

LITHIUM-ION BATTERY AND METHOD FOR THE MANUFACTURE
THEREOFTechnical field of the invention

The present invention relates to the field of batteries, and more particularly to lithium-ion batteries. The invention relates to lithium-ion batteries with a new architecture that provides them with an improved service
5 life. The invention also relates to a new method for manufacturing such batteries.

Prior art

All-solid-state lithium-ion rechargeable batteries are known. WO 2016/001584 (I-TEN) describes a lithium-ion
10 battery manufactured from anode foils comprising a conductor substrate covered successively with an anode layer and an electrolyte layer, and cathode foils comprising a conductor substrate covered successively with a cathode layer and an electrolyte layer; these foils are
15 cut, before or after deposition, according to U-shaped patterns. These foils are then stacked alternately so as to constitute a stack of several elementary cells. The patterns of the cuts of the anode and cathode foils are placed in a "head-to-tail" configuration in such a way
20 that the stack of cathodes and anodes is offset laterally. After the step of stacking, an encapsulation system with a layer with a thickness of about ten microns is deposited on the stack and in the cavities available present within the stack. This makes it possible to ensure, on the one
25 hand, the rigidity of the structure at the cutting planes and, on the other hand, the protection of the cell of the battery with regards to the atmosphere. Once the stack is

carried out and encapsulated, it is cut according to the cutting planes in order to obtain unitary batteries, with the exposing on each one of the cutting planes of the cathode connection areas and of the anode connection areas of the batteries. It happens that during these cuttings, the encapsulation system can be pulled off, which results in a discontinuity of the tightness of the battery. It is also known to add terminations (i.e. electrical contacts) at the location where these cathode and anode connections areas are apparent.

It has appeared that this known solution can however have certain disadvantages. Indeed, according to the positioning of the electrodes, in particular of the proximity of the edges of the electrodes for multilayer batteries and of the cleanliness of the cuts, a leakage current can appear at the ends, typically in the form of a rampant short-circuit. This rampant short-circuit decreases the performance of the battery, and this, despite the use of an encapsulation system around the battery and at the approaches to the cathode and anode connection areas. Moreover, an unsatisfactory deposition of the encapsulation system on the battery is sometimes observed, in particular on the edges of the battery at the spaces created by the lateral offsets of the electrodes on the battery edges.

Moreover, given that the terminations, respectively anode and cathode, are located retracted from the adjacent, respectively cathode and anode, foils, it is necessary to make a cut of large dimensions. Such a cut must then be filled using an insulating material. Given its substantial dimensions, this cut leads to a substantial loss of material useful for the carrying out of the battery

strictly speaking. Moreover, it imposes depositing high thicknesses of insulator, in the cavities available present within the stack. A thick insulator risks weakening the entire encapsulation system of the battery. During the cutting, the encapsulation system deposited as a thick layer tends to delaminate. The architecture according to the prior art therefore has certain technical but also economic disadvantages.

The present invention aims to overcome at least partially certain disadvantages of the prior art mentioned hereinabove, in particular obtaining rechargeable lithium-ion batteries with a high energy density and high power density.

It aims in particular to increase the production yield of rechargeable lithium-ion batteries with a high energy density and high power density, and to carry out higher-efficiency encapsulations at least cost.

It aims in particular to propose a method that decreases the risk of a rampant or accidental short-circuit and that makes it possible to manufacture a battery that has a low self-discharge.

It aims in particular to propose a method, that makes it possible to simply, reliably and quickly manufacture a battery that has a very high service life.

It also aims to propose such a method, that uses a better quality cutting step, in particular cleaner than in the prior art.

It also aims to propose a method for manufacturing batteries that generates less loss of materials.

Objects of the invention

A first object of the invention is a battery 1000 comprising at least one elementary cell 100, said elementary cell 100 comprising successively at least one planar anode current collector substrate 10, at least one
5 anode layer 20, at least one layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode layer 50, and at least one planar cathode current collector substrate 40,

said battery 1000 comprising longitudinal edges 1011,
10 1012, a first lateral edge 1001 comprising at least one anode connection area 1002 and a second lateral edge 1005 comprising at least one cathode connection area 1006, said anode 1002 and cathode 1006 connection areas being preferably laterally opposite,

15 characterized in that each elementary cell 100 comprises a primary body 111, a secondary body 112 and a tertiary body 113, said secondary body and said tertiary body being arranged on either side of said primary body, with the understanding that each one of the primary 111,
20 secondary 112 and tertiary 113 bodies comprises successively at least one planar anode current collector substrate 10, at least one anode layer 20, at least one layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode
25 layer 50, and at least one planar cathode current collector substrate 40,

said secondary body 112 being separated from the primary body 111 by a notch 120 free from any anode, electrolyte, separator impregnated with an electrolyte,
30 cathode and anode current collector substrate material, with the understanding that said notch extends from a longitudinal edge 1011 to the opposite longitudinal edge

of the battery 1012 in a direction perpendicular to the main plane of the battery, and

said tertiary body 113 being separated from the primary body 111 by a recess 130 free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and cathode current collector substrate material, with the understanding that said recess 130 extends from a longitudinal edge 1011 to the opposite longitudinal edge of the battery 1012 in a direction perpendicular to the main plane of the battery.

Advantageously, the battery according to the invention comprises a plurality of elementary cells, and is characterized in that all the notches of each one of the elementary cells are superimposed, in a direction perpendicular to the main plane of the battery, in such a way that each planar cathode current collector substrate collects the cathode current of the elementary cell through the cathode connection area, and in that all the recesses of each one of the elementary cells are superimposed, in a direction perpendicular to the main plane of the battery, in such a way that each planar anode current collector substrate collects the anode current of the elementary cell through the anode connection area.

In a preferred embodiment, said battery is a lithium-ion battery. Advantageously, the battery according to the invention comprises an encapsulation system entirely covering four of the six faces of said battery, the two remaining faces comprising an anode connection area and a cathode connection area. Advantageously the encapsulation system comprises:

- at least one first cover layer, preferably selected from parylene, parylene F, polyimide, epoxy resins,

silicone, polyamide, sol-gel silica, organic silica and/or a mixture thereof, deposited on the battery,

- at least one second cover layer comprised of an electrically-insulating material, deposited by atomic
5 layer deposition on said at least first cover layer,

with the understanding that this sequence of at least one first cover layer and of at least one second cover layer can be repeated z times with $z \geq 1$.

Advantageously, the anode connection area and the
10 cathode connection area are covered by terminations.

Advantageously, the terminations comprise:

- a first layer of a material loaded with graphite, preferably with an epoxy resin base loaded with graphite disposed on at least the cathode connection area and/or at
15 least the anode connection area,

- a second dense layer of metal copper disposed on the first layer of the termination system,

- optionally, a third layer with a tin-tin zinc alloy base, disposed on the second layer,

20 - optionally, a fourth layer with a tin base or with a base of a silver, palladium and copper alloy, disposed on the third layer of the termination system.

Advantageously, the width of said notch is comprised between 0.01 mm and 0.5 mm.

