

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
20 November 2003 (20.11.2003)

PCT

(10) International Publication Number  
WO 03/096441 A2

- (51) International Patent Classification<sup>7</sup>: **H01M**
- (21) International Application Number: PCT/IB03/02145
- (22) International Filing Date: 8 May 2003 (08.05.2003)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
60/378,848 8 May 2002 (08.05.2002) US
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(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

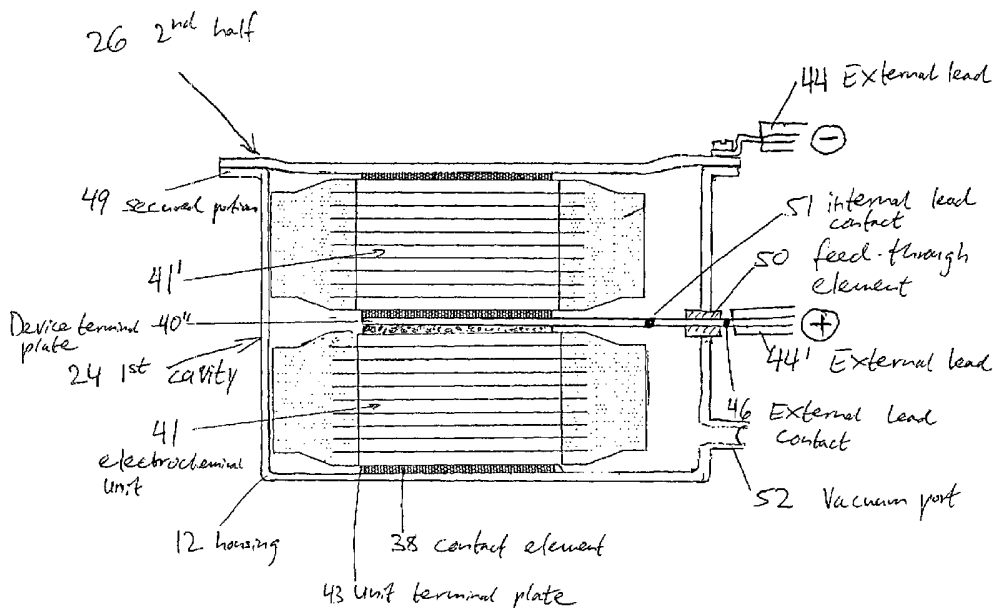
(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF,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

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**Published:**  
— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: PACKAGING DEVICE FOR AN ELECTROCHEMICAL DEVICE AND METHOD FOR MAKING THE SAME



(57) Abstract: The present invention relates to a packaging device for use in association with an electrochemical device. The packaging device includes a housing having two halves, a top surface, a bottom surface and an open region adjacent to the top surface for enabling placement, and, in turn, encapsulation of at least a portion of an electrochemical device within the housing. The packaging device also includes means for is encased within the housing; and means for securing the housing in a folded orientation.

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**TITLE OF THE INVENTION****PACKAGING DEVICE FOR AN ELECTROCHEMICAL DEVICE AND METHOD FOR MAKING THE SAME****BACKGROUND OF THE INVENTION**

## 5 1. Field of the Invention

The invention relates in general to a packaging device for an electrochemical device, and more particularly, to a packaging device for electrochemical devices such as secondary batteries and super capacitors. Throughout this disclosure "electrochemical device" means a combination of at least one individually packaged unit providing electrochemically stored energy, preferably  
10 with the at least two unit terminal plates of the at least one unit being parallel to each other. A "unit" means at least one or a combination of cells. This invention however deals not with packaging single cells, but with packaging an electrochemical device consisting of at least two cells.

## 2. Background Art

15 Electrochemical devices that are based on the Li-ion technology are well known in the art.

Their use in the market place is limited to either cylindrical cells or to prismatic ones with a footprint of well below 100 cm<sup>2</sup>, particularly if high power density is required. One of the main restrictions for larger footprint devices is adequate stack compression, for instance exerted as mechanical pressure, which is necessary for good high power performance and for long cycle life.  
20 Sufficient stack compression can be achieved easily in cylindrical cells through tight electrode winding and a tight fit of the electrode pack into the cylindrical battery case. Adequate stack compression is also achieved relatively easily in the case of rigid steel cases, particularly if the maximum device footprint is well below 100 cm<sup>2</sup>. In order to decrease the weight of portable electrochemical devices, the thickness of battery cases has been reduced and steel has been  
25 replaced by aluminum or by a thin laminate of aluminum foil and suitable polymer layers. While

such batteries are much lighter, their casing does not offer the rigidity for optimum stack compression and cycle life suffers unless special measures are taken to keep the electrodes tightly together without a rigid battery case. Such measures can involve lamination processes and the use of gel or polymer-based electrolytes. Such gel or polymer-based electrolyte systems are, however, of lower electrolytic conductivity than systems based on liquid electrolyte solutions, and therefore do not offer the same high power performance as electrochemical devices based on liquid electrolyte solutions.

Conventional methods of packaging electrochemical devices are also relatively expensive, and each application requires specific, relatively complicated configurations for the outer casing as well as for the internal components to provide electrical contact between individual cells connected in series and/or in parallel.

Accordingly it is an object of the present invention to provide adequate packaging, which is light-weight, low cost and still exerts sufficient stack pressure, prevents atmospheric ingress and/or electrolyte egress and allows for simple and low cost series and/or parallel connections of single cells or multi-cell batteries.

The problem of sufficient stack compression is not limited to Li-ion batteries. It is known that cycle and calendar life of lead-acid batteries can be improved significantly by adequate stack pressure. This invention is not limited to any particular battery technology.

**SUMMARY OF THE INVENTION**

To address the above-discussed deficiencies of the prior art, it is the primary object of this invention to provide a packaging device for electrochemical devices that is 1) hermetically sealed to minimize atmospheric ingress and/or electrolyte egress; 2) provides a means for current collection  
5 from at least two cells; 3) exerts mechanical pressure up to one atmosphere; 4) provides additional safety by electrically insulating the terminal plates; 5) may provide additional safety by comprising a safety valve; and 6) may provide additional mechanical protection for the electrochemical device. Specifically, the present invention relates to a packaging device for use in association with an electrochemical device as well as a method for making the packaging device. The packaging device  
10 includes a housing having a top segment, a bottom segment and, optionally, one or more cavities formed on at least the top or the bottom segments of the housing. The one or more cavities have an open region for enabling placement, and, in turn, encapsulation of at least a portion of an electrochemical device within the cavity. The top and the bottom segments of the packaging device may consist of one piece only and be separated by a transverse axis. The packaging device may  
15 further include means for folding the housing along the transverse axis, wherein, upon folding, an electrochemical device is encased within the housing. The packaging device also includes means for securing the electrochemical device inside the housing. In addition, the present invention also contemplates a method for fabricating a packaging device as well as a packaging device and an associated electrochemical device.

20 The foregoing has outlined rather broadly the features and technical advantages of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features and advantages of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art should appreciate that they may readily use the conception and the specific embodiment disclosed as a basis

for modifying or designing other structures for carrying out the same purposes of the present invention. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIGURE 1 illustrates an exemplary, side cross-sectional view of a packaging device for use in association with an electrochemical device according to the principles of the present invention;

FIGURE 2 illustrates an exemplary, top plan view of a packaging device for use in association  
5 with an electrochemical device according to the principles of the present invention;

FIGURE 3 illustrates an exemplary, side cross-sectional view of a packaging device prior to folding the housing along the transverse axis and after the electrochemical device is placed in the housing;

FIGURE 4 illustrates an exemplary, side cross-sectional view of a packaging device after  
10 folding the housing along the transverse axis and sealing the housing; and

FIGURE 5 illustrates an exemplary, side cross-sectional view of another packaging device, according to the principles of the present invention, with two electrochemical devices connected in parallel.

FIGURE 6 is a graph displaying the capacity output as a function of cycle number for an  
15 electrochemical device packaged according to the present invention (A) and for two comparative examples (B) and (C).

**BEST MODE FOR PRACTICING THE INVENTION**

While this invention is susceptible of embodiment in many different forms, there is shown herein the drawings and will be described in detail only a limited number of specific embodiments with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiments described and illustrated.

Referring initially to FIGURE 1, illustrated is an exemplary, side cross-sectional view of the packaging device 10 for use in association with an electrochemical device according to the principles of the present invention. The packaging device 10 includes a housing 12 having an edge surface 16 and a center surface 18. FIGURE 1 shows as an example an embodiment having a transverse axis 14, separating one side 20 of the packaging device 10 from another side 22 of the packaging device 10. The center surface 18 may include one or more cavities 24 formed on at least one side 20 of the transverse axis 14. As shown in FIGURE 1, a second cavity 26 may be located on the second side 22 of the transverse axis 14. The one or more cavities 24 have an open region 28 adjacent to the edge surface 16 for enabling placement, and, in turn, encapsulation of at least a portion of an electrochemical device within the cavity.

