A BATTERY HAVING A THIN PROFILE AND FLEXIBLE STRUCTURE AND A METHOD FOR PRODUCING THE SAME

The invention provides a battery having an electrode, a counter electrode, and a separator disposed between the electrode and the counter electrode. First and second current collectors sandwich the electrode, the separator, and the counter electrode to define a package for the battery, with the first and second current collectors being major external surfaces of the package. A method of producing a battery in accordance with the present invention is also provided. The method includes the steps of: providing an electrode, providing a counter electrode, disposing a separator between the electrode and the counter electrode, and sandwiching the electrode, the separator, and the counter electrode between first and second current collectors to define a package for the battery, where the first and second current collectors are major external surfaces of the package.
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A BATTERY HAVING A THIN PROFILE AND FLEXIBLE STRUCTURE
AND A METHOD FOR PRODUCING THE SAME

Field of the Invention

This invention relates to a battery and a method for producing the same.

Background of the Invention

A battery cell typically includes a separator material sandwiched between two oppositely-charged electrodes. The oppositely-charged electrodes are generically referred to as an electrode and a counter electrode. The term electrode identifies either a positive (cathodic) electrode or a negative (anodic) electrode and the term counter electrode identifies the other electrode.

Most electronic devices receive operating power from a primary external power supply. Many of these electronic devices also include a rechargeable internal power source. Typically, the internal power source functions as a back-up or secondary power supply for powering microelectronic applications, such as smart cards, keep-alive circuitry, or low power transponders, when the primary external power supply is disrupted. Most electronic devices, especially portable or hand-held devices, have limited internal packaging space. As a result, the internal power source is preferably of the smallest possible dimensions.

Several known batteries have been proposed to address such packaging space constraints. Although such batteries provide the required power, they have several shortcomings. Known batteries have large dimensions relative to the limited amount of packaging space available
within a typical electronic device. More specifically, in electronic circuitry, battery height profiles are often minimized in order to best utilize the volume in a product package. Further, known batteries are structurally stiff and, therefore, highly susceptible to damage by external mechanical forces. For example, stiff batteries are prone to fail when subjected to impact shock created when the electrical device is dropped. Accordingly, it would be desirable to provide a rechargeable battery having a thin profile and flexible structure as well as a method of producing the same.

**Summary of the Invention**

The present invention provides a battery having an electrode, a counter electrode, and a separator disposed between the electrode and the counter electrode. First and second current collectors sandwich the electrode, the separator, and the counter electrode to define a package for the battery, with the first and second current collectors being major external surfaces of the package.

A method of producing a battery in accordance with the present invention is also provided. The method includes the steps of: providing an electrode, providing a counter electrode, disposing a separator between the electrode and the counter electrode, and sandwiching the electrode, the separator, and the counter electrode between first and second current collectors to define a package for the battery, where the first and second current collectors are major external surfaces of the package.

These and other objects, features, and advantages will become apparent from the following description of the preferred embodiments, claims, and accompanying drawings.
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Brief Description of the Drawings

Figure 1 is a perspective view of a battery having a thin profile and flexible structure in accordance with the present invention.

Figure 2 is a fragmented cross-sectional view of the battery along lines 2-2 of Figure 1.

Figure 3 is a perspective view of a seal for sealing the battery.

Figure 4 is side view of the battery illustrating the battery in a flexed position with solid lines and an un-flexed position with dashed lines.

Description of the Preferred Embodiments

Referring to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views, Figure 1 shows a perspective view of a battery 10 having a thin profile and flexible structure in accordance with the present invention. The battery 10 includes a first current collector 12, a second current collector 14, and a seal 16. The seal 16 is disposed between the first current collector 12 and the second current collector 14 for preventing leakage of electrolyte from the battery 10. Preferably, the seal 16 is disposed in a layered relationship between the first current collector 12 and the second current collector 14. Optionally, the first current collector 12 may include a first tab 18 and the second current collector 14 may include a second tab 20 for charging and discharging the battery 10. The seal 16 preferably includes an overhang portion 22 for preventing a short circuit between the first tab 18 and the second current collector 14 or a short circuit between the second tab 20 and the first current collector 12.
Figure 2 is a fragmented cross-sectional view of the battery 10 along lines 2-2 of Figure 1. The battery 10 further includes an electrode 24, a counter electrode 26, and a separator 28 disposed between the electrode 24 and the counter electrode 26. The first and second current collectors 12 and 14 sandwich or encapsulate the electrode 24, the separator 28, and the counter electrode 26 to define a package 30 for the battery 10, with the first and second current collectors 12 and 14 being major external surfaces of the package 30. This arrangement of material layers forms a rechargeable, bi-polar cell. The separator 28 is preferably disposed in a layered relationship between the electrode 24 and the counter electrode 26. The first current collector 12 is preferably disposed in a layered relationship with the electrode 24 opposite the separator 28. The second current collector 14 is preferably disposed in a layered relationship with the counter electrode 26 opposite the separator 28.