25 Advantageously, the width of said recess is comprised between 0.01 mm and 0.5 mm.

Advantageously, the width of the secondary bodies is comprised between 0.5 mm and 20 mm. A second object of the invention is a method for manufacturing a battery 1000,
30 said battery comprising at least one elementary cell 100, said elementary cell 100 comprising successively at least one planar anode current collector substrate 10, at least

one anode layer 20, at least one layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode layer 50, and at least one planar cathode current collector substrate 40, said
5 method of manufacturing comprising:

(a) the providing of at least one foil of planar anode current collector substrate 10 covered with an anode layer 20, and optionally covered with a layer of an electrolyte material 30 or of a separator impregnated with an
10 electrolyte 31, called hereinafter anode foil 2, said anode foil comprising at least one anode slot 80, said anode slot 80 comprising two main vertical anode and parallel cavities 82, which are connected in their upper portion by a horizontal anode channel 84, substantially perpendicular
15 to the two main anode vertical cavities 82, these main vertical anode cavities being intended for delimiting the longitudinal edges of the battery,

(b) the providing of at least one foil of planar cathode current collector substrate 40 covered with a
20 cathode layer 50, and optionally covered with a layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, called hereinafter cathode foil 5, said cathode foil comprising at least one cathode slot 70, said cathode slot comprising two main vertical cathode and
25 parallel cavities 72, which are connected in their upper portion by a horizontal cathode channel 74, substantially perpendicular to the two main vertical cathode cavities 72, these main vertical cathode cavities being intended for delimiting the longitudinal edges of the battery,

30 (c) the carrying out of a first and of a second notches, in the vicinity of each anode 80, respectively cathode 70, slot of at least the foil supplied in step a),

respectively in step b), in such a way as to form anode trenches 86, 88, respectively cathode trenches 76, 78, in a direction perpendicular to the main plane of the battery and in a direction parallel to the horizontal anode channel 84, of the anode slot 80, respectively to the horizontal cathode channel 74 of the cathode slot 70, with the understanding that

- o the first and second notches are made on either side of the anode 2, respectively cathode 5, foil,

- o the second notch is made in the extension of the first notch, and

- o the anode trenches 86, 88, respectively the cathode trenches 76, 78, obtained from the first and second notches are free from any electrolyte material or separator impregnated with an electrolyte and from any anode material, respectively are free from any electrolyte material or separator impregnated with an electrolyte and from any cathode material, and

- o said anode trenches 86, 88, respectively the cathode trenches 76, 78 extend between the opposite longitudinal edges 1011, 1012 of the battery in a direction perpendicular to the main plane of the battery in such a way as to connect the two main vertical anode and parallel cavities of each anode slot 80, respectively to connect the two main vertical cathode and parallel cavities of each cathode slot 70, the foil obtained after the carrying out of these notches being called hereinafter notched anode foil 2e, respectively notched cathode foil 5e,

- (d) the carrying out of an alternating stack I of at least one notched anode foil 2e and of at least one notched cathode foil 5e, in such a way as to obtain successively at least one planar anode current collector substrate 10,

at least one anode layer 20, at least one layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode layer 50, and at least one planar cathode current collector substrate 40; in such way that, for each anode slot 80 of at least one notched anode foil 2e, respectively for each cathode slot 70 of at least one notched cathode foil 5e, the anode trenches 86, 88 of at least the notched anode foil, respectively the cathode trenches 76, 78, of at least the notched cathode foil 5e, are disposed in the extension of the horizontal cathode channel 74 of the cathode slot 70 of the adjacent notched cathode foil 5e, respectively of the horizontal anode channel 84 of the anode slot 80, of the adjacent notched anode foil 2e in a direction perpendicular to the main plane of the battery,

(e) the carrying out of a heat treatment and/or of a mechanical compression of the stack of alternating foils obtained in step d), in such a way as to form a consolidated stack,

(f) the carrying out of two cuts D_n , D'_n extending at least partially inside said anode 80, respectively cathode 70 slot, according to a plane parallel to the horizontal anode 84, respectively cathode 74 channel, the first cut extending between the horizontal anode channel 84 of the anode slot 80 and the end facing the longitudinal edges, while the second cut extends between the horizontal cathode channel 74 of the cathode slot 70 and the end facing the longitudinal edges, in such a way as to form a cut stack exposing at least the anode and cathode connection areas.

Advantageously, after step (e), and preferably before step (f), a step (g) of encapsulating the consolidated stack is carried out, by depositing:

- at least one first cover layer, preferably selected from parylene, parylene F, polyimide, epoxy resins, silicone, polyamide, sol-gel silica, organic silica and/or a mixture thereof, on the battery, and then

5 - at least one second cover layer comprised of an electrically-insulating material, deposited by atomic layer deposition on said at least first cover layer,

with the understanding that the sequence of at least one first cover layer and of at least one second cover
10 layer can be repeated z times with $z \geq 1$.

Advantageously, when a separator is used in the batteries according to the invention, the separator is impregnated by an electrolyte, preferably, by a lithium ion carrier phase such as liquid electrolytes or an ionic
15 liquid containing lithium salts.

Advantageously, after step (f), the terminations of the battery are carried out by depositing successively on at least the anode and cathode connection areas:

- a first layer of a material loaded with graphite,
20 preferably with an epoxy resin base loaded with graphite,

- a second dense layer of metal copper disposed on the first layer of the termination system, and

- optionally, a third layer with a tin-zinc alloy base, disposed on the second layer of the termination
25 system,

- optionally, a fourth layer with a tin base or with a base of a silver, palladium and copper alloy, disposed on the third layer of the termination system.

Advantageously, the two notches made in step (d)
30 forming trenches 76, 78, 86, 88 are carried out via laser ablation.

Advantageously, each cut is carried out via laser.

Advantageously, each elementary cell defines on a first face, a continuity area of the planar anode current collector substrate and an emerging notch 120, and on the opposite face, a continuity area of the planar cathode current collector substrate and an emerging recess 130.

Advantageously, the continuity area of the planar anode current collector substrate is located facing the notch 120, and the continuity area of the planar cathode current collector substrate is located facing the recess 130 in a direction perpendicular to the plane of the battery.

Advantageously, the battery according to the invention is characterized in that:

- o the planar anode current collector substrate is the anode current collector substrate of two adjacent elementary cells, and in that

- o the planar cathode current collector substrate is the cathode current collector substrate of two adjacent elementary cells.

Figures

The accompanying figures, given as non-limiting examples, represent different aspects and embodiments of the invention.

[Fig. 1] is a perspective view of the notched anode and notched cathode foils intended for forming a stack according to the method for the manufacturing of batteries in accordance with the invention.

[Fig. 2] is a front view, showing one of the foils of figure 1.

[Fig. 3] is a front view, on a larger scale, showing a ladder-shaped groove arranged in an anode foil.

[Fig. 4] is a perspective view, also on a large scale, showing these ladder-shaped grooves arranged in adjacent
5 foils.

[Fig. 5] is a top view, showing a step of cutting carried out on different grooves arranged in the stack of the preceding figures.

[Fig. 6] is a top view, showing on a larger scale the
10 cuts arranged on a ladder-shaped groove.

[Fig. 7] is a cross-section view, according to the line VII-VII indicated in figure 6.

[Fig. 8] is a cross-section view, according to the line VII-VII indicated in figure 6.

[Fig. 9] is an exploded cross-section view, according
15 to the line VII-VII indicated in figure 6 showing a stack comprised of three elementary cells.

[Fig. 10] is a top view showing a battery in accordance with the invention, that is able to be obtained
20 in particular according to the method of the preceding figures.

[Fig. 11] is a front view showing a battery in accordance with the invention, that is able to be obtained
25 in particular according to the method of the preceding figures.

[Fig. 12] is a perspective view showing a battery in accordance with the invention, that is able to be obtained in particular according to the method of the preceding figures.

[Fig. 13] is a perspective view showing a battery
30 according to the prior art.

The following marks are used in these figures and in the following description:

[Table 1]: Alphanumeric marks used in the present application

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Mark	Meaning	Mark	Meaning
1000	Battery according to the invention	I	Stack of foils of substrate, covered with a layer of electrode (anode or cathode) and with a foil of electrolyte or of a separator impregnated with an electrolyte
1011, 1012	Longitudinal edges of the Battery 1000	1	Substrate foil
1001, 1005	Lateral edges of the battery 1000	2, 2'	Anode foil
1002	Anode connection area	2 ^e	Notched anode foil
1006	Cathode connection area	5, 5'	Cathode foil
100, 100', 100''	Elementary cell	5 ^e	Notched cathode foil
111	Primary body of 100	4	Perforated central area of the cathode foil
112	Secondary body of 100	6	Peripheral frame of the cathode foil
113	Tertiary body of 100	7	Perforations present at the four ends of the foils of substrate, anode, cathode, electrolyte or of a separator impregnated with an electrolyte
120	Notch	8	Bridges of material between two lines
130	Recess	H ₈	Height of the bridges

