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ELECTROCHEMICAL CELL WITH ANODE FRAME CONFINEMENT

Abstract

An electrochemical cell has an anode of an active anode material disposed opposite a cathode of an active cathode material. The anode active material is confined laterally by an impermeable anode frame to prevent the anode active material from expanding the area of the anode as the cell is charged and discharged.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION [0001] This application claims priority to U.S. Provisional Patent Application 63/553,052 entitled "Electrochemical Cell with Anode Frame Confinement" filed 13 Feb. 2024 and incorporated herein by reference.

BACKGROUND
[0002] An electric battery includes one or more electric cells. Each cell includes a positive electrode (cathode) and a negative electrode (anode) physically separated by an ion conductor (electrolyte). When a cell is discharged to power an external circuit, the anode supplies negative charge carriers (electrons) to the cathode via the external circuit and positive charge carriers (cations) to the cathode via the internal electrolyte. During charging, an external power source drives electrons from the cathode to the anode and the resultant charge imbalance pulls cations from the cathode to the anode via the electrolyte.
[0003] Lithium-ion (Li-ion) batteries store charge in the anode as Li cations (aka Li ions). Li-ion cells are rechargeable and ubiquitous in mobile communications devices and electric vehicles due to their high energy density, a lack of memory effect, and low self-discharge rate. Lithium-metal cells store charge in the anode as lithium metal, which is superior to Li ions due to a higher theoretical specific capacity, lower electrochemical potential, and lower density. Unfortunately, rechargeable lithium-metal cells have yet to be commercialized at scale.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0004] The detailed description is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:
[0005] FIG. **1**A depicts a partial cell **100** in accordance with an embodiment in which a frame **105** is used in an electrochemical cell;
[0006] FIG. **1**B depicts an expanded view of a full cell **150** with components from partial cell **100** of FIG. **1**A; and
[0007] FIG. **2** is an expanded view of an electrochemical cell **200**, a coin cell, with a metal anode **205** opposite the active surface of a cathode **210** and separated therefrom via a separator **215**.
DETAILED DESCRIPTION
[0008] FIG. **1** depicts a partial cell **100** in accordance with an embodiment in which a frame **105** is used in an electrochemical cell (e.g., a pouch, prismatic, or cylindrical cell). An adhesive **107**, e.g. polyvinylidene fluoride, bonds frame **105** to a separator **110**. When partial cell **100** is assembled into a complete cell, frame **105** frames an anode **115** of e.g. lithium metal on a side of separator **110** opposite a cathode electrode **120**. Frame **105** defines an opening **125** in a plane parallel to the active surface of cathode **120**. After assembly, anode **115** is confined laterally within opening **125** to prevent the anode active material, e.g. lithium metal, from expanding the area of the active surface of anode **115** as the assembled cell is charged and discharged.
[0009] Adhesive **107** can be on either or both sides of frame **105**, and each instance can include an aperture like opening **125** more or less matching that of frame **105**. Adhesive **107** is shown separately for ease of illustration but may be a coating or layer on a surface to be bonded in assembly. Anode **115** can overlap or be confined within frame **105** after cell **100** is assembled. Separator **110** extends over an area that entirely overlaps and extends beyond the periphery of

opening **125**. Separator **110** is wetted with an electrolyte (not shown) that contains a dissolved salt of a metal, the ionic form of which is used to conduct charge. The area of separator **110** exceeds the area of anode **115**, fully covering opening **125**. In other embodiments, separator **110** is or includes a solid electrolyte to facilitate the movement of ions (e.g. of Li). The area of cathode **120** is coextensive with opening **125** in this example. In other embodiments the cathode area less than that of opening **125**.

[0010] Frame **105** addresses peripheral accumulation by confining the anode active material within opening **125**. Frame **105** is a barrier to ionic conduction, mass transport, and anode material migration, especially metallic lithium, to or beyond the periphery of the anode. Frame **105** can be of a compressible, non-conductive polymer that is impermeable to the electrolyte, thus forming a seal effective against creep migration of the active anode material. In another embodiment, frame **105** may be formed as part of an anode structure and disposed at the periphery of anode **115**.

[0011] In some embodiments, anode **115** is coated or laminated with frame **105** at the periphery. Non-porous frame **105** and porous separator **110** can be formed together of the same or different materials. Frame **105** can distribute local electric fields more uniformly to reduce peripheral metal accumulation. During assembly, frame **105** ensures precise fit and alignment of battery components, and the resultant anode confinement enhances safety, reliability, and cell life.

[0012] Anode **115** is a lithium foil in this example but can be elsewise in other embodiments. Anode **115** can include an active layer in which a carpet of carbon nanotubes is alternatively coated with and depleted of metal when charged and discharged. For a suitable anode, see U.S. Patent Publication 2022/0209216 to Salvaterra et al., which is incorporated herein by reference. Cathode **120** can be of any number of available cathode active materials, including a sulfurized-carbon material detailed in the above-referenced document.

[0013] FIG. **1**B includes assembled and expanded views of a pouch cell **150** that includes components of the type described above in connection with FIG. **1**A. Assembled pouch cell **150**, at the top of the page, includes a sealed, flexible foil pouch that contains electrode and electrolyte materials. Stacks of negative and positive tabs **155** and **160** extend from the foil pouch. Tabs are typically bonded using ultrasonic or laser welding.