In this same embodiment, the packaging device 10 includes means for folding the housing 12 (not shown) along the transverse axis 14, wherein, upon folding, an electrochemical device is encased within the housing 12. The packaging device 10 further includes means for mechanically securing the electrochemical device within the housing 12 (not shown). In a preferred embodiment, the housing 12 includes one or more lead openings 30 allowing external leads 44 extending from the electrochemical device to be connected to an external device. The present invention is particularly useful, but not limited to, encasing electrochemical devices that comprise bipolar electrode plates, that are joined in series, and end in terminal unit plates of the opposite

polarity in a prismatic monolithic unit. The present invention is also useful in packaging electrochemical devices, where 2 or another number of prismatic monolithic units are electrically connected in series and/or in parallel. In such a configuration, one of the lead openings may preferably be through one of the side surfaces of the housing 12, rather than through the top or  
5 bottom surface of the housing 12. However, those skilled in the art should understand that the present invention might be used to encase other types of electrochemical devices, independent of the cell chemistry employed.

In one embodiment, the housing 12 may be fabricated of heat-sealable laminate material. However, those skilled in the art understand that any material or any combination of materials  
10 may be used to fabricate the housing 12 so long as the material or the combination of materials provide electrical insulation between opposite polarities of the electrochemical device and does not become damaged upon exposure to the specific components/materials that is in physical contact with the packaging device 10. Examples of such acceptable materials include plastic, metal and metal alloys, preferably in sheet, film or foil form. Metal sheet and foil has the  
15 advantage of optimum barrier properties, while polymeric materials have the advantage of optimum electrical insulation. Therefore, a combination of metal and polymeric film may be of particular advantage. In a preferred embodiment, fabrication of the housing 12 may be accomplished through a deep-drawing process. However, other conventional manufacturing processes may be used to fabricate the housing 12. Alternatively, the at least one cavity can be  
20 created in situ, starting from one or two flat segments, during the subsequent encapsulation process.

Referring now to FIGURE 2, with continuing reference to FIGURE 1, illustrated is an exemplary, top plan view of the packaging device 10. The open regions 28 define the first and second cavities 24, 26 to encapsulate the electrochemical device. As illustrated in FIGURE 2,

both of the first and second cavities 24, 26 have a periphery on the edge surface 16 corresponding to the periphery of each other. In one aspect of this embodiment, the first cavity periphery 32 and the second cavity periphery 34 is of substantially equal distance from the transverse axis 14 so as to result in a substantially symmetric orientation of the first cavity periphery 32 and the second cavity periphery 34 relative to the transverse axis 14. In one embodiment, the first and second cavities 24, 26 have corresponding geometries. However, an infinite number of configurations and depths are likewise contemplated, depending on the desired application and positioning within a particular device.

Referring now to FIGURE 3, illustrated is a side cross-sectional view of the housing 12 prior to folding the housing 12 on the transverse axis 14 and after the electrochemical device 36 is placed in the housing 12. The electrochemical device 36 consists of at least 2 electrochemical cells 42, preferably with the unit terminal plates 43 being parallel to each other. FIGURE 3 shows as an example an electrochemical device consisting of two units 41 stacked on top of each other. Each unit 41 consists of at least one single cell 42 or a combination of cells. As illustrated in FIGURE 3, the electrochemical device 36 is placed in the first cavity 24 on one side 20 of the transverse axis 14. In one embodiment, particularly if the housing comprises insulating materials such as polymers, the packaging device 10 comprises at least one device terminal plate 40. The at least one device terminal plate 40 consists of an electrically conducting material such as aluminum, copper, any alloy or any other electrically conducting material in bulk or based on particles such as powder, flakes, fibers or the like. In a preferred embodiment, the at least one device terminal plate 40 is integral part of the housing, by hermetically attaching the at least one device terminal plate 40 to the center surface 18 of the at least one cavity 24. Attachment can be achieved through any welding or gluing technique known to those skilled in the art. If the housing consists of a thin laminate of metal and polymer foil or film, the attachment may be

achieved preferably through a thermo-bonding process. Alternatively, the metal-polymer film laminate can be thermally attached directly to at least one of the unit terminal plates 43, while leaving a suitable opening for the electrical leads. The packaging device may further comprise contact elements 38, providing a low resistance contact as well as elasticity to maintain reliable electrical contact between the at least one device terminal plate 40 and the at least one unit terminal plate 43. The contact element may consist of a light-weight plate or mat with a surface providing a large number of contact points in a uniform way over the whole surface. Preferred contact elements consist of a metal foam or felt mat or of a light-weight metal mesh.

The electrochemical device 36 may consist of units 41 of stackable cells 42. Inasmuch as each cell 42 of the electrochemical device 36 has a known capacity and voltage, any overall device voltage and capacity can be created by combining stackable cells 42 in series and/or in parallel. Indeed, the only limitation on stackability and shape of the cells 42 would be as a result of the particular dimensional configuration of the packaging device 10. If the electrochemical device includes at least two units 41, 41', at least one additional contact element 38" may be placed between the two facing terminal plates of the units. Alternatively, the ends of optional cell leads (not shown) may be folded into the area of the lead openings 30 of the housing 12.

The stackable cells 42 may be constructed with electrolytes such as a polymer or liquid electrolyte (not shown). Stackable cells 42 include positive and negative electrodes (not shown). A combination of at least two stackable cells 42 makes up an electrochemical device comprising at least two unit end plates 43, at least one of positive and one of negative polarity. As explained, the particular shape of each stackable cell 42 is dependent on the particular configuration of the packaging device 10 to be used.

Turning now to FIGURE 4, illustrated is a side cross-sectional view of the packaging device 10 after folding the housing 12 on the transverse axis 14 and sealing the housing 12. In a

particularly advantageous embodiment, the transverse axis 14 is fabricated such as to facilitate folding along the transverse axis 14. External leads 44 may be attached directly to the housing 10 and/or to the at least one of the device terminal plates 40 and or to at least one of the unit terminal plates 43, thereby creating external lead connections 46. As will be explained and

5 illustrated in FIGURE 4, the housing 12 and/or at least one of the device terminal plates 40 is in electrically conducting contact with the electrochemical device 36, within the packaging device 10. The external lead connections 46 for electrical contact may be achieved through any welding, soldering or mechanical attachment process, such as bolting or riveting at any suitable stage of the assembly process. The lead opening 30 may be of any size or shape. It can comprise a

10 significant portion of at least one of the unit terminal plates 43 or at least one of the terminal plates 44. FIGURES 3 and 4 show as an example, how a hermetically sealed lead opening 30 can be created within the housing where the external leads 44, 44' are attached to the device terminal plates 40,40' via the external lead connections 46, 46'. The external lead connections 46 may be protected by insulation 48, which may consist of an insulating adhesive or hotmelt. The present

15 invention also contemplates that external lead connections 46 of the fabricated electrochemical device 36 are configured at any desired location or orientation, depending on the specific application of use. Indeed, the positioning of the external lead connections 46 may be altered externally of the packaging device 10 as well as within the packaging device 10. Furthermore, it is contemplated that the lead connections be constructed in such a manner so as to result in an in-

20 line fuse. Alternatively, at least one of the contact elements 38 or at least one of the device terminal plates 40 may comprise a thermofuse such as a PTC element so as to result in an additional safety element in case of excessive device temperature.

After proper positioning of the electrochemical device 36 in the first cavity 24, the second cavity 26 is then folded on the transverse axis 14 or otherwise positioned such that the center

surface 18 of the second cavity 26 comes into mechanical contact with at least a fraction of the top unit terminal plate 43' of the electrochemical device, either directly or via the device top terminal plate 40' and/or the top contact element 38'. In this process the two edge surfaces 16, 16' of the two segments 20, 22 of the housing 12 may also come into mechanical contact with each other around their respective perimeters. Simultaneous mechanical contact between the center surfaces 18 as well as the edge surfaces 16 after folding would require very tight mechanical tolerances, which would result in high cost of the entire device. As will be explained hereinafter, it is not necessary, at least in the initial stage of the assembly process, that the two sets of aforementioned surfaces are in immediate mechanical contact. In a preferred embodiment, the housing provides sufficient flexibility to be processed to a configuration which provides overall mechanical contact by applying mechanical pressure during the subsequent processing steps and/or by applying a partial vacuum to the interior of the housing.