L ₁₂₀	Width of the notch between 111 and 112	9	Strips of material between two rows
L ₁₃₀	Width of the recess between 111 and 113	L ₉	Width of the strips
10	Planar anode current collector substrate	XX	Longitudinal or horizontal direction of the stack
20	Anode layer	YY	Vertical or transversal direction of the stack
30	Layer of an electrolyte material	L	Line of slots in the shape of a ladder
31	Layer of a separator impregnated with an electrolyte	R	Row of slots in the shape of a ladder
50	Cathode layer	70	H-shaped slots in the cathode foils, cathode slot
40	Planar cathode current collector substrate	XH	Median horizontal axis of the H ₇₂ -shaped slots
80	H-shaped slots in the anode foils, anode slot	D, D', D _n , D' _n , D _{n+1} , D' _{n+1}	Cut
H ₅₀	Total height of the H-shaped slot	H ₇₀	Total height of the H-shaped slot
L ₈₀	Total width of the H-shaped slot	L ₇₀	Total width of the H-shaped slot
82	Main vertical cavities of 80	72	Main vertical cavities of 70
L ₈₂	Width of each main cavity 82	L ₇₂	Width of each main cavity 72
84	Horizontal channel of 80	74	Horizontal channel of 70
84', 84''	Portion of the horizontal channel 84 belonging to an elementary cell called	74, 74''	Portion of the horizontal channel 74 belonging to an elementary cell called

	hereinafter portion of the horizontal channel		hereinafter portion of the horizontal channel
H ₈₄	Height of the horizontal channel 84	H ₇₄	Height of the horizontal channel 74
D ₈₄	Distance between the top of 82 and of 84	D ₇₄	Distance between the top of 72 and of 74
86	First horizontal trench of 80	76	First horizontal trench of 70
H ₈₆	Height of the first horizontal trench of 80	H ₇₅	Height of the first horizontal trench of 70
D ₈₅	Distance between the base of 82 and of 86	D ₇₅	Distance between the base of 72 and of 76
88	Second horizontal trench of 80	78	Second horizontal trench of 70
H ₈₈	Height of the second horizontal trench of 80	H ₇₈	Height of the second horizontal trench of 70
90	Material scrap	91	Material scrap
D ₈₅	Distance between the cut D _n and the face facing the horizontal channel 84	D ₇₅	Distance between the cut D' _n and the face facing the horizontal channel 74
D ₈₇	Distance between the cut D' _n and the face facing the first horizontal trench 86 or the second horizontal trench 88	D ₇₇	Distance between the cut D _n and the face facing the first horizontal trench 76 or the second horizontal trench 78
AA	Madian axis of the anode current collector substrate	CC	Madian axis of the cathode current collector substrate
60,61	Grooves in the shape of a ladder	2000	Battery according to prior art
2002	Anode connection zone	2006	Cathode connection zone
2095	Encapsulation system		

Description of the invention

The method in accordance with the invention comprises first of all a step wherein a stack I of alternating foils

is carried out, these foils being called hereinafter, according to the case, "anode foils" 2 or "cathode foils" 5. As shall be seen in more detail, each anode foil 2 is intended for forming the anode of several batteries, and
5 each cathode foil 5 is intended for forming the cathode of several batteries. In the example shown in figure 1, two notched cathode foils 5e are shown, as well as two notched anode foils 2e. In practice, this stack is formed by a higher number of foils, typically comprised between ten
10 and thousand. The number of notched cathode foils 5e is identical to the number of notched anode foils 2e used constituting the stack I of alternating foils of opposite polarity.

In an advantageous embodiment, each one of these foils
15 has perforations 7 at its four ends in such a way that when these perforations 7 are superimposed, all the cathodes and all the anodes of these foils are arranged specifically, as shall be explained in greater detail hereinafter (cf. figures 1 and 2). These perforations 7 at
20 the four ends of the foils can be carried out by any suitable means, in particular on anode 2 and cathode 5 foils after manufacture, or on substrate foils 10, 40 covered with a cathode 50 or anode 20 layer, and optionally covered with a layer of an electrolyte material 30 or of
25 a separator 31 in such a way that this layer of an electrolyte material 30 or this separator 31 is inserted between two foils of opposite polarity, i.e. between the anode foil 2 and the cathode foil 5.

Each anode foil 2 comprises a planar anode current
30 collector substrate 10 covered with an active layer of an anode material 20, hereinafter anode layer 20. Each cathode foil 5 comprises a planar cathode current collector

substrate 40 covered with an active layer of a cathode material 50, called hereinafter cathode layer 50. Each one of these active layers can be solid, and more particularly of a dense or porous nature. Moreover, in order to prevent
5 any electrical contact between two active layers of opposite polarities, a layer of electrolyte 30 or of a separator 31 impregnated with an electrolyte is disposed on the active layer of at least one of these planar cathode current collector substrates covered beforehand with the
10 active layer, in contact with the active layer facing. The layer of electrolyte 30 or the separator 31, can be disposed on the anode layer 20 and/or on the cathode layer 50; the layer of electrolyte or the separator is an integral part of the anode foil 2 and/or of the cathode
15 foil 5 that comprises it.

Advantageously, the two faces of the planar anode 10, respectively cathode 40, current collector substrate, are covered with an anode layer 20, respectively with a cathode layer 50, and optionally with a layer of electrolyte 30 or
20 of separator 31, disposed on the anode layer 20, respectively on the cathode layer 50. In this case, the planar anode 10, respectively cathode 40, current collector substrate, will be used as a current collector for two adjacent elementary cells. Using these substrates
25 in the batteries makes it possible to increase the production yield of rechargeable batteries with a high energy density and high power density.

The mechanical structure of one of the anode foils 2 is described hereinafter, with the understanding that the
30 other anode foils 2 have an identical structure. Moreover, as shall be seen in what follows, the cathode foils 5 have a structure close to that of the anode foils 2.

As can be seen in figure 2, the notched anode foil 2e has a quadrilateral shape, substantially of the square type. It delimits a so-called perforated central area 4, wherein ladder-shaped grooves are made which shall be described hereinafter. In reference to the positioning of these ladder-shaped grooves, a so-called vertical direction YY of the foil is defined, which corresponds to the vertical direction of these ladder-shaped grooves, as well as a so-called horizontal direction XX of the foil, perpendicular to the direction YY. The central area 4 is bordered by a peripheral frame 6 that is solid, namely devoid of grooves. The function of this frame is in particular to ensure an easy handling of each foil.

The ladder-shaped grooves are distributed along lines L_1 to L_y , disposed one beneath the other, as well as along rows R_1 to R_x provided one next to the other. As non-limiting examples, in the framework of manufacturing micro-batteries of the surface-mounted component (hereinafter CMS) type, the anode and cathode foils used can be 100 mm x 100 mm plates. Typically, the number of lines of these foils is comprised between 10 and 500, while the number of rows is comprised between 10 and 500. According to the desired capacity of the battery, its dimensions can vary and the number of lines and rows per anode and cathode foils can consequently be adapted. The dimensions of the anode and cathode foils used can be modulated according to need. As shown in figure 2, two adjacent lines are separated by bridges of material 8, of which H_8 denotes the height, which is comprised between 0.05 mm and 5 mm. Two adjacent rows are separated by strips of materials 9, of which L_9 denotes the width, which is comprised between 0.05 mm and 5 mm. These bridges 8 and

strips 9 of material of the anode and cathode foils provide these foils with a mechanical rigidity that is sufficient for them to be able to be handled easily.

5 The ladder-shaped grooves 60, 61 comprise notches 76, 78, 86, 88 and H-shaped slots 70, 80. These H-shaped slots are through-slots, namely they open onto the opposite respectively upper and lower faces of the foil.

10 The H-shaped slots 70, 80 can be carried out in a manner known per se, directly on the planar current collector substrate, before any deposition of anode or cathode materials by chemical etching, by electroforming, by laser cutting, by microperforation or by stamping. These H-shaped slots 70, 80 can also be carried out on planar cathode current collector substrates covered with a layer
15 of anode or cathode materials, on planar cathode current collector substrates covered beforehand with a layer of anode or cathode materials, and covered with a layer of electrolyte or of a separator, i.e. on anode or cathode foils in a manner known per se, for example by laser
20 cutting (or laser ablation), by femtosecond laser cutting, by microperforation or by stamping. The H-shaped slots 70, carried out in all of the cathode foils, are superimposed. The H-shaped slots 80, carried out in all the anode foils, are superimposed.

