CLAIMS

1. A bipolar electrode comprising:

a bipolar electrode plate, the bipolar electrode plate comprising a front surface and a back surface; and

a cathode assembly comprising

a carbon material;

a separator; and

a cathode cage,

wherein the cathode cage holds the carbon material in electrical communication with the front surface of the bipolar electrode plate, and the bipolar electrode plate and the cathode cage comprise a titanium material.

2. The bipolar electrode of claim 1, wherein at least a portion of the back surface of the bipolar electrode plate is a rough surface.

3. The bipolar electrode of either of claims 1 or 2, wherein at least a portion of the bipolar electrode plate and at least a portion of the cathode cage comprise a titanium carbide coating.

4. The bipolar electrode of any one of claims 1-3, wherein the front surface of the bipolar electrode plate further comprises a recessed portion.

5. The bipolar electrode of claim 4, wherein the recessed portion of the front surface of the bipolar electrode plate is configured to accommodate at least a portion of the carbon material.

6. The bipolar electrode of claim 5, wherein the cathode cage is disposed over the carbon material such that the carbon material is disposed between the recessed portion and the cathode cage.

7. The bipolar electrode of any one of claims 1-6, wherein the separator is disposed between the carbon material and the cathode cage.

8. The bipolar electrode of any one of claims 1-7, wherein the cathode cage comprises a pocket region, and the pocket region comprises a plurality of thru holes.

9. The bipolar electrode of claim 8, wherein the plurality of thru holes are evenly spaced and distributed along rows in an alternating repeating pattern.

10. The bipolar electrode of either of claims 8 or 9, wherein each of the thru holes comprises a calculated diameter based upon a spacing between the cathode assembly and the back surface of an adjacent bipolar electrode plate at each of a plurality of locations corresponding to locations of the plurality of holes.

11. The bipolar electrode of claim 10, wherein the calculated diameter for each hole is further based upon a nominal hole area and a nominal minimum spacing between the cathode assembly and the back surface of the adjacent bipolar electrode plate.

12. The bipolar electrode of either of claims 10 or 11, wherein the spacing between the cathode assembly and the back surface of the adjacent bipolar electrode plate at each location is calculated using a fit equation based on a measured delta from flat for each of the cathode assembly and the back surface of the adjacent bipolar electrode plate at each of the plurality of locations.

13. The bipolar electrode of any one of claims 1-12, wherein the separator comprises a carbon cloth or carbon felt.

14. The bipolar electrode of any one of claims 1-13, wherein the carbon material of the bipolar electrode comprises a carbon black material.

15. The bipolar electrode of any one of claims 1-14, wherein the carbon material further comprises PTFE.

16. The bipolar electrode of any one of claims 1-15, further comprising from 1 to 5 blocks of carbon material.

17. A rechargeable bipolar electrochemical cell comprising:

an aqueous zinc-halide electrolyte;

a bipolar electrode comprising

a bipolar electrode plate, the bipolar electrode plate comprising a first titanium material;

a carbon material;

a cathode cage that holds the carbon material in electrical communication with a front surface of the bipolar electrode plate, the cathode cage comprising a second titanium material; and

a separator interposed between at least a portion of the cathode cage and the carbon material; and

a terminal endplate parallel with and adjacent to the first bipolar electrode plate, the terminal endplate comprising a third titanium material, the terminal endplate having an inner surface that opposes the front surface of the first bipolar electrode, and at least a portion of the inner surface is a rough surface,

wherein the bipolar electrode and the terminal endplate are at least partially disposed in the electrolyte.

18. The electrochemical cell of claim 17, wherein the separator comprises a carbon cloth or carbon felt.

19. The electrochemical cell of either of claims 17 or 18, wherein the first titanium material of the bipolar electrode plate is at least partially coated with titanium carbide.

20. The electrochemical cell of any one of claims 17-19, wherein the carbon material of the bipolar electrode comprises a carbon black material.

21. The electrochemical cell of any one of claims 17-20, wherein the carbon material further comprises PTFE.

22. The electrochemical cell of any one of claims 17-21, wherein the third titanium material of the terminal endplate is at least partially coated with titanium carbide.

23. The electrochemical cell of any one of claims 17-22, wherein the bipolar electrode plate further comprises a recessed portion.

24. The electrochemical cell of claim 23, wherein the recessed portion of the front surface of the bipolar electrode plate is configured to accommodate at least a portion of the carbon material.