In an alternative embodiment of the present invention, the battery 10 further includes a first foilcoat 32 disposed between the first current collector 12 and the electrode 24 and a second foilcoat 34 disposed between the second current collector 14 and the counter electrode 26. The foilcoats are adapted to promote or facilitate the adhesion or bonding of the electrode 24 to the first current collector 12 and the adhesion or bonding of the counter electrode 26 to the second current collector 14.

The electrode 24, the separator 28, and the counter electrode 26 are made from a flexible polymer film material. The electrode 24 and the counter electrode 26 may be chosen from any polymer film material which can be bonded to the respective foilcoat 32 and 34. Preferably, the electrode 24, the separator 28, and the counter electrode 26 comprises polyvinylidene difluoride-co-
hexafluoropropylene (PVDF-co-HFP). Alternatively, the electrode 24, the separator 28, and the counter electrode 26 may comprise of polyethylene (PE), polypropylene (PP), polytetrafluoroethylene (PTFE), or polyvinylidene fluoride (PVDF). Preferably, the electrode 24 has a thickness of .02 millimeters to .08 millimeters, the counter electrode 26 has a thickness of .04 millimeters to .18 millimeters, and the separator 28 has a thickness of .02 millimeters to .06 millimeters. At most, the electrode 24 has a thickness of .15 millimeters, the counter electrode 26 has a thickness of .30 millimeters, and the separator 28 has a thickness of .08 millimeters.

The first and second current collectors 12 and 14 are made from a flexible metal foil material. Preferably, the first current collector 12 comprises copper foil and the second current collector 14 comprises aluminum foil. Alternatively, the first and second current collectors 12 and 14 may comprise nickel, stainless steel (Alloy grades 302, 304, and 316L), or nickel plated steel. Preferably, the first current collector 12 and the second current collector 14 each have a thickness of .013 millimeters. At most, the first current collector 12 and the second current collector 14 each have a thickness of .05 millimeters.

As shown in Figure 2, the seal 16 is disposed or positioned between the outer edge 36 of the first current collector 12 and the outer edge 38 of the second current collector 14. Preferably, the seal 16 is disposed or positioned about the entire periphery of the battery 10 between the outer edge 36 of the first current collector 12 and the outer edge 38 of the second current collector 14.

Figure 3 is a perspective view of the seal 16. Preferably, the seal 16 includes a first C-shaped portion 40 having an opening or mouth 42 and a second plug portion
44 for enclosing the opening 42 of the first C-shaped portion 40. One of ordinary skill in the art will recognize that the present invention is not limited to a C-shaped seal configuration. Preferably, the seal 16 comprises ethylene acrylic acid. Alternatively, the seal 16 may comprise Surlyn™ or a modified polyethylene/polypropylene. The seal 16 may be fabricated by injection molding or may be punched from a sheet of material.

To promote structural or mechanical flexibility of the battery 10, the first current collector 12 is bonded to the electrode 24, the second current collector 14 is bonded to the counter electrode 26, and the separator 28 is bonded between the electrode 24 and the counter electrode 26. The bonding may be accomplished by way of lamination or co-extrusion.

The battery 10 has a predetermined performance. For purposes of this patent, the term "predetermined performance" means the battery 10 can maintain a constant Current Drain Rate up to 3C with greater than 85% Rated Capacity, between the temperatures of 0°C and 60°C. The Current Drain Rate for a cell is the current, in amperehours or milliamperehours, that will transfer the Rated Capacity of the cell in 1 hour. If a cell has a Rated Capacity of 1 amperehour (C=1 Ahr), a current of 1 ampere will either discharge or charge the cell in 1 hour (1 ampere x 1 hour = 1 amperehour = Rated Capacity of the cell). Thus, 3C is 3 times the Current Drain Rate meaning the cell would discharge or charge in 1/3 hour or 20 minutes. The battery 10 also has a flexible structure. For purposes of this patent, the term "flexible structure" means that the battery 10 and the package 30 can be bowed, flexed, deformed, etc., return from such condition to its original shape, and maintain its predetermined performance.
Figure 4 is side view of the battery 10 illustrating the battery 10 in a flexed position with solid lines and an un-flexed position with dashed lines. In a preferred embodiment of the present invention, the battery 10 can be flexed 30° (thirty degrees) from one end or edge 46 of the battery 10 to the opposite end or edge 48 of the battery 10, as illustrated in Figure 4, without being damaged, delaminated, buckled, cracked, fractured or the like. In other words, the battery 10 can be flexed 30° from edge to edge and still maintain its predetermined performance.

The battery 10 also has a thin profile or large aspect ratio. For purposes of this patent, the term "aspect ratio" is defined as the measure of the shorter of the length or width of a battery with respect to the thickness of the battery. Preferably, the battery 10 has an aspect ratio of at least 15:1. More preferably, the battery 10 has an aspect ratio of at least 50:1. Most preferably, the battery 10 has an aspect ratio of at least 100:1.

The present invention also provides a method of producing a battery having a thin profile and flexible structure. The steps of the method include: providing an electrode; providing a counter electrode; disposing or positioning a separator between the electrode and the counter electrode; and sandwiching or encapsulating the electrode, the separator, and the counter electrode between first and second current collectors to define a package for the battery, where the first and second current collectors are major external surfaces of the package.