25 One of the ladder-shaped grooves 60 such as shown in figure 3 shall now be described, with the understanding that all of the cuts of the anode foil are identical. Each ladder-shaped groove 60 comprises a, H-shaped through-slot 80 formed by two main vertical and parallel cavities 82,
30 which are connected in their upper portion by a horizontal channel 84, preferably perpendicular to the two main vertical and parallel cavities 82. Each groove further

comprises, in the lower portion of the H-shaped slot, a first horizontal anode trench 86 and a second horizontal anode trench 88. As shown in particular in figure 3, the first 86 and second 88 horizontal anode trenches are carried out on either side of the anode foil 2 in such a way that the second horizontal anode trench 88 is carried out in the extension of the first horizontal anode trench 86.

The first and second anode trenches 86, 88 are free from any electrolyte material or separator and from any anode material. These first and second anode trenches 86, 88 are carried out in such a way as to remove any electrolyte material or separator, and any anode material, and to leave at least one portion of the planar anode current collector substrate defining a continuity area of the planar anode current collector substrate. The first and second anode trenches 86, 88 can be carried out via laser ablation.

The first and second anode trenches 86, 88 extend between the opposite longitudinal edges 1011, 1012 of the battery in a direction perpendicular to the main plane of the battery in such a way as to connect the two main vertical and parallel cavities 82 of each slot 80, called hereinafter anode slot.

The horizontal channel 84 on the one hand and the first and second horizontal anode trenches 86, 88 on the other hand, are mutually symmetrical seen from the top, with respect to the median axis of the Hs, which is noted as XH.

The anode foil 2 obtained after the carrying out of slots 80 and of notches forming the first and second

horizontal anode trenches 86, 88 is called hereinafter notched anode foil 2e.

Note

- H_{80} the height of the entire slot, that is typically
5 comprised between 0.25 mm and 10 mm;
- L_{80} its width, that is typically comprised between 0.25 mm and 10 mm;
- L_{82} the width of each main vertical cavity, that is typically comprised between 0.02 mm and 5 mm;
- 10 • H_{84} the height of each channel, that is typically comprised between 0.01 mm and 0.5 mm;
- D_{84} the difference in heights between the top of the main vertical and parallel cavities 82 and the top of the horizontal channel 84, that is typically comprised between
15 0.05 mm and 2 mm;
- H_{86} the height of each first horizontal anode trench 86, that is typically comprised between 0.01 mm and 0.5 mm;
- D_{86} the difference in heights between the base of
20 the main vertical and parallel cavities 82 and the base of each first horizontal anode trench 86, that is typically comprised between 0.05 mm and 2 mm.

Each cathode foil 5 is also provided with different lines and rows of ladder-shaped grooves 61, provided in
25 the same number as the ladder-shaped grooves 60. As shown in particular in figure 4, the structure of each ladder-shaped groove 61 is substantially similar to that of each ladder-shaped groove 60, namely in that this ladder-shaped groove 61 comprises two main vertical cathode cavities 72,
30 connected by a horizontal channel 74. The dimensions of the main vertical cathode cavities 72 are identical to those of the main vertical anode cavities 82 and, similarly,

the dimensions of the channels 74 are similar to those of the channels 84.

Seen from above, the main vertical cathode cavities 72 are superimposed with those 82. The only differences, between the ladder-shaped grooves 60 and 61, reside in the fact that the channels 74 are provided in the lower portion and that the first and second horizontal cathode trenches 76, 78 are provided in the upper portion. The first 76 and second horizontal cathode trenches 78 are carried out on either side of the cathode foil 5 in such a way that the second horizontal cathode trench 78 is carried out in the extension of the first horizontal cathode trench 76.

The first and second cathode trenches 76, 78 are free from any electrolyte material or separator and from any cathode material. These first and second cathode trenches 76, 78 are carried out in such a way as to remove any electrolyte or separator material, and any cathode material, and to leave at least one portion of the cathode current collector substrate defining a continuity area of the planar cathode current collector substrate. The first and second cathode trenches 76, 78 can be carried out via laser ablation in a manner known per se. The first and second cathode trenches 76, 78 extend between the opposite longitudinal edges 1011, 1012 of the battery in a direction perpendicular to the main plane of the battery in such a way as to connect the two main vertical and parallel cavities 72 of each slot 70, called hereinafter cathode slot 70.

As shown in particular in figure 4, the horizontal channel 74 on the one hand and the first and second horizontal cathode trenches 76, 78 on the other hand, are

mutually symmetrical seen from the top, with respect to the median axis of the Hs, which is noted as XH.

The cathode foil 5 obtained after the carrying out of slots 70 and of notches forming the first and second
5 horizontal cathode trenches 76, 78 is called hereinafter notched cathode foil 5e.

An alternating stack I of at least one notched anode foil 2e and of at least one notched cathode foil 5e is then carried out, in such a way as to obtain successively
10 at least one planar anode current collector substrate 10, at least one anode layer 20, at least one layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode layer 50, and at least one planar cathode current collector substrate 40.

15 The alternating stack I is carried out in such a way that:

- for each anode slot 80 of at least one notched anode foil 2e, the anode trenches 86, 88 of at least the notched anode foil 2e, are disposed in the extension of the
20 horizontal cathode channel 74 of the cathode slot 70 of the adjacent notched cathode foil 5e in a direction perpendicular to the main plane of the battery, and in such a way that,

- for each cathode slot 70 of at least one notched
25 cathode foil 5e, the cathode trenches 76, 78, of at least the notched cathode foil 5e, are disposed in the extension of the horizontal anode channel 84 of the anode slot 80, of the adjacent notched anode foil 2e in a direction perpendicular to the main plane of the battery.

30 It is supposed that the stack, described hereinabove, is subjected to steps aiming to ensure the overall mechanical stability thereof. These steps, of a type known

per se, include in particular the thermopressing of the different layers. As shall be seen hereinbelow, this stack allows for the formation of individual batteries, of which the number is equal to the product between the number of
5 lines Y and the number of rows X.

For this purpose, in reference to figure 5, three lines L_{n-1} to L_{n+1} are shown as well as three rows R_{n-1} to R_{n+1} . In accordance with the invention, two cuts D_n and D'_n are carried out by line of slots. Each cut, which is
10 carried out in a through manner, namely it extends over the entire height of the stack, is carried out in a manner known per se. As non-limiting examples, mention will be made of cutting by sawing, in particular dicing, guillotine cutting or laser cutting.

15 As shown in particular in figure 6, which is a view on a larger scale of one of the grooves of figure 5, each cut is carried out between a respective channel and the end facing the H-shaped slot. In these conditions, in reference to this figure 6, as non-limiting examples, note:

20 • the distance D_{85} between the cut D_n and the face facing the horizontal channel 84 is comprised between 0.05 mm and 2 mm, with the understanding that this distance D_{85} is less than or equal to D_{84} ;

• the distance D_{87} between the cut D'_n and the face
25 facing the first horizontal anode trench 86, comprised between 0.05 mm and 2 mm, with the understanding that this distance D_{87} is less than or equal to D_{86} .

In reference again to figure 5, each final battery is delimited, at the top and at the bottom, by the two cuts
30 D_n and D'_n and, on the right and on the left, by the inside faces of the main vertical and parallel cavities.

This figure 5 shows in a hatched manner the batteries 1000 once cut along the cutting lines D_n and D'_n . In addition, the areas 90 of foils of the stack are shown with a dotted filling, which do not form the batteries, while the volume of the slots is left in white.

Figures 7 and 8 are cross-section views, taken according to the cutting line VII-VII that extends through the battery. In figure 7, only the arrangement of a notched anode foil 2e and of a notched cathode foil 5e, one with respect to the other, is shown. In figure 8, the alternating arrangement of two notched anode foils 2e and of two notched cathode foils 5e is shown. In the same figure, the zones 90 are referenced, also shown in figure 5, which correspond to material scrap, in particular scraps of anode, cathodes and electrolyte material or separator.

