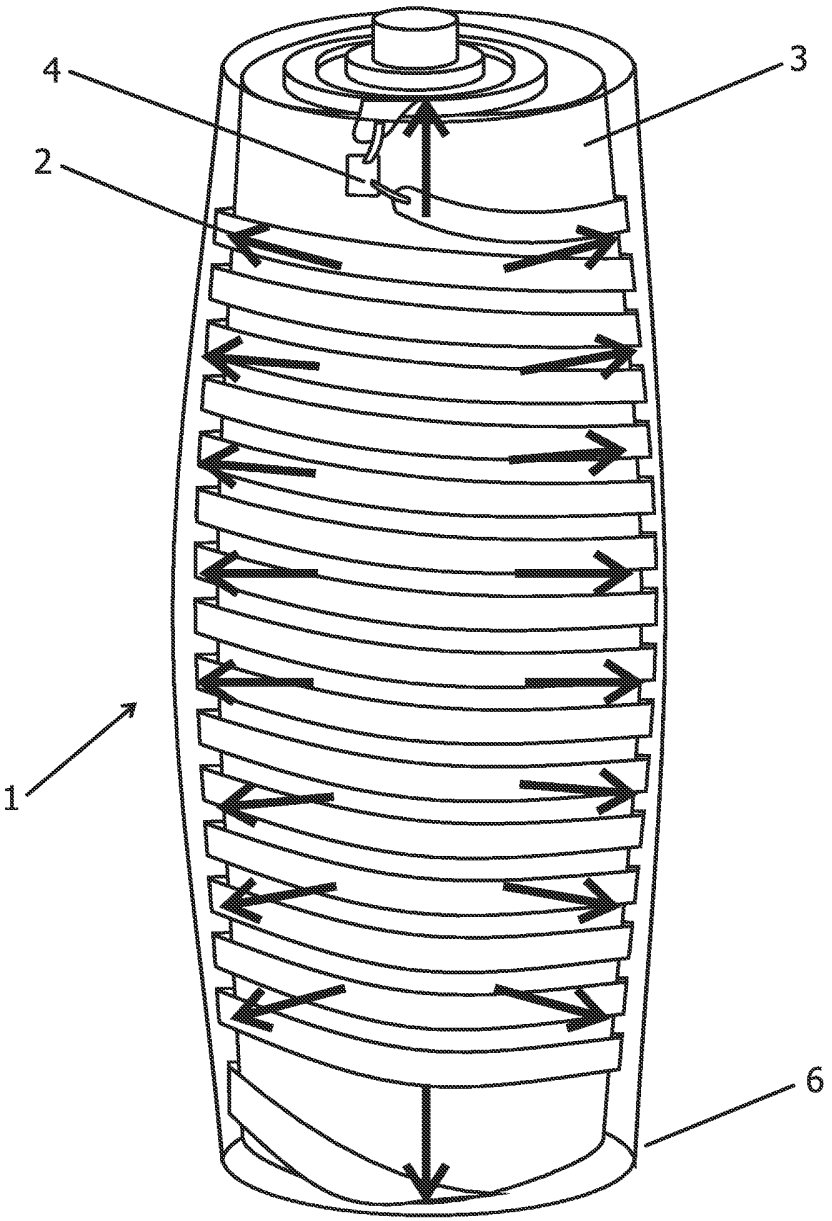


FIG.2

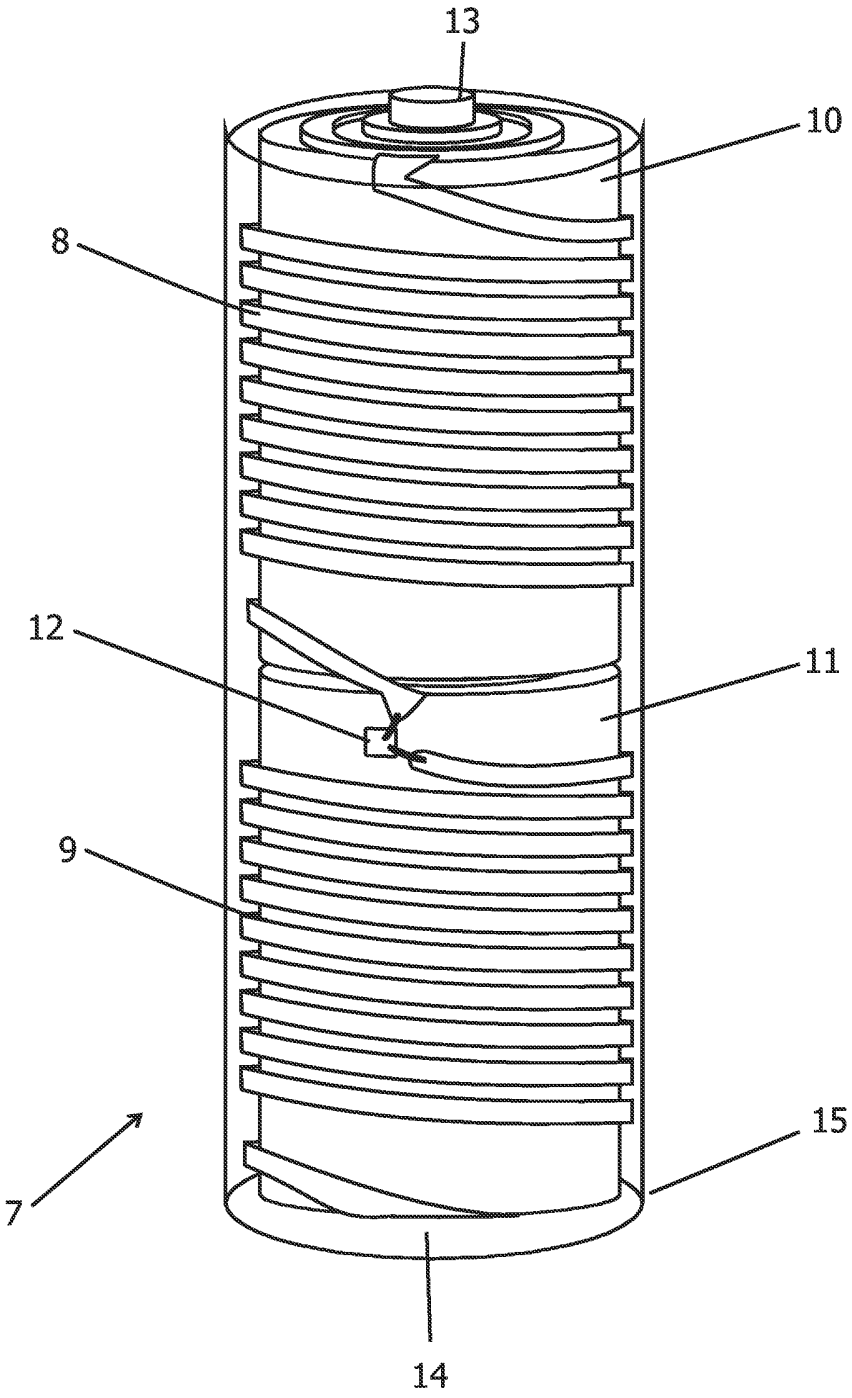


FIG.3

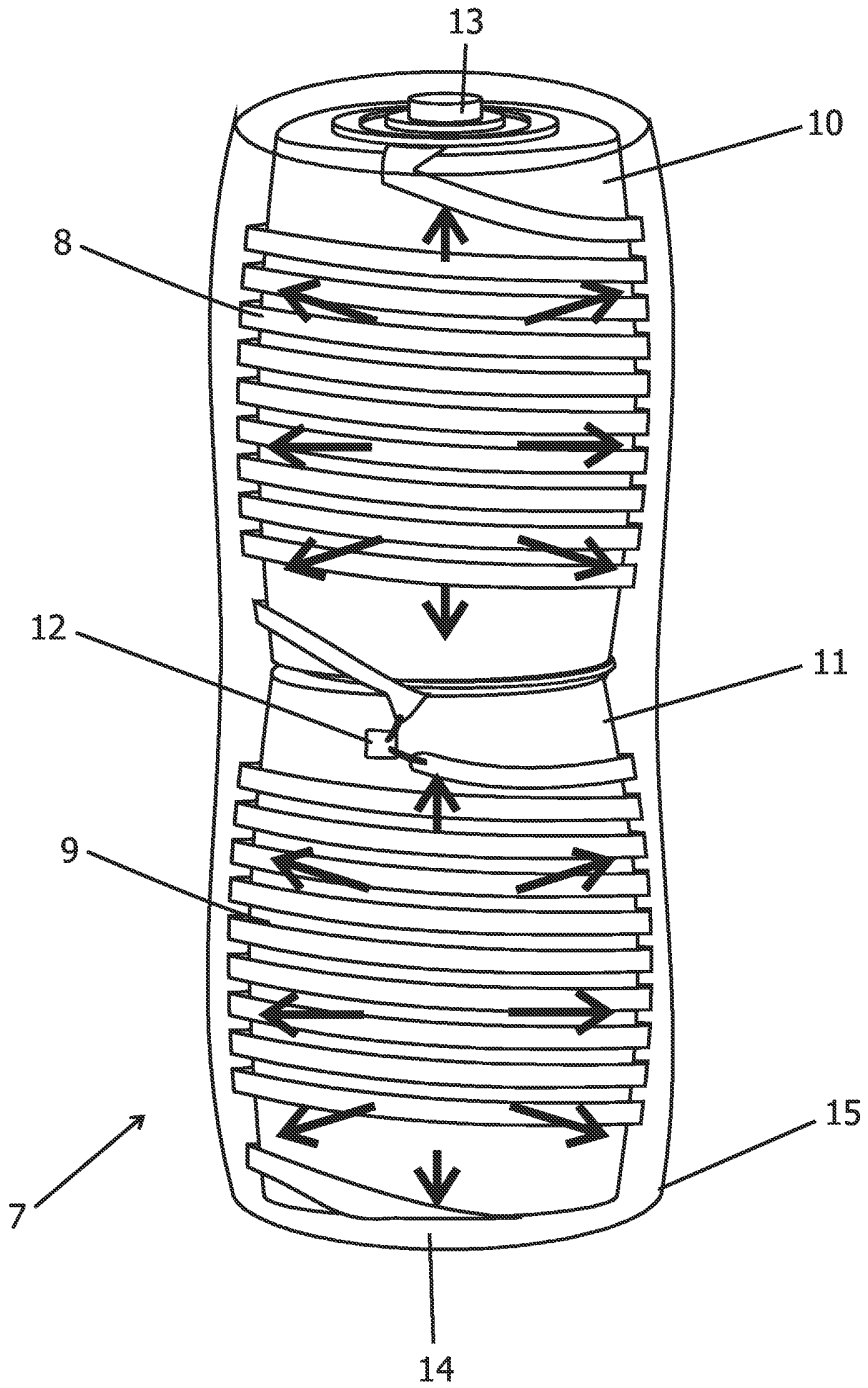


FIG.4

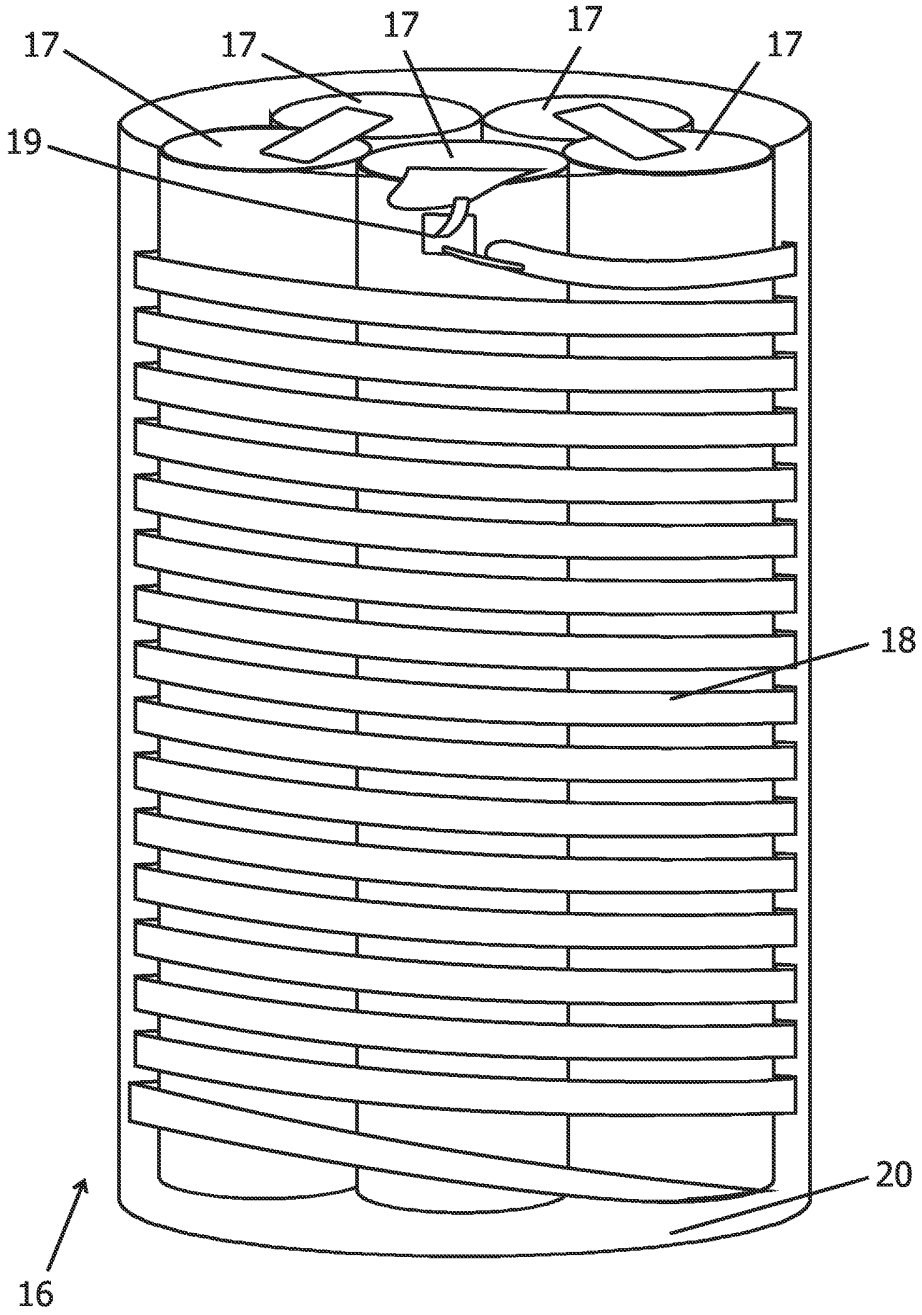


FIG.5

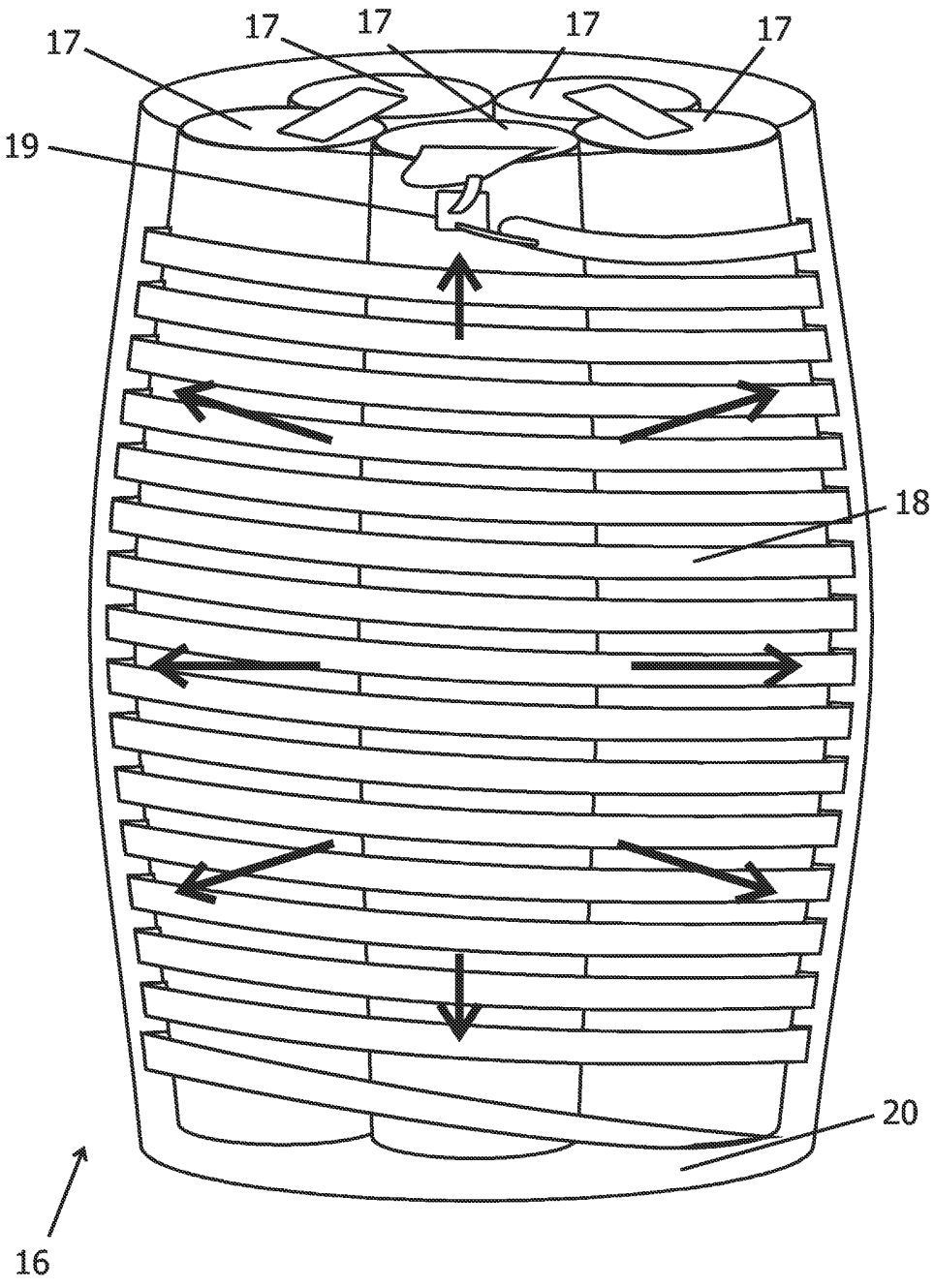


FIG.6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/050148

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M10/44 H01M10/48

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

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 practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/119364 A1 (BUSHONG WILLIAM H ET AL) 29 August 2002 (2002-08-29) figures 10,14-16 paragraphs [0129], [0130], [0135], [0137] - [0140] claims 47-49,52,53	1-3,10, 11
A	US 5 694 018 A (GILLISSEN ET AL) 2 December 1997 (1997-12-02) cited in the application figure 1 claim 1	1-13
A	US 5 640 077 A (GILLISSEN ET AL) 17 June 1997 (1997-06-17) figure 1 column 3, lines 8-35 claims 1,2,4-6,12	1-13

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[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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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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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
14 June 2006	21/06/2006

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, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Knoflacher, A

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/050148

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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