After one segment 20 of the housing 12 and the other segment 22 of the housing 12 are positioned on top of each other, the two segments of the housing 12 are secured together through any number of ways including, but not limited to, welding, crimping, bolting, adhesive, snap fit, etc, as well as being integrally attached as part of the housing 12 itself. A key feature of this invention is the establishment of at least a partial vacuum inside the housing 12 during or after the process step which secures the two segments 20, 22. In a preferred embodiment the applied vacuum is at least -0.8 bar or better. If the vacuum inside the housing 12, is -0.8 bar, a mechanical force of 0.8 kg/cm<sup>2</sup> is exerted over the entire surface of the unit terminal plates 43 of the electrochemical device, as long as the device terminal plates 40 and contact elements 38 are dimensioned properly and as long as the material of construction of the housing 12 is flexible enough to be tightly pressed towards the terminal plates 43 by the pressure differential between the inside and the outside of the housing 12. Additionally, securement means can also be

accomplished by use of a secondary casing or by wrapping an electrically insulating shrink tube or a label around the packaging device 10. Use of a secondary casing provides the ability to manufacture batteries with only a few different type of “primary case” sizes and dimensions toward facilitating standardization thereof. Accordingly, such standardized primary cased cells  
5 can then be used in “secondary casings” that have had their configurations altered to correspond to the specific battery compartment/location within the particular device of choice.

In one embodiment, the securement means comprises a means for thermally welding the two edge surfaces 16, 16' of the housing 12 around its perimeter. In a preferred embodiment this process is undertaken in a vacuum chamber, where a vacuum of -0.8 bar or better is applied  
10 before heat-sealing the two edge surfaces 16, 16' together. Such a process can be readily achieved at low cost in standard equipment available for food packaging. As schematically shown in Figure 4, the heat-welded or otherwise secured portions 49 of the housing may fully or partially be folded back in order to decrease the space required for the volume and thus increase its energy and power density. In another preferred embodiment, the securement means includes  
15 means for sealing the housing 12 so as to preclude ingress or egress of moisture in and out of the one or more cavities 24. The sealing means advantageously results in a hermetic seal to minimize moisture ingress and/or electrolyte egress. In a particularly advantageous embodiment for Li-ion based electrochemical devices, the packaging device 10 includes means for adsorbing or absorbing moisture that may inadvertently exist in the housing 12 or by absorbing any trace  
20 amounts of gas which may be formed inside any of the cells 42 during normal mode of use or during abuse conditions. For example, the means for absorbing moisture may be a moisture barrier that includes moisture-trapping agents such as zeolite or silica powder or beads. Other agents may also be used to adsorb and absorb moisture or any other volatile components such as carbon dioxide or hydrocarbons within the packaging device 10. Alternatively catalytic agents

may be used to recombine gaseous compounds formed by the cells 42, such as hydrogen plus oxygen being converted back to water. Such an arrangement may be of particular use for aqueous batteries such as lead-acid, nickel-cadmium or nickel-metal hydride.

In another embodiment schematically shown in FIGURE 5, the first cavity 24 may consist  
5 of a deep-drawn thin metal foil dish of preferably less than 1mm thickness and the second  
“cavity” 26 of a flat metal foil of preferably less than 1mm thickness. FIGURE 5 shows as an  
example a packaging device 10 comprising two electrochemical units 41, 41', which are  
connected in parallel within the housing 12. In this specific embodiment, the entire metallic  
housing corresponds to the negative pole of the electrochemical storage device. Thus one of the  
10 external leads 44 may be directly welded, bolted, riveted or otherwise secured to the housing.  
The second external lead 44' may be connected to an insulated, hermetically sealed feed-through  
element 50 which is connected to a central device terminal plate 40" via an internal lead contact  
51. The two metallic segments 24, 26 of the housing 10 of this particular embodiment may be  
welded together by a TIG welding process. Vacuum may then be applied through a vacuum port  
15 52. In a preferred embodiment, vacuum port 52 can act in addition as a safety valve for the case  
of excessive internal pressure. The housing 12 can be electrically insulated by encapsulating the  
housing in a shrink wrap, a secondary insulating casing or any other encapsulant known to those  
skilled in the art.

Thus, by fabricating the packaging device 10 according to the features and steps of the  
20 present invention, the packaging device 10 for electrochemical devices such as secondary  
batteries and supercapacitors is advantageously 1) hermetically sealed to minimize atmospheric  
ingress and/or electrolyte egress; 2) provides a means for current collection from at least two  
cells; 3) exerts mechanical pressure up to one atmosphere; 4) provides additional safety by  
electrically insulating the unit terminal plates 43 and/or device terminal plates 40; 5) may provide

additional safety by comprising a safety valve which, at the same time, may act as the vacuum port; and 6) may provide additional mechanical protection for the electrochemical device.

The principles of the invention described above, and specifically claimed herein, were used to assemble a battery device consistent with the above disclosure. However, the present disclosure is not intended to limit the invention to any of the particularly disclosed structures, except insofar as the appended claims are so limited.

In order to construct a device according to the present invention and to compare with the state of the art, two identical bipolar electrochemical monolithic units were prepared. Each of the electrochemical units consisted of one anode end plate, a bipolar plate and a cathode endplate.

10 The anodes consisted of a dried 100x100 mm<sup>2</sup> film coated from a slurry of Li<sub>4</sub>Ti<sub>5</sub>O<sub>12</sub>, carbon black and PVDF in N-methyl-2-pyrrolidinone onto a 120x120 mm<sup>2</sup> sheet of 75 μm thick aluminum foil, which was previously primed with a thin carbonaceous film. The cathodes consisted of a dried 100x100 mm<sup>2</sup> film coated from a slurry of Li<sub>1.05</sub>Cr<sub>0.10</sub>Mn<sub>1.9</sub>O<sub>4</sub>, carbon black and PVDF in N-methyl-2-pyrrolidinone onto a 120x120 mm<sup>2</sup> sheet of 75 μm thick aluminum foil,

15 which was previously primed with a thin carbonaceous film. Bipolar batteries were obtained by stacking the anode end plate, the bipolar plate and the cathode end plate – each separated by a layer of polyolefinic microporous separator - on top of each other and by heat-sealing almost all around their entire perimeter using Surlyn® 1652 film-based frames. 2.4 ml of electrolyte consisting of 1M LiPF<sub>6</sub> in a 1:1 mixture of ethylene carbonate and diethyl carbonate was then

20 injected into each of the cells through the non-sealed portion of the perimeter of the device. The whole assembly was then evacuated to close to -1.0 bar, heat-sealed under vacuum, to close the remaining unsealed portions of the perimeter, and then allowed to equilibrate back to ambient pressure. This procedure resulted in two identical 2-cell bipolar monolithic units of 5 V nominal voltage.

**Example 1**

Two 2mm thick aluminum plates of 146x146 mm<sup>2</sup> size were each fitted with a 4.5 mm diameter aluminum rod of 10mm length, brazed perpendicularly to one aluminum face, for the purpose of electrical contact. A circular hole of 14mm diameter was punched into each of two

5 200x200 mm<sup>2</sup> size sheets of packaging film based on a PET/aluminum/polyolefin laminate obtained from Sumitomo Electric Industries, Ltd. The hole was positioned to properly fit the aforementioned aluminum contact rod through its center. The two pieces of packaging film were heat-welded each to one face of the aforementioned 146x146 mm<sup>2</sup> size aluminum plates using a hydraulic press with heated platens. One platen was modified to suitably accommodate the aforementioned aluminum

10 contact rod without exerting any pressure on said rod. The first of the aforementioned two identical 2-cell bipolar monolithic units of 5 V nominal voltage was placed between two pieces of 1 mm thick 100x100 mm<sup>2</sup> nickel foam mat with 60 ppi pore size. This assembly was then placed between the aforementioned 146x146 mm<sup>2</sup> size aluminum plates with each aluminum face contacting the outward-facing sides of the nickel foam mat. Three edges of the packaging laminate were thermally sealed

15 together over the entire length of the packaging film and over a width of close to 10 mm to result in an electrochemical device inside a housing which was still open on one side. This assembly was then evacuated to close to -1.0 bar, heat-sealed under vacuum, to close the remaining unsealed edge of the housing, and was then allowed to equilibrate back to ambient pressure. The four sealed edge portions were when folded back to result in a hermetically packaged device "A" of less than

20 150x150 mm<sup>2</sup> footprint. Device "A" was connected to a commercial battery-testing unit, using the aforementioned aluminum contact rods as electrical contacts. Curve A in FIGURE 6 shows that the capacity output over 60 charge/discharge cycles, performed at the 1C charge and discharge rate, is relatively stable, due to the mechanical compression of close to 1 kg/cm<sup>2</sup> exerted by the pressure differential between inside and outside the housing. The housing effectively minimizes ingress and

gress of moisture and any other volatile components, effectively collects the current from the two cells of the device, exerts mechanical pressure onto the electrode plates, and offers effective insulation of the unit terminal plates and is therefore in the spirit of this invention.