The notched anode foil 2e comprises a planar anode current collector substrate 10 covered with an anode layer 20, itself optionally covered with a layer of electrolyte 30 or of a separator 31 impregnated with an electrolyte. Each notched cathode foil 5e comprises a planar cathode current collector substrate 40 covered with an active layer of a cathode material 50, itself optionally covered with a layer of electrolyte 30 or of a separator 31 impregnated with an electrolyte. In order to prevent any electrical contact between two active layers of opposite polarity, i.e. between the anode layer 20 and the cathode layer 50, at least one layer of electrolyte 30 or of a separator 31 impregnated or later impregnated with an electrolyte is disposed between the anode layer 20 and the cathode layer 50. In figure 7 an elementary cell 100 is shown comprising successively at least one planar anode current collector substrate 10, at least one anode layer 20, at least one

layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode layer 50, and at least one planar cathode current collector substrate 40.

5 Each elementary cell 100 comprises a primary body 111, a secondary body 112 and a tertiary body 113. The secondary body 112 and the tertiary body 113 are disposed on either side of the primary body 111. Each one of the primary 111, secondary 112 and tertiary 113 bodies comprises
10 successively at least one planar anode current collector substrate 10, at least one anode layer 20, at least one layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode layer 50, and at least one planar cathode current collector
15 substrate 40. The succession of the different layers is the same for the primary 111, secondary 112 and tertiary 113 body; the anode layer of the primary body is facing the anode layer of the secondary body and that of the tertiary body, the cathode layer of the primary body is
20 facing the cathode layer of the secondary body and that of the tertiary body, and the layer of electrolyte or separator of the primary body is facing the layer of electrolyte or separator of the secondary body and that of the tertiary body. The secondary body 112 is separated
25 from the primary body 111 by a notch 120 free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and anode current collector substrate material, in such a way that said notch extends from a longitudinal edge 1011 to the opposite longitudinal edge
30 of the battery 1012 in a direction perpendicular to the main plane of the battery.

The tertiary body 113 is separated from the primary body 111 by a recess 130 free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and cathode current collector substrate material, in such a way that the recess 130 extends from a longitudinal edge 1011 to the opposite longitudinal edge of the battery 1012 in a direction perpendicular to the main plane of the battery.

Moreover, each notched anode, respectively notched cathode, foil has ladder-shaped grooves. Each groove 60, 61 comprises a horizontal channel 84, 74, a first 86, 76 and a second horizontal trench 88, 78 such as those shown in figure 7. The first 86, 76 and second horizontal trenches 88, 78 are carried out on either side of the anode/cathode foils in such a way that the second horizontal trench 88, 78 is carried out in the extension of the first horizontal trench 86, 76. Moreover each notched anode 2e and notched cathode 5e foil are arranged in such a way that:

- the first 86 and second 88 horizontal anode trenches are disposed in the extension of the horizontal cathode channel 74 of the ladder-shaped groove 61 present on the adjacent notched cathode foil 5e, and in that

- the first 76 and second 78 horizontal cathode trenches are disposed in the extension of the horizontal anode channel 84 of the ladder-shaped groove 60 present on the adjacent notched anode foil 2e.

This is a particularly advantageous characteristic of the invention, since this makes it possible to prevent the presence of a short-circuit at the lateral edges of the battery, to prevent the presence of leakage current, and

to facilitate the making of electrical contact at the anode 1002 and cathode 1006 connection areas.

As a cross-section view, the main vertical cathode cavities 72 are superimposed with those 82. The only
5 differences, between the ladder-shaped grooves 60 and 61, resides in the fact that the channels 74 are provided in the lower portion and that the first and second horizontal cathode trenches 76, 78 are provided in the upper portion. The first 76 and second 78 horizontal cathode trenches are
10 carried out on either side of the cathode foil 5 in such a way that the second horizontal cathode trench 78 is carried out in the extension of the first horizontal cathode trench 76.

The first and second cathode trenches 76, 78 are free
15 from any electrolyte material or separator and from any cathode material. The first and second cathode trenches 76, 78 extend between the opposite longitudinal edges 1011, 1012 of the battery in a direction perpendicular to the main plane of the battery in such a way as to connect the
20 two main vertical and parallel cavities 72 of each slot 70, called hereinafter cathode slot 70.

As shown in particular in figure 4, the horizontal channel 74 on the one hand and the first and second horizontal cathode trenches 76, 78 on the other hand, are
25 mutually symmetrical seen from the top, with respect to the median axis of the Hs, which is noted as XH.

The cathode foil 5 obtained after the carrying out slots 70 and notches forming the first and second horizontal cathode trenches 76, 78 is called hereinafter
30 notched cathode foil 5e.

In figures 7 and 8 note that the cut D'n is carried out both through the notched anode foil and the notched

cathode foil, namely at a distance D_{75} from the channels of the ladder-shaped grooves 61 present on the notched cathode foils 5e, which also corresponds to the distance D_{87} from the first 86 and second horizontal anode trenches 88 of the ladder-shaped grooves 60 present on the notched anode foils 2e. The cut Dn is carried out both through the notched anode foil and the notched cathode foil, namely at a distance D_{85} from the channels of the ladder-shaped grooves 60 present on the notched anode foils 2e, which also corresponds to the distance D_{77} from the first 76 and second horizontal cathode trenches 78 of the ladder-shaped grooves 61 present on the notched cathode foils 5e. Carrying out cuts Dn and D'n through the notched anode foil and the notched cathode foil is a particularly advantageous characteristic of the invention, since this makes it possible to improve the quality of the cut with respect to the prior art, as is explained in greater detail hereinafter.

Application WO 2016/001584 describes stacks of several elementary cells, consisting of anode 2' and cathode 5' foils stacked alternately and offset laterally (cf. figure 13), encapsulated in an encapsulation system 2095 in order to ensure the protection of the cell of the battery 2000 with regards to the atmosphere. The cutting of these encapsulated stacks making it possible to obtain unitary batteries, with exposed anode 2002 and cathode 2006 connection areas, is carried out according to a cutting plane passing through an alternating succession of electrode and encapsulation system. Through the difference in density that exists between the electrode and the encapsulation system of the battery of the prior art, the cut carried out along this cutting plane induces a risk of

pulling off of the encapsulation system at the approaches to the cutting plane, and thus the creation of short-circuits. In application WO 2016/001584, during the encapsulation, the encapsulation layer fills the interstices of the stack of foils bearing U-shaped cuts. This encapsulation layer introduced at these interstices is thick and does not adhere very well to the stack inducing this risk of pulling off of the encapsulation system 2095 during the later cutting.

10 According to the present invention, this risk is suppressed with the use of foils bearing ladder-shaped grooves, because the thermopressed mechanical structure in the shape of a ladder is extremely rigid at the approaches to the cut, due to the alternating superposition of cathode and anode foils. Using such a rigid structure, with the use of foils bearing cuts in the shape of a ladder, makes it possible to reduce the number of defects during cuts, increase the cutting speed and thus improve the production yield of the batteries.

20 According to the invention, the cuts D'_n and D_n are carried out through notched anode foils 2e and notched cathode foils 5e of comparable density inducing a clean cut of better quality. In addition, the presence of notches free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and anode current collector substrate material as well as the presence of recesses free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and cathode current collector substrate material, prevents any risk of a short-circuit and of leakage current.

30 In reference to figure 9, one 1000 of the batteries is shown in an exploded manner in accordance with the

invention comprising, as a non-limiting example, three elementary cells 100, 100', 100''. Each elementary cell 100 comprises a primary body 111, a secondary body 112 and a tertiary body 113. The secondary body 112 and the tertiary body 113 are disposed on either side of the primary body 111. Each one of the primary 111, secondary 112 and tertiary 113 bodies comprises successively at least one planar anode current collector substrate 10, at least one anode layer 20, at least one layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode layer 50, and at least one planar cathode current collector substrate 40. The secondary body 112 is separated from the primary body 111 by a notch 120 free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and anode current collector substrate material. The notch 120 comprises either a portion of the channel 84 hereinafter 84'' and the first cathode trench 76, or a portion of the channel 84 hereinafter 84' and the second cathode trench 78 as shown in figure 9. The portions 84' and 84'' of the horizontal channel 84 are symmetrical with respect to the median axis AA of the anode current collector substrate. The blind end of the notch 120 of each elementary cell defines a continuity area of the cathode current collector, in such a way as to allow the making of electrical contact at the cathode connection area 1006.