[0014] In the expanded view, cell **150** is a sandwich structure with alternating anode and cathode elements between pouch halves **165**. Pouch halves **165** need not be separate sheets but are shown so for ease of illustration. The pouch is typically a laminated film composed of aluminum and polymer layers that, when encompassing the electrically active materials, provides a barrier against environmental factors like moisture and oxygen and keeps the internal components from contacting other conductive materials that could lead to shorts.

[0015] The uppermost electrode is a copper film **170** with one of negative tabs **155** and anode material (not shown) bounded by a frame **105** on the underside. A separator **110** and electrolyte (not shown) separates this uppermost electrode from a two-sided cathode electrode in which an aluminum film **175** has a tab **160** and is coated on both sides with layers of cathode material **120**. Another separator **110** and the electrolyte separates this cathode electrode from a two-sided anode electrode like the uppermost electrode but with anode material **115** and a frame **105** on both sides. Third and final separator **110** and the electrolyte separates this anode electrode from a one-sided cathode electrode. The number of electrode layers can be more or fewer, and the assembly can be wound or stacked.

[0016] FIG. **2** is an expanded view of an electrochemical cell **200**, a coin cell, with a metal anode **205** opposite the active surface of a cathode **210** and separated therefrom via a separator **215**. A frame **220** defines an opening **225** in a plane parallel to the active surface of cathode **210**. When cell **200** is assembled anode **205** is confined laterally within opening **225** to prevent the anode active material, e.g. lithium metal, from expanding the area of anode **205** as cell **200** is charged and discharged.

[0017] Negative and positive terminals **230** and **235** are brought together in assembly to form a case. Though not shown, a sealing ring electrically isolates terminals **230** and **235** and seals the cell contents. When assembled, a spacer **240** of stainless-steel compresses frame **220**, a polymer in this embodiment, to secure separator **215** and cathode **210** to positive terminal **235**. Assembly also compresses a Belleville spring **245** that urges a second spacer **250** of e.g. stainless steel to press anode **205** against separator **215**.

[0018] In conventional cells, repeated charge and discharge cycles can cause metal to accumulate around the perimeter of the anode. The accumulated metal can extend to the case and thus short the cell. Peripheral metal accumulation, and thus cell performance, can vary considerably between cells. This lack of consistency can introduce severe quality issues into cell performance and pose severe safety hazards via short circuits.

[0019] The foregoing discussion focuses on electrochemical cells that employ lithium ions as charge carriers but other charge carriers can be used. Moreover, anode frames can be adapted for cathodes, and for use in cells of other shapes and sizes. Other variations will be obvious to those of ordinary skill in the art. Therefore, the spirit and scope of the appended claims should not be limited to the foregoing description. Only those claims specifically reciting “means for” or “step for” should be construed in the manner required under the sixth paragraph of 35 U.S.C. § 112.

Claims

1. An electrochemical cell comprising: a cathode with an active cathode surface; an anode with an active anode surface opposite the active cathode surface, the anode including: a frame defining an opening in a plane parallel to the active cathode surface; and active anode material confined within the opening.

2. The electrochemical cell of claim 1, further comprising a casing encapsulating the cathode and the anode.

3. The electrochemical cell of claim 1, wherein the opening extends over an opening area in the plane, the electrochemical cell further comprising a separator between the active cathode surface and the active anode surface, the separator extending over a separator area greater than the opening area.

4. The electrochemical cell of claim 3, further comprising a liquid electrolyte permeating the separator, wherein the frame is impermeable to the liquid electrolyte.

5. The electrochemical cell of claim 1, wherein the frame adheres to the active anode material.

6. The electrochemical cell of claim 1, wherein the frame is electrically non-conductive.

7. The electrochemical cell of claim 6, wherein the frame is of a polymer.

8. The electrochemical cell of claim 1, wherein the active anode material is of an alkali metal.

9. The electrochemical cell of claim 8, wherein the alkali metal is a metallic lithium.

10. The electrochemical cell of claim 1, wherein the active anode material is a carpet of carbon nanotubes.

11. The electrochemical cell of claim 10, wherein the carbon nanotubes are coated with an alkali metal.

12. The electrochemical cell of claim 11, wherein the alkali metal is metallic lithium.

13. The electrochemical cell of claim 11, further comprising a separator between the cathode and the anode.

14. The electrochemical cell of claim 13, wherein the separator includes an adhesive opposite the anode active material.

15. The electrochemical cell of claim 14, wherein the adhesive includes an aperture opposite the opening.

16. A method for assembling an electrochemical cell, the method comprising: forming anode active material of an anode area; forming cathode active material of a cathode area; electrochemically attaching the anode active material to the cathode active material via a separator of a separator area greater than the anode area; and framing the anode active material within the anode area.

17. The method of claim 16, wherein the framing comprises encompassing the anode active material within a frame.

18. The method of claim 17, further comprising attaching the frame to the separator.

19. The method of claim 18, wherein attaching the frame to the electrolyte layer comprises attaching the frame to the separator.

20. The method of claim 17, wherein the separator comprises the frame.