5

### Example 2

The second of the two identical 2-cell bipolar monolithic units of 5 V nominal voltage was placed between two pieces of 1mm thick 100x100 mm<sup>2</sup> nickel foam mat with 60 ppi pore size. This assembly was then placed between two terminal plates of 1mm aluminum of 100x100 mm<sup>2</sup> size, with a 10 mm wide tab being integral part of each sheet, and then between two insulating plates of 1mm  
10 FORMICA® sheet of 110x110 mm<sup>2</sup> size. This assembly was then placed into a spring-loaded mechanical compression device based on 200x200mm<sup>2</sup> size aluminum platens of 20mm thickness. The mechanical device was tightened, using four bolts, four spring loads and four M8-threaded bars to exert a total force of 981 N over an area of 100x100 mm<sup>2</sup> size, i.e. a pressure of 1 kg/cm<sup>2</sup>. The resulting electrochemical device "B" has the disadvantage of being very heavy and relatively large  
15 and is therefore not in the spirit of the present invention. This example is included for comparative purposes only. Electrochemical device "B" was connected to a commercial battery-testing unit, using the aforementioned tabs of the two terminal plates as electrical contacts. Curve B in FIGURE 6 shows that capacity output over 60 charge/discharge cycles performed at the 1C rate is very similar to curve A obtained for the much lighter and more compact device "A" according to the present  
20 invention.

**Example 3**

A third electrochemical device "C" was prepared based on the same type of electrodes of 100x100 mm<sup>2</sup> size coated onto 75 μm thick aluminum foil. The only difference consisted in the size of the aluminum foil unit terminal plates which were cut to 120x160 mm<sup>2</sup>, in order to create electrical contact areas (= tabs) to the unit terminal plates outside the sealed area, while taking particular care not to create any short circuit between the tabs. The bipolar battery of this example was obtained by stacking the anode end plate (120x160 mm<sup>2</sup>), the bipolar plate (120x120 mm<sup>2</sup>) and the cathode end plate (120x160 mm<sup>2</sup>) - each separated by a layer of polyolefinic microporous separator - on top of each other and by heat-sealing almost all around their entire perimeter using Surlyn® 1652 film-based frames. 2.4 ml of electrolyte consisting of 1M LiPF<sub>6</sub> in a 1:1 mixture of ethylene carbonate and diethyl carbonate was then injected into each of the cells through the non-sealed portion of the perimeter of the device. The whole assembly was then evacuated to close to -1.0 bar, heat-sealed under vacuum, to close the remaining unsealed portions of the perimeter, and then allowed to equilibrate back to ambient pressure. This procedure resulted in a 2-cell bipolar monolithic unit "C" of 5 V nominal voltage. No additional mechanical force was exerted to electrochemical unit "C", which was connected to a commercial battery-testing unit, using the aforementioned tabs as electrical contacts. Curve C in FIGURE 6 shows that the capacity output over 60 charge/discharge cycles performed at the 1C rate fades considerably faster than for the device according to the present invention shown by curve B in FIGURE 6. Example 3 therefore documents the importance of properly adjusted mechanical compression for the specific devices documented in above Examples.

The foregoing description, drawings and examples merely explain and illustrate the invention and the invention is not limited thereto except insofar as the appended claims are so limited, as those skilled in the art that have the disclosure before them will be able to make modifications without departing from the scope of the invention.

**CLAIMS**

What we claim is:

1. A packaging device for use in association with a device requiring mechanical pressure up to  
5 about one atmosphere, comprising:
  - a housing having at least two segments, an edge surface, and a region adjacent to the edge surface for enabling placement, and, in turn, encapsulation of at least a portion of a device requiring mechanical pressure within the housing;
  - means for securing the at least two segments ; and
  - 10 - means for imparting mechanical pressure within the housing on the portion of the device requiring mechanical pressure.
  
2. The invention according to Claim 1, additionally comprising means for folding the housing  
15 along a transverse axis located between at least two of the at least two segments.
  
3. The invention according to Claim 2, wherein the folding means comprises a fold region  
along the transverse axis.
  
4. The invention according to Claim 2, wherein the housing comprises a first cavity on one  
20 side of the transverse axis and a second cavity on another side of the transverse axis and both of the first and second cavities having a periphery corresponding to the periphery of each other.

5. The invention according to Claim 4, wherein the periphery of the first and second cavities is of substantially equal distance from the transverse axis of the housing so as to result in a substantially symmetric orientation of the periphery of the first and second cavities relative to the transverse axis.
- 5
6. The invention according to Claim 5, wherein the first and second cavities have corresponding geometries.
7. The invention according to Claim 1, wherein the securing means results in a hermetic seal.
- 10 8. The invention according to Claim 7, wherein the securing means includes means for sealing the housing so as to preclude ingress or egress of moisture in and out of the housing.
9. The invention according to Claim 1, wherein the mechanical pressure imparting means comprises the housing, once hermetically sealed, containing a vacuum.
- 15
10. The invention according to Claim 1, wherein the device comprises an electrochemical device having one or more electrochemical cells, with its terminals being properly insulated.
11. The invention according to Claim 10, wherein the electrical insulation is achieved through an insulating layer throughout the two segments of the housing.
- 20
12. The invention according to Claim 10, wherein the electrical insulation is achieved through at least one electrical insulating feed-through element through the housing wall.

13. The invention according to Claim 10, wherein the housing includes means for attaching at least one terminal plate of the electrochemical device to a surface of the housing.
14. The invention according to Claim 13, wherein the attaching means comprises a bonding material associated with a surface of the housing, wherein such material results in a bond between the at least one terminal plate and a surface of the housing.
15. The invention according to Claim 10, the housing having one or more cavities, wherein the electrochemical device is operatively positioned within the one or more cavities.
16. The invention according to claim 10, wherein the electrochemical device comprises two or more electrochemical cells electrically connected in at least one of series and parallel connections.
17. The invention according to claim 16, wherein the electrochemical cells connected in series are in bipolar configuration.
18. The invention according to Claim 1 further comprising means for adsorbing or absorbing moisture that may inadvertently exist in the housing.
19. The invention according to Claim 18, wherein the adsorbing or absorbing means is a moisture barrier.

20. The invention according to Claim 19, wherein the moisture barrier includes moisture trapping agents such as zeolite, silica powder and beads.
21. The invention according to Claim 1, wherein the housing is fabricated from a sheet of impermeable material.
22. The invention according to Claim 21, wherein the impermeable material is a metal or a metal-polymer combination.
23. The invention according to Claim 1, wherein the housing includes one or more lead openings.
24. The invention according to Claim 23, wherein the at least one lead opening is protected by an electrical insulation.
25. The invention according to Claim 1, wherein a significant part of the housing is electrically insulated.
26. The invention according to Claim 25, wherein the electrical insulation is a layer of insulating film, insulating self-adhesive tape or insulating shrink tubing.
27. The invention according to Claim 1, wherein the housing comprises a safety valve.

28. The invention according to Claim 1, wherein the housing comprises agents for trapping any gaseous products released by the device, such as carbon dioxide, hydrogen, hydrocarbons or oxygenated hydrocarbons.
- 5 29. A packaging device for use in association with an electrochemical device requiring mechanical pressure up to about one atmosphere, comprising:
- a housing having at least two segments, an edge surface, and a region adjacent to the edge surface for enabling placement, and, in turn, encapsulation of at least a portion of an electrochemical device requiring mechanical pressure within the housing;
  - 10 - means for securing the at least two segments ; and
  - means for imparting mechanical pressure within the housing on the portion of the electrochemical device requiring mechanical pressure.
30. The invention according to Claim 29, additionally comprising means for folding the housing along a transverse axis located between at least two of the at least two segments.
- 15 31. The invention according to Claim 30, wherein the folding means comprises a fold region along the transverse axis.
32. The invention according to Claim 30, wherein the housing comprises a first cavity on one  
20 side of the transverse axis and a second cavity on another side of the transverse axis and both of the first and second cavities having a periphery corresponding to the periphery of each other.