Similarly, the tertiary body 113 is separated from the primary body 111 by a recess 130 free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and cathode current collector substrate material. The recess 130 comprises either a portion of the channel 74 hereinafter 74'' and the first anode trench 86, or a

portion of the channel 74 hereinafter 74' and the second anode trench 88 as shown in figure 9. The portions 74' and 74'' of the horizontal channel 74 are symmetrical with respect to the median axis CC of the cathode current collector substrate. The blind end of the recess 130 of each elementary cell defines a continuity area of the anode current collector, in such a way as to allow the making of electrical contact at the anode connection area 1002.

As shown in figure 9, each elementary cell comprises respectively upper and lower faces, each face being parallel to the main plane of the battery. Note that, each elementary cell comprises a recess 130 and a notch 120. The recess 130 opens onto a first face, here lower face of the elementary cell 100 and has a blind end that leaves a continuity area of the planar anode current collector substrate 10. The notch 120 opens onto a second face, here upper face of the elementary cell 100 and has a blind end that leaves a continuity area of the planar cathode current collector substrate 40. The anode connection areas 1002 and the cathode connection areas 1006 are preferably laterally opposite.

As shown in figure 9, the recess 130 of an elementary cell 100 extends in the extension of the recess 130 made in the adjacent elementary cell 100' located below the elementary cell 100, in a direction perpendicular to the main plane of the battery. Similarly, the notch 120 of an elementary cell 100' extends in the extension of the notch 120 made in the adjacent elementary cell 100'' located below the elementary cell 100', in a direction perpendicular to the main plane of the battery.

As shown in figure 9, the planar anode current collector substrate 10 of an elementary cell 100' can be

placed next to the planar anode current collector substrate 10 of the adjacent elementary cell 100''. Similarly, the planar cathode current collector substrate 40 of an elementary cell 100 can be placed next to the planar cathode current collector substrate 40 of the adjacent elementary cell 100'.

In an advantageous embodiment, the planar anode 10, respectively cathode 40, current collector substrate, can be used as a current collector for two adjacent elementary cells, as is in particular shown in figure 7. As explained hereinabove, the two faces of the planar anode 10, respectively cathode 40, current collector substrate, are covered with an anode layer 20, respectively with a cathode layer 50, and optionally with a layer of electrolyte 30 or of separator 31, disposed on the anode layer 20, respectively on the cathode layer 50. This makes it possible to increase the production yield of the batteries. Now in reference to figures 10 to 12, one 1000 of the batteries is shown in accordance with the invention. On note 1001 and 1005 the lateral edges, 1011 and 1012 the longitudinal edges of this battery.

Each battery comprises at least one elementary cell 100. The elementary cell 100 comprises a primary body 111, a secondary body 112 and a tertiary body 113. The secondary body 112 and the tertiary body 113 are disposed on either side of the primary body 111. Each one of the primary 111, secondary 112 and tertiary 113 bodies comprises successively at least one planar anode current collector substrate 10, at least one anode layer 20, at least one layer of an electrolyte material 30 or of a separator impregnated with an electrolyte 31, at least one cathode layer 50, and at least one planar cathode current collector

substrate 40. The secondary body 112 is separated from the primary body 111 by a notch 120 free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and anode current collector substrate material.

5 The notch 120, of which the width L_{120} corresponds to that of the channel 84 of the slot 80 (or of the ladder-shaped groove 60) described hereinabove, extends from a longitudinal edge 1011 to the opposite longitudinal edge of the battery 1012 in a direction perpendicular to the
10 main plane of the battery. The notch 120 comprises either a portion 84'' of the channel 84 and the first cathode trench 76, or a portion 84' of the channel 84 and the second cathode trench 78 as shown in figure 7.

The tertiary body 113 is separated from the primary
15 body 111 by a recess 130 free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and cathode current collector substrate material. The recess 130, of which the width L_{130} corresponds to that of the channel 74 of the slot 70 (or of the ladder-shaped groove
20 61) described hereinabove, extends from a longitudinal edge 1011 to the opposite longitudinal edge of the battery 1012 in a direction perpendicular to the main plane of the battery. The recess 130 comprises either a portion 74'' of the channel 74 and the first anode trench 86, or a portion
25 74' of the channel 74 and the second anode trench 88 as shown in figure 7.

The width of the secondary body 112 corresponds to the distance D_{85}/D_{77} , such as described in reference to figures 6, 7 or 8. The width of the tertiary body 113
30 corresponds to the distance D_{87}/D_{75} , such as described in reference to figures 6, 7 or 8. In an advantageous embodiment, the distances D_{85}/D_{77} and D_{87}/D_{75} are equal.

The singular structure of the battery according to the invention makes it possible to prevent the presence of short-circuits at the lateral edges of the battery, to prevent the presence of leakage current and to facilitate the making of electrical contact at the anode 1002 and cathode 1006 connection areas. Indeed, the presence of notches 120 and recess 130 in the battery according to the invention prevents the lateral leaking of lithium ions and facilitates the balancing of the battery; the effective surfaces of the electrodes in contact with one another, and delimited by the notches 120 and the recesses 130 are substantially identical.

The effective surfaces of the electrodes of each elementary cell according to the invention are facing one another in such a way that the notch 120 and the recess 130 delimit the lateral edges of the primary body 111 of each elementary cell. The blind end of the recess 130 of each elementary cell defines a continuity area of the anode current collector, in such a way as to allow for the making of electrical contact at the anode connection area 1002. The blind end of the notch 120 of each elementary cell defines a continuity area of the cathode current collector, in such a way as to allow for the making of electrical contact at the cathode connection area 1006. The presence of a notch 120 and of a recess 130 within the elementary cell makes it possible to prevent the presence of a short-circuit at the lateral edges of the battery, to prevent the presence of leakage current, and to facilitate the making of electrical contact, and this, only at the anode 1002 and cathode 1006 connection areas.

Advantageously, after the carrying out of the stack of notched anode 2e and notched cathode 5e foils, the heat

treatment of the latter allowing for the assembly of the battery is carried out at a temperature comprised between 50°C and 500°C, preferably at a temperature less than 350°C, and/or the mechanical compression of the stack of notched
5 anode and notched cathode foils to be assembled is carried out at a pressure comprised between 10 MPa and 100 MPa, preferably between 20 MPa and 50 MPa. In a particular embodiment, after the carrying out of the stack and the step of heat treatment of the latter, the stack is
10 encapsulated by depositing an encapsulation system in order to ensure the protection of the cell of the battery with regards to the atmosphere. The encapsulation system has to be chemically stable, resist a high temperature and be impermeable to the atmosphere in order to perform its
15 function as a barrier layer. Advantageously, the stack of notched anode and notched cathode foils according to the invention, can be covered with a sequence, preferably with z sequences, of an encapsulation system comprising:

- a first dense and insulating cover layer, preferably
20 selected from parylene, parylene F, polyimide, epoxy resins, silicone, polyamide and/or a mixture thereof, deposited on the stack of notched anode 2e and notched cathode 5e foils; and

- a second cover layer comprised of an electrically-
25 insulating material, deposited by atomic layer deposition on said first cover layer.

This sequence can be repeated z times with $z \geq 1$. This multilayer sequence has a barrier effect. The more the sequence of the encapsulation system is repeated, the
30 more substantial this barrier effect will be.

Typically, the first cover layer is selected from the group formed by: silicones (deposited for example via

impregnation or via plasma enhanced chemical vapor deposition from hexamethyldisiloxane (HMDSO)), epoxy resins, polyimide, polyamide, poly-para-xylylene (also called poly(p-xylylene), known better as parylene), and/or
5 a mixture thereof. This first cover layer makes it possible to protect the sensitive elements of the battery from its environment. The thickness of said first cover layer is, preferably, comprised between 0.5 μm and 3 μm .

Different variants of parylene can be used.
10 Advantageously, the first cover layer can be made from parylene C, parylene D, parylene N (CAS 1633-22-3), parylene F or a mixture of parylene C, D, N and/or F. Parylene is a dielectric, transparent, semi-crystalline material that has high thermodynamic stability and
15 excellent resistance to solvents as well as a very low permeability. Parylene also has barrier properties that make it possible to protect the battery from its external environment. The protection of the battery is increased when this first cover layer is made from parylene F. This
20 first cover layer is advantageously obtained from the condensation of gaseous monomers deposited via chemical vapor deposition (CVD) on the surfaces, which makes it possible to have conformal, thin and uniform coverage of all the accessible surfaces of the stack. This first cover
25 layer is advantageously rigid; it cannot be considered as a flexible surface.