25. The electrochemical cell of claim 24, wherein the cathode cage is disposed over the carbon material such that the carbon material is disposed between the recessed portion and the cathode cage.

26. The electrochemical cell of any one of claims 17-25, wherein the aqueous zinc-halide electrolyte comprises zinc bromide, zinc chloride, or any combination thereof.

27. The electrochemical cell of any one of claims 17-26, wherein the aqueous zinc-halide electrolyte comprises an indium-containing compound, a tin-containing compound, a lead-containing compound, or any combination thereof.

28. The electrochemical cell of any one of claims 17-27, wherein the cathode cage comprises a pocket region, and the pocket region comprises a plurality of thru holes.

29. The electrochemical cell of claim 28, wherein the plurality of thru holes are evenly spaced and distributed along rows in an alternating repeating pattern.

30. The electrochemical cell of either of claims 28 or 29, wherein each of the thru holes comprises a calculated diameter based upon a spacing between the cathode assembly and the back surface of an adjacent bipolar electrode plate at each of a plurality of locations corresponding to locations of the plurality of holes.

31. The electrochemical cell of claim 30, wherein the calculated diameter for each hole is further based upon a nominal hole area and a nominal minimum spacing between the cathode assembly and the back surface of the adjacent bipolar electrode plate.

32. The electrochemical cell of either of claims 30 or 31, wherein the spacing between the cathode assembly and the back surface of the adjacent bipolar electrode plate at each location is calculated using a fit equation based on a measured delta from flat for each of the cathode assembly and the back surface of the adjacent bipolar electrode plate at each of the plurality of locations.

33. A rechargeable bipolar zinc-halide battery stack comprising:

a plurality of bipolar electrodes;

a terminal cathode assembly;

a terminal anode assembly; and

an aqueous zinc-halide electrolyte,

wherein each bipolar electrode comprises a cathode cage, a carbon material, a separator, and a bipolar electrode plate; the terminal cathode assembly comprises a first terminal endplate; the terminal anode assembly comprises a second terminal endplate; the bipolar electrode plate,

the cathode cage, the first terminal endplate, and the second terminal endplate each comprise a titanium material that is at least partially coated with titanium carbide.

34. The battery stack of claim 33, wherein the separator comprises a carbon cloth or a carbon felt.

35. The battery stack of either of claims 33 or 34, wherein the carbon material comprises a carbon black material.

36. The battery stack of any one of claims 33-35, wherein the aqueous zinc-halide electrolyte comprises zinc bromide, zinc chloride, or any combination thereof.

37. The battery stack of any one of claims 35-36, wherein the aqueous zinc-halide electrolyte comprises an indium-containing compound, a tin-containing compound, a lead-containing compound, or any combination thereof.

38. The battery stack of any one of claims 33-37, wherein the front surface of each bipolar electrode plate further comprises a recessed portion.

39. The battery stack of claim 38, wherein the recessed portion of the front surface of each bipolar electrode plate is configured to accommodate at least a portion of the carbon material.

40. The battery stack of claim 39, wherein the cathode cage is disposed over the carbon material such that the carbon material is disposed between the recessed portion and the cathode cage.

41. The battery stack of any one of claims 33-40, wherein the separator is disposed between the carbon material and the cathode cage.

42. The battery stack of any one of claims 33-41, wherein the cathode cage comprises a pocket region, and the pocket region comprises a plurality of thru holes.

43. The battery stack of claim 42, wherein the plurality of thru holes are evenly spaced and distributed along rows in an alternating repeating pattern.

44. The battery stack of either of claims 42 or 43, wherein each of the thru holes comprises a calculated diameter based upon a spacing between the cathode assembly and the back surface of an adjacent bipolar electrode plate at each of a plurality of locations corresponding to locations of the plurality of holes.

45. The battery stack of claim 44, wherein the calculated diameter for each hole is further based upon a nominal hole area and a nominal minimum spacing between the cathode assembly and the back surface of the adjacent bipolar electrode plate.

46. The battery stack of either of claims 44 or 45, wherein the spacing between the cathode assembly and the back surface of the adjacent bipolar electrode plate at each location is calculated using a fit equation based on a measured delta from flat for each of the cathode assembly and the back surface of the adjacent bipolar electrode plate at each of the plurality of locations.

47. The battery stack of any one of claims 33-46, wherein at least a portion of the back surface of each bipolar electrode plate is a rough surface.