33. The invention according to Claim 32, wherein the periphery of the first and second cavities is of substantially equal distance from the transverse axis of the housing so as to result in a substantially symmetric orientation of the periphery of the first and second cavities relative to the transverse axis.
- 5
34. The invention according to Claim 33, wherein the first and second cavities have corresponding geometries.
35. The invention according to Claim 29, wherein the securing means results in a hermetic seal.
- 10
36. The invention according to Claim 35, wherein the securing means includes means for sealing the housing so as to preclude ingress or egress of moisture in and out of the housing.
37. The invention according to Claim 29, wherein the mechanical pressure imparting means  
15 comprises the housing, once hermetically sealed, containing a vacuum.
38. The invention according to Claim 29, wherein the electrochemical device comprises one or more electrochemical cells, with its terminals being properly insulated.
- 20 39. The invention according to Claim 38, wherein the electrical insulation is achieved through an insulating layer throughout the two segments of the housing.
40. The invention according to Claim 38, wherein the electrical insulation is achieved through at least one electrical insulating feed-through element through the housing wall.

41. The invention according to Claim 38, wherein the housing includes means for attaching at least one terminal plate of the electrochemical device to a surface of the housing.
42. The invention according to Claim 41, wherein the attaching means comprises a bonding material associated with a surface of the housing, wherein such material results in a bond between the at least one terminal plate and a surface of the housing.
43. The invention according to Claim 29, the housing having one or more cavities, wherein the electrochemical device is operatively positioned within the one or more cavities.
44. The invention according to claim 29, wherein the electrochemical device comprises two or more electrochemical cells electrically connected in at least one of series and parallel connections.
45. The invention according to claim 44, wherein the electrochemical cells connected in series are in bipolar configuration.
46. The invention according to Claim 29 further comprising means for adsorbing or absorbing moisture that may inadvertently exist in the housing.
47. The invention according to Claim 46, wherein the adsorbing or absorbing means is a moisture barrier.
48. The invention according to Claim 47, wherein the moisture barrier includes moisture trapping agents such as zeolite, silica powder and beads.

49. The invention according to Claim 29, wherein the housing is fabricated from a sheet of impermeable material.
50. The invention according to Claim 49, wherein the impermeable material is a metal or a metal-polymer combination.
51. The invention according to Claim 29, wherein the housing includes one or more lead openings.
52. The invention according to Claim 51, wherein the at least one lead opening is protected by an electrical insulation.
53. The invention according to Claim 29, wherein a significant part of the housing is electrically insulated.
54. The invention according to Claim 53, wherein the electrical insulation is a layer of insulating film, insulating self-adhesive tape or insulating shrink tubing.
55. The invention according to Claim 29, wherein the housing comprises a safety valve.
56. The invention according to Claim 29, wherein the housing comprises agents for trapping any gaseous products released by the device, such as carbon dioxide, hydrogen, hydrocarbons or oxygenated hydrocarbons.

57. A packaging device for use in association with an electrochemical device requiring mechanical pressure up to about one atmosphere, comprising:
- a housing having at least two segments, an edge surface, and a region adjacent to the edge surface for enabling placement, and, in turn, encapsulation of at least a portion of an electrochemical device requiring mechanical pressure within the housing;
  - means for securing the at least two segments ; and
  - means for imparting mechanical pressure within the housing on the portion of the electrochemical device requiring mechanical pressure, the mechanical pressure imparting means comprising the housing containing a vacuum.
58. The invention according to Claim 57, additionally comprising means for folding the housing along a transverse axis located between at least two of the at least two segments.
59. The invention according to Claim 58, wherein the folding means comprises a fold region along the transverse axis.
60. The invention according to Claim 58, wherein the housing comprises a first cavity on one side of the transverse axis and a second cavity on another side of the transverse axis and both of the first and second cavities having a periphery corresponding to the periphery of each other.

61. The invention according to Claim 60, wherein the periphery of the first and second cavities is of substantially equal distance from the transverse axis of the housing so as to result in a substantially symmetric orientation of the periphery of the first and second cavities relative to the transverse axis.
- 5
62. The invention according to Claim 61, wherein the first and second cavities have corresponding geometries.
63. The invention according to Claim 57, wherein the securing means results in a hermetic seal.
- 10
64. The invention according to Claim 63, wherein the securing means includes means for sealing the housing so as to preclude ingress or egress of moisture in and out of the housing.
65. The invention according to Claim 57, wherein the electrochemical device comprises one or more electrochemical cells, with its terminals being properly insulated.
- 15
66. The invention according to Claim 65, wherein the electrical insulation is achieved through an insulating layer throughout the two segments of the housing.
- 20
67. The invention according to Claim 65, wherein the electrical insulation is achieved through at least one electrical insulating feed-through element through the housing wall.
68. The invention according to Claim 65, wherein the housing includes means for attaching at least one terminal plate of the electrochemical device to a surface of the housing.

69. The invention according to Claim 68, wherein the attaching means comprises a bonding material associated with a surface of the housing, wherein such material results in a bond between the at least one terminal plate and a surface of the housing.
- 5 70. The invention according to Claim 57, the housing having one or more cavities, wherein the electrochemical device is operatively positioned within the one or more cavities.
71. The invention according to claim 57, wherein the electrochemical device comprises two or more electrochemical cells electrically connected in at least one of series and parallel connections.
- 10
72. The invention according to claim 71, wherein the electrochemical cells connected in series are in bipolar configuration.
- 15 73. The invention according to Claim 57 further comprising means for adsorbing or absorbing moisture that may inadvertently exist in the housing.
74. The invention according to Claim 73, wherein the adsorbing or absorbing means is a moisture barrier.
- 20
75. The invention according to Claim 74, wherein the moisture barrier includes moisture trapping agents such as zeolite, silica powder and beads.
76. The invention according to Claim 57, wherein the housing is fabricated from a sheet of impermeable material.

77. The invention according to Claim 76, wherein the impermeable material is a metal or a metal-polymer combination.
78. The invention according to Claim 57, wherein the housing includes one or more lead  
5 openings.
79. The invention according to Claim 78, wherein the at least one lead opening is protected by an electrical insulation.
- 10 80. The invention according to Claim 57, wherein a significant part of the housing is electrically insulated.
81. The invention according to Claim 80, wherein the electrical insulation is a layer of insulating film, insulating self-adhesive tape or insulating shrink tubing.
- 15 82. The invention according to Claim 57, wherein the housing comprises a safety valve.
83. The invention according to Claim 57, wherein the housing comprises agents for trapping any gaseous products released by the device, such as carbon dioxide, hydrogen, hydrocarbons or  
20 oxygenated hydrocarbons.

84. Method for constructing a packaging device for use in association with an electrochemical device, wherein the method comprises the steps of:
- fabricating a housing having at least two segments and one or more lead openings;
  - forming one or more cavities in at least one of the segments of the housing, wherein  
5 the one or more cavities have an open region adjacent to the edge surface for enabling placement, and, in turn, encapsulation of at least a portion of an electrochemical device within the cavity;
  - securing the housing using a securement process; and
  - exerting mechanical pressure on the electrochemical device by applying a vacuum to  
10 the inside of the housing.
85. The process according to Claim 84, wherein the step of forming one or more cavities includes the step of:
- forming a first cavity on one side of the transverse axis and a second cavity another  
15 side of the transverse axis, such that both of the first and second cavities have a periphery corresponding to the periphery of each other.
86. The process according to Claim 85, wherein the step of forming first and second cavities includes the step of:
- forming the first and second cavities such that the periphery of the first and second  
20 cavities are at a substantially equal distance from the transverse axis of the housing so as to result in a substantially symmetric orientation of the periphery of the first and second cavities relative to the transverse axis.