The second cover layer is comprised of an electrically-insulating material, preferably inorganic. It is deposited by atomic layer deposition (ALD), in such a
30 way as to obtain a conformal coverage of all the accessible surfaces of the stack covered beforehand with the first cover layer. The layers deposited via ALD are very fragile

mechanically and require a rigid bearing surface in order to ensure their protective role. The deposition of a fragile layer on a flexible surface would lead to the formation of cracks, generating a loss of integrity in this protective layer. Moreover, the growth of the layer deposited via ALD is influenced by the nature of the substrate. A layer deposited via ALD on a substrate that has areas of different chemical natures will have inhomogeneous growth, that can generate a loss of integrity in this protective layer.

ALD deposition techniques are particularly well suited for covering surfaces that have a high roughness in an entirely sealed and conformal manner. They make it possible to carry out conformal layers, free of defects, such as holes (layers referred to as "pinhole free", i.e. free of holes) and represent very good barriers. Their WVTR coefficient is very low. The WVTR coefficient (water vapor transmission rate) makes it possible to evaluate the permeance to water vapor of the encapsulation system. The lower the WVTR coefficient is, the tighter the encapsulation system is.

The second cover layer can be made from ceramic material, vitreous material or vitroceramic material, for example in the form of oxide, of the Al_2O_3 type, of nitride, of phosphates, of oxynitride, or of siloxane. This second cover layer has, preferably, a thickness comprised between 10 nm and 50 nm.

This second cover layer deposited via ALD on the first cover layer makes it possible on the one hand, to endure the tightness of the structure, i.e. to prevent the migration of water inside the object and on the other hand to protect the first cover layer, preferably made of

parylene F, from the atmosphere, in particular from air and humidity, from thermal exposure in order to prevent the degradation thereof. This second cover layer thus improves the service life of the encapsulated battery.

5 The stack of notched anode 2e and notched cathode 5e foils thus encapsulated in this sequence of the encapsulation system, preferably in z sequences, can then be covered with a last cover layer in such a way as to mechanically protect the stack thus encapsulated and
10 possibly provide it with an aesthetic aspect. This last cover layer protects and improves the service life of the battery. Advantageously this last cover layer is also chosen to resist a high temperature, and has a mechanical resistance that is sufficient to protect the battery during
15 the later use thereof. Advantageously, the thickness of this last cover layer is comprised between 1 μm and 50 μm . Ideally, the thickness of this last cover layer is about 10 μm to 15 μm ; such a range of thickness makes it possible to protect the battery from mechanical damage.

20 This last cover layer is preferably with a base of epoxy resin, polyethylene naphthalate (PEN), polyimide, polyamide, polyurethane, silicone, sol-gel silica or organic silica. Advantageously, this last cover layer is deposited via dipping.

25 The stack of notched anode 2e and notched cathode 5e foils thus coated is then cut by any suitable means along the cutting lines D'_n and D_n in such a way as to expose the anode and cathode connection areas and to obtain unitary batteries.

30 Terminations (electrical contacts) are added where the cathode, respectively anode connection areas, are apparent. These contact areas are, preferably, disposed on

the opposite sides of the stack of the battery in order to collect the current (lateral current collectors). The terminations are disposed on at least the cathode connection area and on at least the anode connection area, preferably on the face of the coated and cut stack comprising at least the cathode connection area and on the face of the coated and cut stack comprising at least the anode connection area.

The connection areas are metalized using techniques known to those skilled in the art, preferably via immersion in a conductive epoxy resin and/or a bath of molten tin. Preferably, the terminations consist, at the approaches of the cathode and anode connection areas, of a first stack of layers comprising successively a first layer of a material loaded with graphite, preferably made of epoxy resin loaded with graphite, and a second layer comprising metal copper obtained from an ink loaded with nanoparticles of copper deposited on the first layer. This first stack of terminations is then sintered by infra-red flash lamp in such a way as to obtain a covering of the cathode and anode connections with a layer of metal copper.

According to the final use of the battery, the terminations can comprise, additionally, a second stack of layers disposed on the first stack of terminations comprising successively a first layer of a tin-zinc alloy deposited, preferably by dipping in a bath of molten tin-zinc, in order to ensure the tightness of the battery at least cost and a second layer with a pure tin base deposited via electrodeposition or a second layer comprising an alloy with a silver, palladium and copper base deposited on this first layer of the second stack.

Terminations make it possible to resume the alternatively positive and negative electrical connections on each one of the ends. These terminations make it possible to carry out the electrical connections in parallel between the different battery elements. For this, only the cathode connections exit on one end, and the anode connections are available on another end.

The method according to the invention is particularly adapted to the manufacture of all-solid-state batteries, i.e. batteries of which the electrodes and the electrolyte are solid and do not comprise a liquid phase, even impregnated in the solid phase.

The method according to the invention is particularly adapted to the manufacture of batteries considered as quasi-solid-state comprising at least one separator impregnated with an electrolyte. The separator is, preferably, a porous inorganic layer that has:

- a porosity, preferably, a mesoporous porosity, greater than 30%, preferably comprised between 35% and 50%, and more preferably between 40% and 50%,
- pores of an average diameter D_{50} less than 50 nm.

The thickness of the separator is advantageously less than 10 μm , and preferably comprised between 2.5 μm and 4.5 μm , in such a way as to reduce the final thickness of the battery without lessening its properties. The pores of the separator are impregnated with an electrolyte, preferably, by a lithium ion carrier phase such as liquid electrolytes or an ionic liquid containing lithium salts. The "nanoconfined" or "nanotrapped" liquid in the porosities, and in particular in the mesoporosities, can no longer exit. It is linked by a phenomenon called here "absorption in the mesoporous structure" (which does not

seem to have been described in the literature in the context of lithium-ion batteries) and it can no longer exit even when the cell is placed in a vacuum. The battery is then considered as quasi-solid-state.

5

CLAIMS

1. Battery (1000) comprising at least one elementary cell (100), said elementary cell (100) comprising successively at least one planar anode current collector substrate (10), at least one anode layer (20), at least one layer of an electrolyte material (30) or of a separator impregnated with an electrolyte (31), at least one cathode layer (50), and at least one planar cathode current collector substrate (40),

said battery (1000) comprising longitudinal edges (1011, 1012), a first lateral edge (1001) comprising at least one anode connection area (1002) and a second lateral edge (1005) comprising at least one cathode connection area (1006), said anode (1002) and cathode (1006) connection areas being preferably laterally opposite,

characterized in that each elementary cell (100) comprises a primary body (111), a secondary body (112) and a tertiary body (113), said secondary body and said tertiary body being arranged on either side of said primary body, with the understanding that each one of the primary (111), secondary (112) and tertiary (113) bodies comprises successively at least one planar anode current collector substrate (10), at least one anode layer (20), at least one layer of an electrolyte material (30) or of a separator impregnated with an electrolyte (31), at least one cathode layer (50), and at least one planar cathode current collector substrate (40),

said secondary body (112) being separated from the primary body (111) by a notch (120) free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and anode current collector substrate material,

with the understanding that said notch extends from a longitudinal edge (1011) to the opposite longitudinal edge of the battery (1012) in a direction perpendicular to the main plane of the battery, and

5 said tertiary body (113) being separated from the primary body (111) by a recess (130) free from any anode, electrolyte, separator impregnated with an electrolyte, cathode and cathode current collector substrate material, with the understanding that said recess (130) extends from
10 a longitudinal edge (1011) to the opposite longitudinal edge of the battery (1012) in a direction perpendicular to the main plane of the battery.

2. Battery (1000) according to claim 1, comprising a
15 plurality of elementary cells, characterized in that all the notches of each one of the elementary cells are superimposed, in a direction perpendicular to the main plane of the battery, in such a way that each planar cathode current collector substrate collects the cathode
20 current of the elementary cell through the cathode connection area, and that all the recesses of each one of the elementary cells are superimposed, in a direction perpendicular to the main plane of the battery, in such a way that each planar anode current collector substrate
25 collects the anode current of the elementary cell through the anode connection area.