A preferred embodiment of the method further includes the steps of: bonding the electrode to the first current collector and bonding the counter electrode to the second current collector; bonding the separator between the
electrode and the counter electrode; and sealing the battery package. Preferably, a combination of heat and pressure is used to thermally bond the electrode to the first current collector and the counter electrode to the second current collector. Preferably, the separator is bonded between the electrode and the counter electrode using combination of heat and pressure. Alternatively, the first current collector, the electrode, the separator, the counter electrode, and the second current collector are bonded together simultaneously.

The sealing of the battery package is initiated by installing or inserting a seal around the outer edges of the battery. Sealing is performed by the application of heat and pressure onto the outer surfaces of both the first and second current collectors, simultaneously, and only directly over the area including the seal. This has the effect of bonding the seal to both the first and second current collectors. The seal may be fabricated by injection molding or may be punched from a sheet of material. Alternatively, the seal can be applied in the form of a hot-melt.

An alternative embodiment of the method further includes the steps of: applying a first foilcoat to the first current collector; applying a second foilcoat to the second current collector; bonding the electrode to the first foilcoat; and bonding the counter electrode to the second foilcoat.

Another alternative embodiment of the method further includes the steps of: coating a layer of electrode to the first current collector; and coating a layer of counter electrode to the second current collector.

Advantageously, the invention provides a battery package where the current collectors form the package. A
seal functions to provide an airtight and watertight package while maintaining the current collectors in a spaced-apart relationship.

While this invention has been described in terms of certain embodiments thereof, it is not intended that it be limited to the above description, but rather only to the extent set forth in the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined in the following claims.
WHAT IS CLAIMED IS:

1. A battery comprising:
   an electrode;
   a counter electrode;
   a separator disposed between said electrode and said counter electrode; and
   first and second current collectors sandwiching said electrode, said separator, and said counter electrode to define a package for the battery, said first and second current collectors being major external surfaces of said package.

2. The battery of claim 1, wherein said first current collector is disposed adjacent to said electrode opposite said separator and said second current collector is disposed adjacent to said counter electrode opposite said separator.

3. The battery of claim 1, wherein said first current collector is bonded to said electrode and said second current collector is bonded to said counter electrode.

4. The battery of claim 1, including a first foilcoat disposed between said first current collector and said electrode to promote adhesion therebetween and a second foilcoat disposed between said second current collector and said counter electrode to promote adhesion therebetween.

5. The battery of claim 1, wherein said separator is bonded between said electrode and said counter electrode.
6. The battery of claim 1, wherein said electrode, said separator, and said counter electrode comprise a flexible polymer film material.

7. The battery of claim 6, wherein said electrode, said separator, and said counter electrode each comprise polyvinylidene difluoride-co-hexafluoropropylene (PVDF-co-HFP).

8. The battery of claim 1, wherein said first and second current collectors comprise a flexible metal foil material.

9. The battery of claim 8, wherein said electrode is an anode, said first current collector comprises copper foil, said counter electrode is a cathode, and said second current collector comprises aluminum foil.

10. The battery of claim 1, including a seal disposed between said first and second current collectors for sealing said package.

11. The battery of claim 10, wherein said seal comprises ethylene acrylic acid.

12. The battery of claim 10, wherein said seal includes a first C-shaped portion having an opening and a second plug portion for enclosing said opening of said first C-shaped portion.

13. The battery of claim 1, wherein said electrode has at most a thickness of .15 millimeters, said counter electrode has at most a thickness of .30 millimeters, said separator has at most a thickness of .08 millimeters, said first current collector has at most a thickness of .05 millimeters, and said second current collector has a thickness of .05 millimeters.
14. The battery of claim 13, wherein said package has an overall thickness at most equal to 1.0 millimeter and an aspect ratio of at least 15:1.

15. The battery of claim 1, wherein said package has a predetermined performance, and said predetermined performance is maintained after said package is flexed 30 degrees edge to edge.

16. The battery of claim 1, wherein said first current collector includes a first tab and said second current collector includes a second tab for charging and discharging the battery.

17. A method of producing a battery, comprising the of steps:
    providing an electrode;
    providing a counter electrode;
    disposing a separator between the electrode and the counter electrode; and
    sandwiching the electrode, the separator, and the counter electrode between first and second current collectors to define a package for the battery, where the first and second current collectors are major external surfaces of the package.

18. The method of claim 17, including the steps of bonding the first current collector to the electrode and bonding the second current collector to the counter electrode.

19. The method of claim 18, including the steps of applying a first foilcoat to the first current collectors, applying a second foilcoat to the second current collectors, bonding the electrode to the first
foilcoat, and bonding the counter electrode to the second foilcoat.

20. The method of claim 18, including the steps of coating a layer of electrode to the first current collector, and coating a layer of counter electrode to the second current collector.

21. The method of claim 18, including the step of bonding the separator between the electrode and the counter electrode.

22. The method of claim 21, including the step of sealing the package.