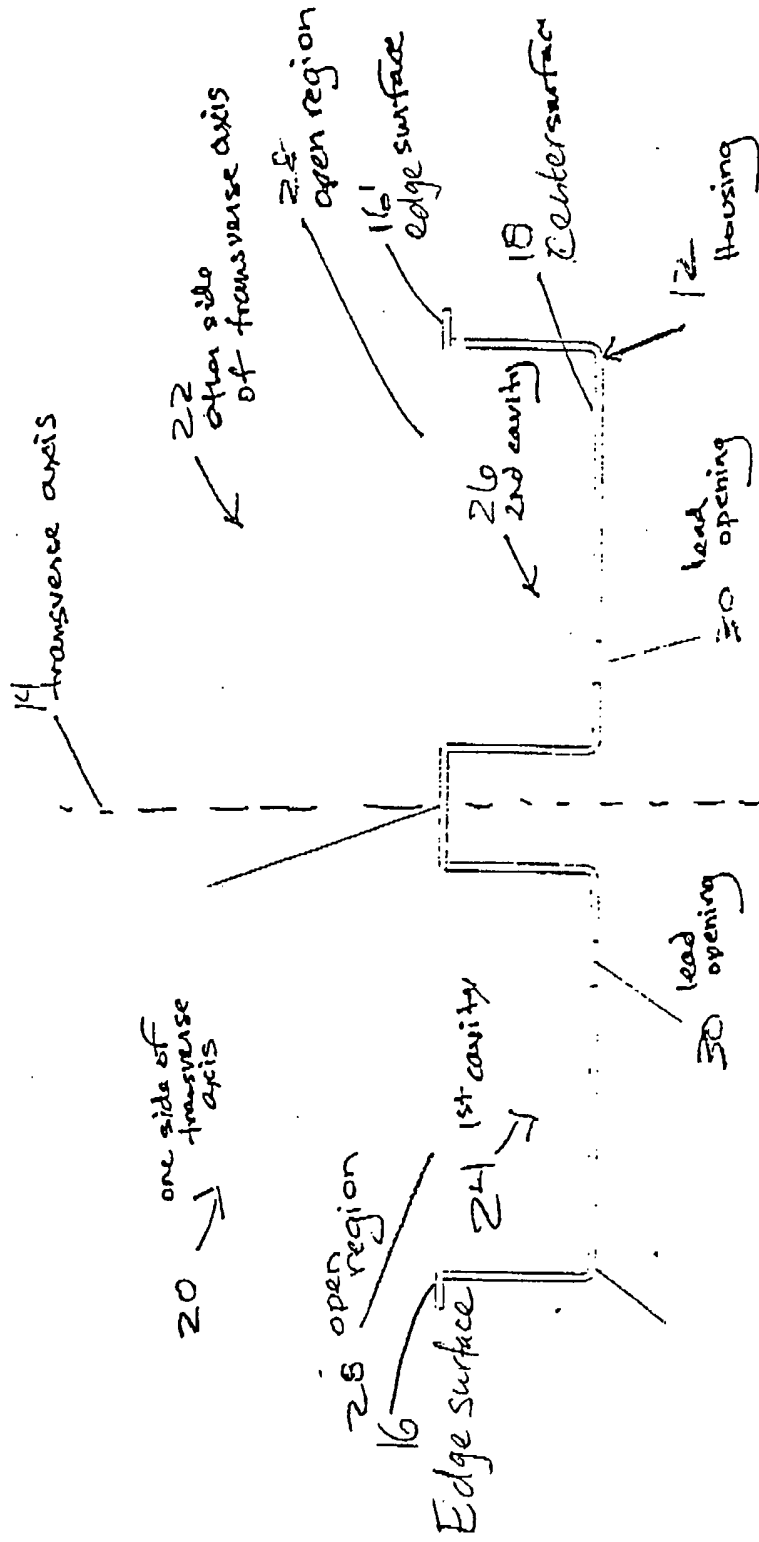
87. The process according to Claim 86, wherein the step of forming the first and second cavities includes the step of forming the first and second cavities to have corresponding geometries.
88. The process according to Claim 84, wherein the step of forming one or more cavities  
5 includes the step of forming one or more cavities by a deep-drawn process.
89. The process according to Claim 84, wherein the step of forming one or more cavities includes the step of forming one or more cavities by a deep-drawn process using heat sealable laminate.  
10
90. The process according to Claim 84, wherein the step of using a securement process to the housing includes the step of applying the securement process to at least a portion of the top surface of the housing on at least one side of the transverse axis.
- 15 91. The process according to Claim 90, wherein the step of using the securement process to the housing includes sealing the housing to form a hermetic seal to the housing after folding.
92. The process according to Claim 91, wherein sealing the housing includes sealing the housing so as to preclude ingress or egress of moisture in and out of the one or more cavities.  
20
93. The process according to Claim 84, wherein the step of fabricating a housing includes the step of attaching at least one terminal plate of the associated electrochemical device to a surface of the housing.

94. The process according to Claim 84, wherein the electrochemical device comprises two or more electrochemical cells electrically connected in at least one of series and parallel connections.
- 5 95. A method for constructing a packaging device for use in association and an associated electrochemical device, wherein the method comprises the steps of:
- fabricating a housing having a transverse axis, a top surface, a bottom surface and one or more lead openings;
  - forming one or more cavities on at least one side of the transverse axis of the housing,  
10 wherein the one or more cavities have an open region adjacent to the top surface for enabling placement, and, in turn, encapsulation of at least a portion of the electrochemical device within the cavity;
  - forming a fold region along the transverse axis, wherein, upon folding, an electrochemical device is encased within the housing;
  - 15 - securing the housing in a folded orientation using a securement process;
  - attaching one or more terminal plates of an associated electrical device to one or more surfaces of the housing; and
  - exerting mechanical pressure on the electrochemical device by applying a vacuum to the inside of the housing.

20

96. The process according to Claim 95, wherein the step of forming one or more cavities includes the step of:
- forming a first cavity on one side of the transverse axis and a second cavity on another side of the transverse axis, such that both of the first and second cavities have a periphery corresponding to the periphery of each other.
- 5
97. The process according to Claim 96, wherein the step of forming the first a second cavity includes the step of:
- forming the first and second cavities such that the periphery of the first and second cavities are formed to be substantially equal distance from the transverse axis of the housing so as to result in a substantially symmetric orientation of the periphery of the first and second cavities relative to the transverse axis.
- 10
98. The process according to Claim 97, wherein the step of forming the first and second cavities includes the step of forming the first and second cavities to have corresponding geometries.
- 15
99. The process according to Claim 95, further including the step of operatively positioning the electrochemical device within the one or more cavities.
- 20
100. The process according to Claim 95, wherein the step of forming the one or more cavities includes the step of forming the first and second cavities by a deep-drawn process.

101. The process according to Claim 95, wherein the step of forming one or more cavities includes the step of forming the first and second cavities by a deep-drawn process using a heat sealable laminate.
- 5 102. The process according to Claim 95, wherein the step of using a securement process includes the step of applying the securement process to at least a portion of the top surface of the housing on at least one side of the transverse axis.
103. The process according to Claim 102, wherein the step of using a securement process  
10 includes sealing the housing to form a hermetic seal to the housing after folding.
104. The process according to Claim 103, wherein the step of sealing the housing includes sealing the housing so as to preclude ingress or egress of moisture in and out of the one or more cavities .
- 15
105. The process according to Claim 95, wherein the step of attaching one or more terminal plates of the associated electrical device to the bottom surface of the housing includes the step of thermally bonding one or more terminal plates of an associated device to the bottom surface of the housing.
- 20
106. The process according to Claim 95, wherein the electrochemical device comprises at least two electrochemical cells electrically connected in at least one of series and parallel connection.