3. Battery according to claim 1 or 2, characterized in that it comprises an encapsulation system entirely
30 covering four of the six faces of said battery, the two remaining faces comprising an anode connection area and a cathode connection area.

4. Battery according to the preceding claim, characterized in that the encapsulation system comprises:

- at least one first cover layer, preferably selected from parylene, parylene F, polyimide, epoxy resins, silicone, polyamide, sol-gel silica, organic silica and/or a mixture thereof, deposited on the battery,
- at least one second cover layer comprised of an electrically-insulating material, deposited by atomic layer deposition on said at least first cover layer, with the understanding that this sequence of at least one first cover layer and of at least one second cover layer can be repeated z times with $z \geq 1$.

5. Battery according to any preceding claim, characterized in that the anode connection area and the cathode connection area are covered by terminations.

6. Battery according to the preceding claim, characterized in that the terminations comprise:

- a first layer of a material loaded with graphite, preferably with an epoxy resin base loaded with graphite disposed on at least the cathode connection area and/or at least the anode connection area,
- a second dense layer of metal copper disposed on the first layer of the termination system,
- optionally, a third layer with a tin-tin zinc alloy base, disposed on the second layer,
- optionally, a fourth layer with a tin base or with a base of a silver, palladium and copper alloy, disposed on the third layer of the termination system.

7. Battery according to any preceding claim, characterized in that the width of said notch is comprised between 0.01 mm and 0.5 mm.

5 8. Battery according to any preceding claim, characterized in that the width of said recess is comprised between 0.01 mm and 0.5 mm.

9. Battery according to any preceding claim, characterized
10 in that the width of the secondary bodies is comprised between 0.5 mm and 20 mm.

10. Battery according to any preceding claim, characterized in that it is a lithium-ion battery.

15

11. Method for manufacturing a battery (1000), said battery comprising at least one elementary cell (100), said elementary cell (100) comprising successively at least one planar anode current collector substrate (10), at least
20 one anode layer (20), at least one layer of an electrolyte material (30) or of a separator impregnated with an electrolyte (31), at least one cathode layer (50), and at least one planar cathode current collector substrate (40), said method of manufacturing comprising:

25 (a) the providing of at least one foil of planar anode current collector substrate (10) covered with an anode layer (20), and optionally covered with a layer of an electrolyte material (30) or of a separator impregnated with an electrolyte (31), called hereinafter anode foil
30 (2), said anode foil comprising at least one anode slot (80), said anode slot (80) comprising two main vertical anode and parallel cavities (82), which are connected in

their upper portion by a horizontal anode channel (84), substantially perpendicular to the two main anode vertical cavities (82), these main vertical anode cavities being intended for delimiting the longitudinal edges of the battery,

(b) the providing of at least one foil of planar cathode current collector substrate (40) covered with a cathode layer (50), and optionally covered with a layer of an electrolyte material (30) or of a separator impregnated with an electrolyte (31), called hereinafter cathode foil (5), said cathode foil comprising at least one cathode slot (70), said cathode slot comprising two main vertical cathode and parallel cavities (72), which are connected in their upper portion by a horizontal cathode channel (74), substantially perpendicular to the two main vertical cathode cavities (72), these main vertical cathode cavities being intended for delimiting the longitudinal edges of the battery,

(c) the carrying out of a first and of a second notches, in the vicinity of each anode (80), respectively cathode (70), slot of at least the foil supplied in step a), respectively in step b), in such a way as to form anode trenches (86, 88), respectively cathode trenches (76, 78), in a direction perpendicular to the main plane of the battery and in a direction parallel to the horizontal anode channel (84), of the anode slot (80), respectively to the horizontal cathode channel (74) of the cathode slot (70), with the understanding that

o the first and second notches are made on either side of the anode (2), respectively cathode (5) slot,

o the second notch is made in the extension of the first notch, and

o the anode trenches (86, 88), respectively the cathode trenches (76, 78), obtained from the first and second notches are free from any electrolyte material or separator impregnated with an electrolyte and from any anode material, respectively are free from any electrolyte material or separator impregnated with an electrolyte and from any cathode material, and

o said anode trenches (86, 88), respectively the cathode trenches (76, 78) extend between the opposite longitudinal edges (1011, 1012) of the battery in a direction perpendicular to the main plane of the battery in such a way as to connect the two main vertical anode and parallel cavities of each anode slot (80), respectively to connect the two main vertical cathode and parallel cavities of each cathode slot (70), the foil obtained after the carrying out of these notches being called hereinafter notched anode foil (2e), respectively notched cathode foil (5e),

(d) the carrying out of an alternating stack (1) of at least one notched anode foil (2e) and of at least one notched cathode foil (5e), in such a way as to obtain successively at least one planar anode current collector substrate (10), at least one anode layer (20), at least one layer of an electrolyte material (30) or of a separator impregnated with an electrolyte (31), at least one cathode layer (50), and at least one planar cathode current collector substrate (40); in such way that, for each anode slot (80) of at least one notched anode foil (2e), respectively for each cathode slot (70) of at least one notched cathode foil (5e), the anode trenches (86, 88) of at least the notched anode foil, respectively the cathode trenches (76, 78), of at least the notched cathode foil

(5e), are disposed in the extension of the horizontal cathode channel (74) of the cathode slot (70) of the adjacent notched cathode foil (e), respectively of the horizontal anode channel (84) of the anode slot (80), of the adjacent notched anode foil (2e) in a direction perpendicular to the main plane of the battery,

(e) the carrying out of a heat treatment and/or of a mechanical compression of the stack of alternating foils obtained in step d), in such a way as to form a consolidated stack,

(f) the carrying out of two cuts (Dn, D'n) extending at least partially inside said anode (80), respectively cathode (70) slot, according to a plane parallel to the horizontal anode (84), respectively cathode (74) channel, the first cut extending between the horizontal anode channel (84) of the anode slot (80) and the end facing the longitudinal edges, while the second cut extends between the horizontal cathode channel (74) of the cathode slot (70) and the end facing the longitudinal edges, in such a way as to form a cut stack exposing at least the anode and cathode connection areas.

12. Method according to claim 11, characterized in that after step (e), a step (g) of encapsulating the consolidated stack is carried out, by depositing:

- at least one first cover layer, preferably selected from parylene, parylene F, polyimide, epoxy resins, silicone, polyamide, sol-gel silica, organic silica and/or a mixture thereof, on the battery, and then
- at least one second cover layer comprised of an electrically-insulating material, deposited by atomic layer deposition on said at least first cover layer,

with the understanding that the sequence of at least one first cover layer and of at least one second cover layer can be repeated z times with $z \geq 1$.

5 13. Method according to any of claims 11 or 12, characterized in that after step (f), the terminations of the battery are carried out by depositing successively on at least the anode and cathode connection areas:

- a first layer of a material loaded with graphite,
- 10 preferably with an epoxy resin base loaded with graphite,
- a second dense layer of metal copper disposed on the first layer of the termination system, and
- optionally, a third layer with a tin-tin zinc alloy base, disposed on the second layer of the termination system,
- 15 - optionally, a fourth layer with a tin base or with a base of a silver, palladium and copper alloy, disposed on the third layer of the termination system.

14. Method according to any of claims 11 to 13, characterized in that the two notches made in step (d) forming trenches (76, 78, 86, 88) are carried out via laser ablation.

15. Method according to any of claims 10 to 14, characterized in that each cut is carried out via laser.

16. Method according to any of claims 11 to 15, characterized in that each elementary cell defines on a first face, a continuity area of the planar anode current collector substrate and an emerging notch (120), and on the opposite face, a continuity area of the planar cathode current collector substrate and an emerging recess (130).

17. Method according to any of claims 11 to 16,
characterized in that the continuity area of the planar
anode current collector substrate is located facing the
5 notch (120), and the continuity area of the planar cathode
current collector substrate is located facing the recess
(130) in a direction perpendicular to the plane of the
battery.

- 10 18. Method according to any of claims 11 to 17,
characterized in that:
- o the planar anode current collector substrate is the anode
current collector substrate of two adjacent elementary
cells, and in that
 - 15 o the planar cathode current collector substrate is the
cathode current collector substrate of two adjacent
elementary cells.