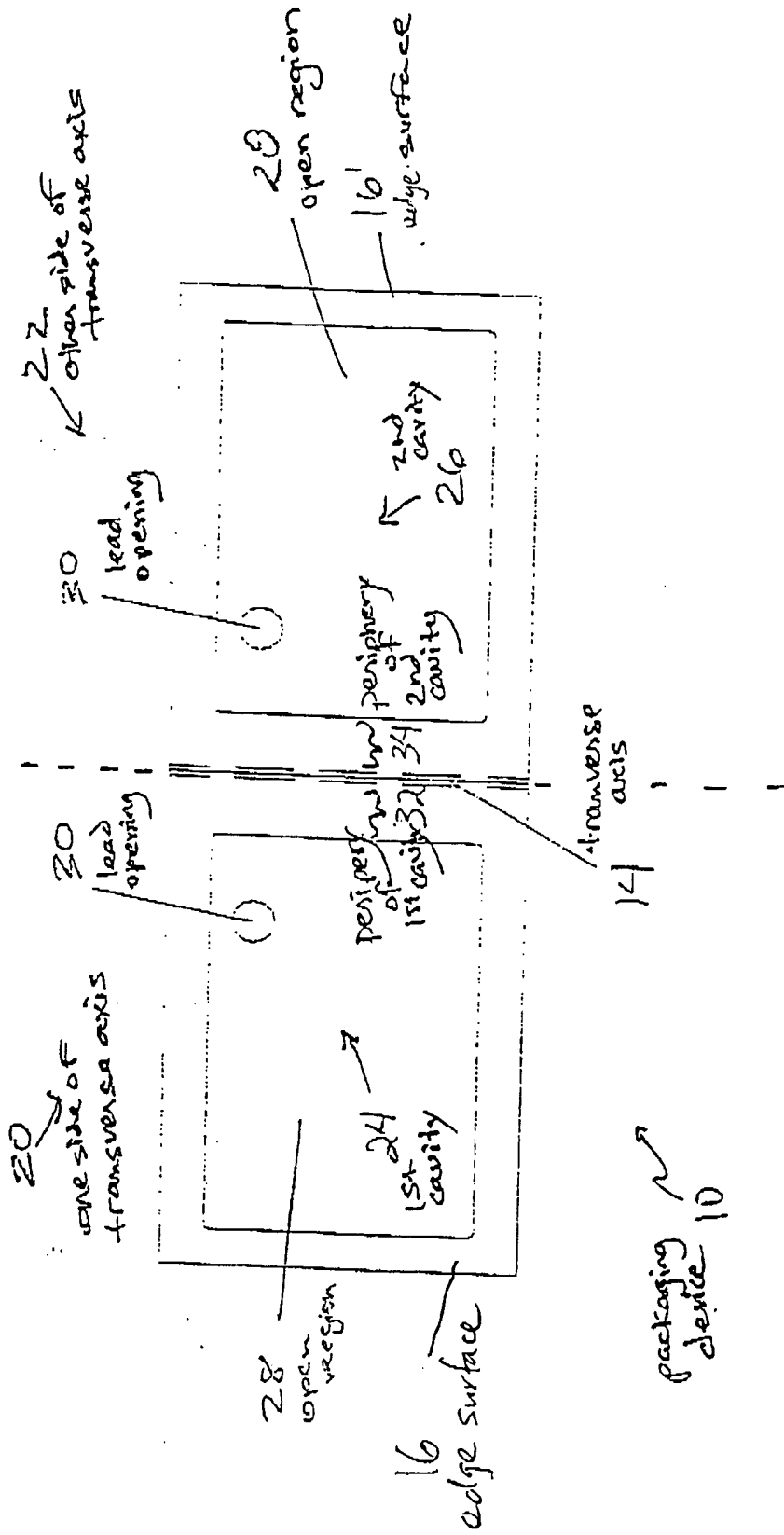


FIGURE 2

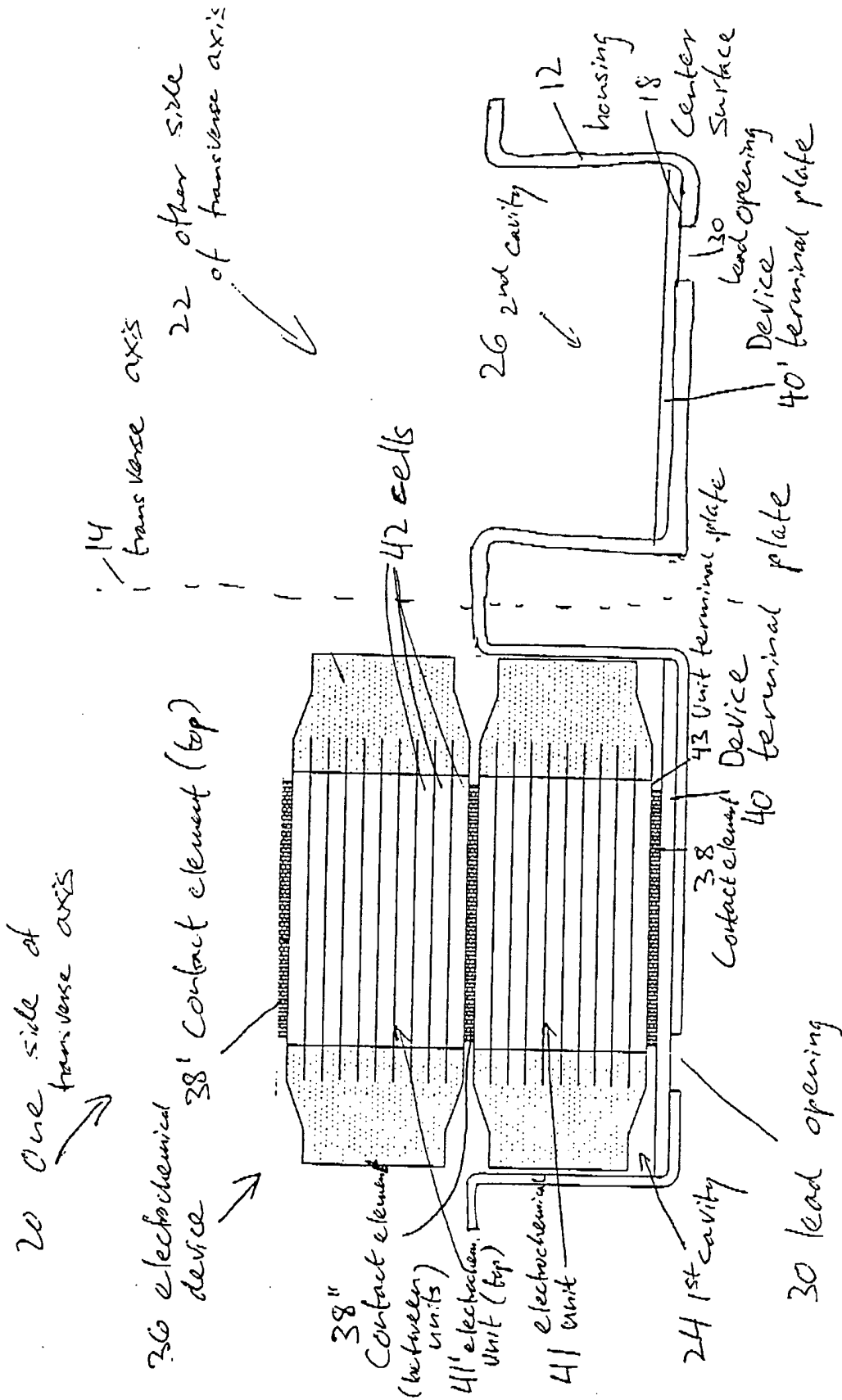


FIGURE 3

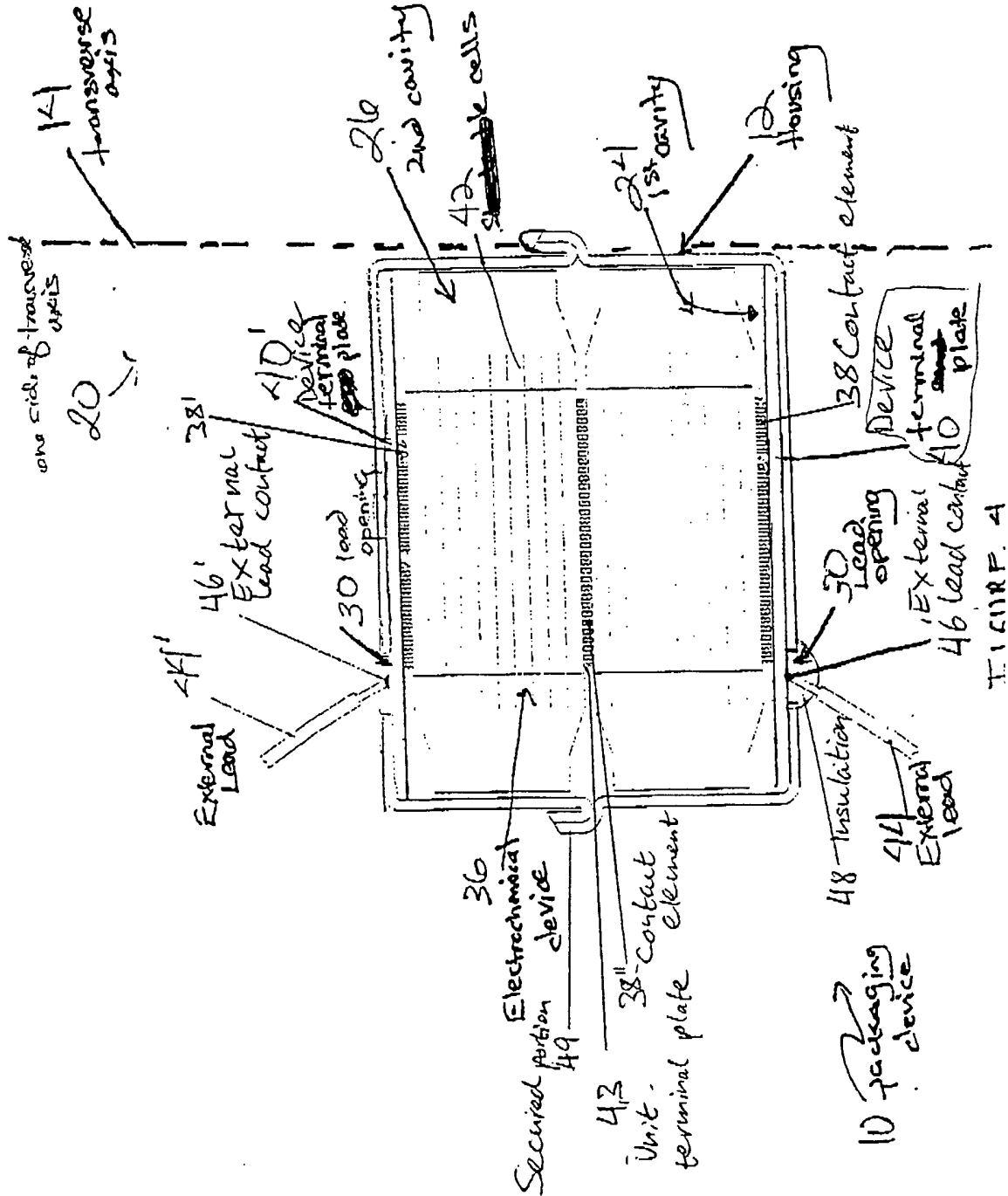


FIGURE 4

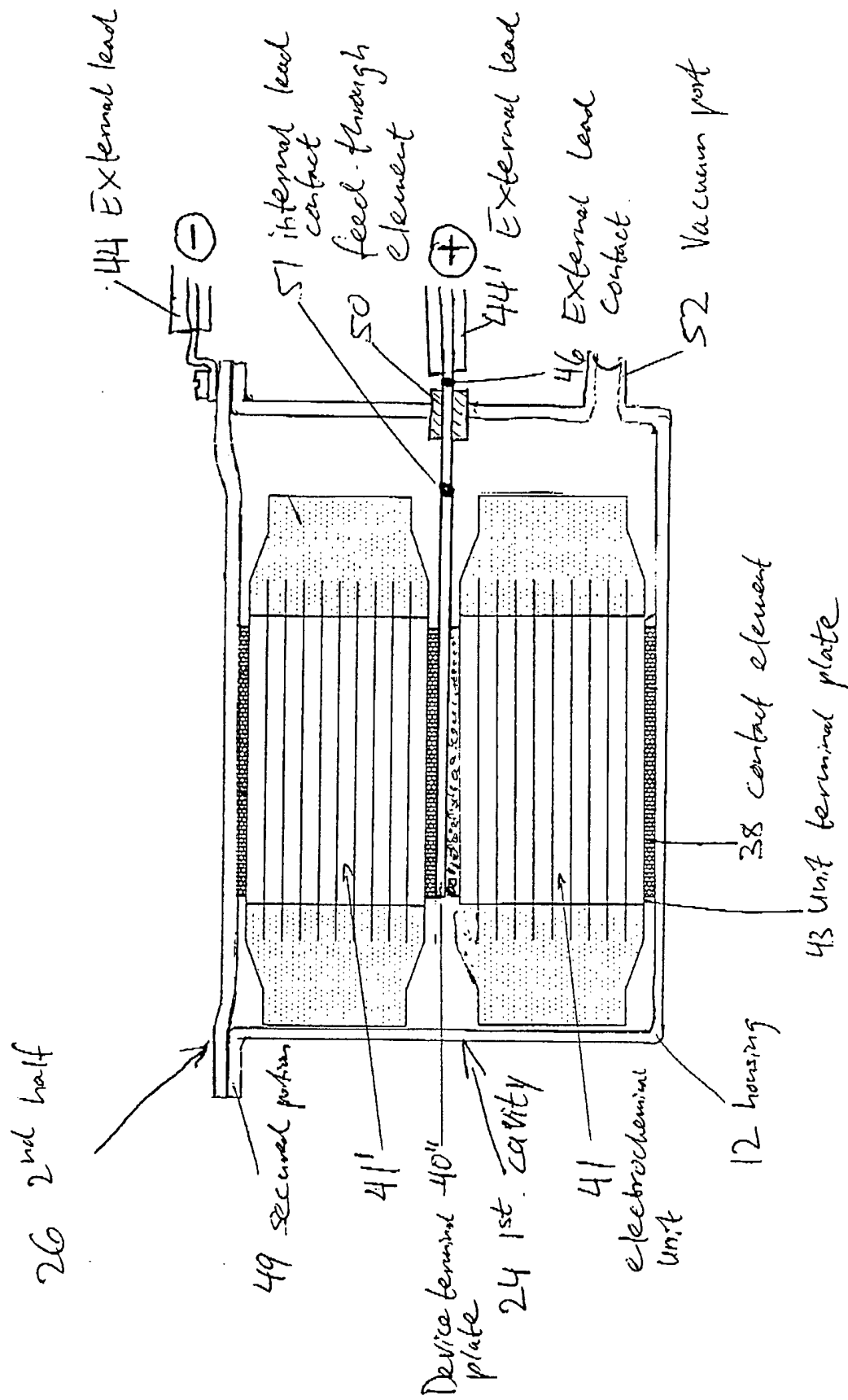


FIGURE 5

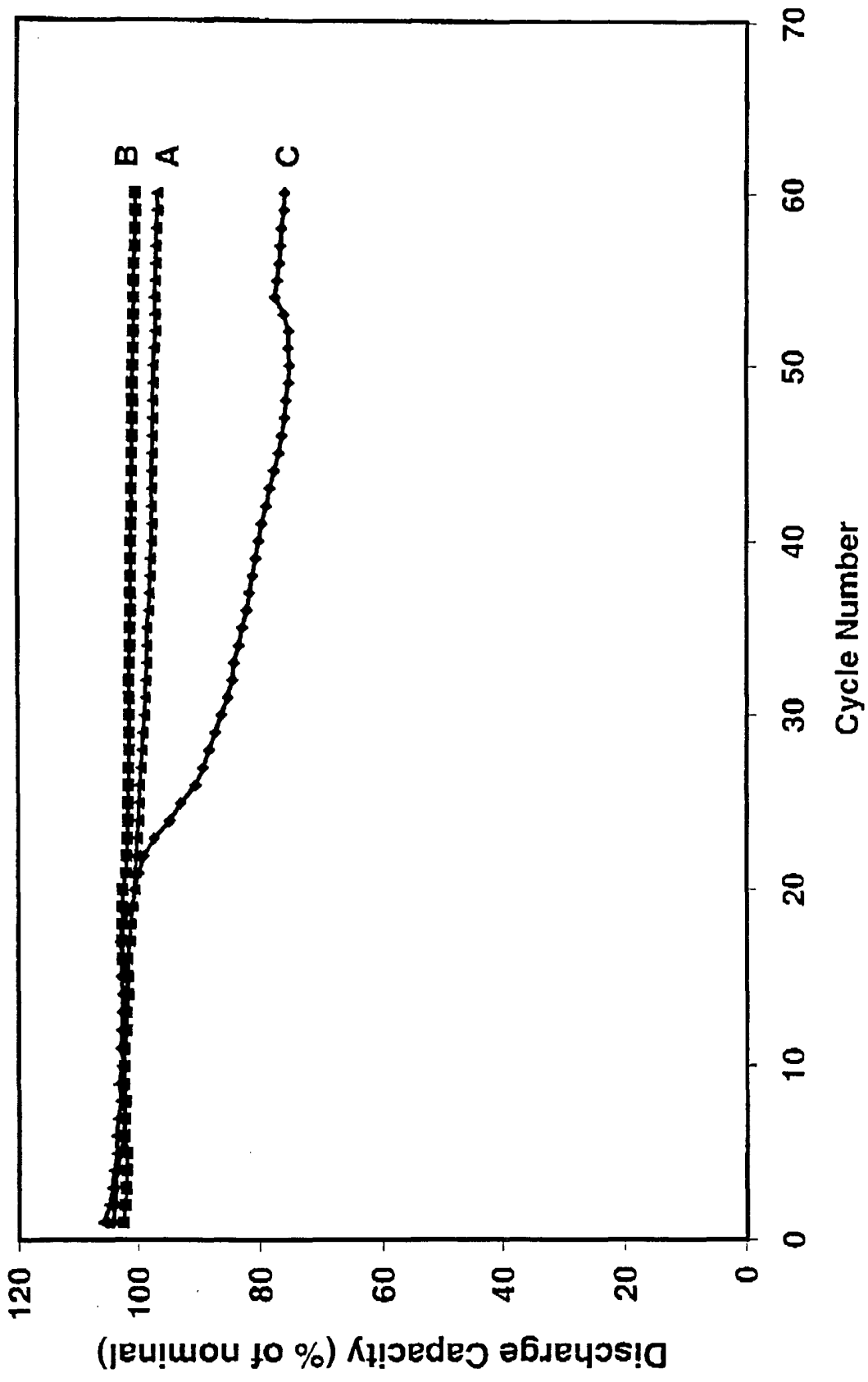


FIGURE 6