LIQUID CATHODE FORMULATION FOR RECHARGEABLE METAL HALIDE BATTERY

TECHNICAL FIELD

[0001] The present invention relates generally to rechargeable batteries and, more specifically, to active cathode electrolyte formulations for rechargeable metal halide batteries.

BACKGROUND OF THE INVENTION

[0002] Rechargeable batteries are in high demand for a wide range of applications, from small batteries for industrial and medical devices, to larger batteries for electric vehicles and grid energy storage systems. Each application requires a range of electrochemical properties, yet today, battery performance is still considered a limiting factor for satisfying the high standard of the customers.

[0003] There are currently two types of rechargeable batteries: batteries that run via electrochemical intercalation/de-intercalation behavior of acting ions, such as lithium ion batteries; and batteries that run via a conversion reaction of active electrode/electrolyte materials, such as nickel metal hydride (NiMH) batteries. The most well-known and widely used rechargeable batteries are lithium-ion batteries that use an intercalated lithium compound as one electrode material, which allows lithium ions to move back and forth in an electrolyte pond. NiMH batteries use nickel hydroxide as a positive electrode, a hydrogen-absorbing alloy as a negative electrode, and an alkaline electrolyte (e.g., potassium hydroxide).

[0004] Lithium-ion and NiMH batteries have shortcomings that are preventing them from being used in a wider range of applications. These shortcomings include slow charging speeds and the high cost of the heavy metal cathode materials required to manufacture the batteries.

SUMMARY OF THE INVENTION

[0005] The present invention overcomes the shortcomings in the art by providing a rechargeable metal halide battery with an optimized active cathode electrolyte solution.

[0006] In one embodiment, the present invention relates to a battery comprising: an anode; a cathode current collector; and an electrolyte that facilitates transport of ions between the anode and the cathode current collector, wherein the electrolyte includes: a solvent comprising one or more organic liquid compounds, an active cathode material comprising a mixture of a metal halide and its corresponding halogen, wherein the metal halide to halogen molar concentration ratio is greater than 0.5, the mixture is dissolved in the solvent, and the active cathode material is in contact with the cathode current collector, and an oxidizing gas dissolved in the solvent.

[0006a] In one aspect, the present disclosure provides a battery, comprising an anode; a cathode current collector; and an electrolyte that facilitates transport of ions between the anode and cathode, wherein the electrolyte

includes a solvent comprising one or more organic liquid compounds, an active cathode material comprising a mixture of a metal halide and its corresponding halogen, wherein the metal halide to halogen molar concentration ratio is 1.0 to 2.3, the mixture is dissolved in the solvent, and the active cathode material is in contact with the cathode current collector, and an oxidizing gas dissolved in the solvent.

[0007] In another embodiment, the present invention relates to an electrolyte for a rechargeable metal halide battery comprising: a solvent comprising one or more organic liquid compounds, an active cathode material.

comprising a mixture of a metal halide and its corresponding halogen, wherein the metal halide to halogen molar concentration ratio is greater than 0.5, the mixture is dissolved in the solvent, and the active cathode material is in contact with the cathode current collector, and an oxidizing gas dissolved in the solvent.

[0007a] In another aspect, the present disclosure provides an electrolyte for a rechargeable metal halide battery comprising a solvent comprising one or more organic liquid compounds, an active cathode material comprising a mixture of a metal halide and its corresponding halogen, wherein the metal halide to halogen molar concentration ratio is 1.0 to 2.3 and the mixture is dissolved in the solvent; and an oxidizing gas dissolved in the solvent.

[0008] In a further embodiment, the present invention relates to a rechargeable battery comprising: an anode; a cathode current collector; and an electrolyte that facilitates transport of ions between the anode and the cathode current collector, wherein the electrolyte includes: a mixed-solvent solution comprising a nitrile-based compound and/or a heterocyclic-based compound, an active cathode material comprising a mixture of a lithium iodide (LiI) and iodine (I_2), wherein the mixture is dissolved in the mixed-solvent solution, the LiI to I_2 molar concentration ratio is in the range of 0.5 to 8, and the active cathode material is in contact with the cathode current collector, and an oxidizing gas dissolved in the solvent.

[0008a] In yet another aspect, there is provided a rechargeable battery, comprising an anode; a cathode current collector; and an electrolyte that facilitates transport of ions between the anode and the cathode current collector, wherein the electrolyte includes a mixed-solvent solution comprising a nitrile-based compound and/or a heterocyclic-based compound, an active cathode material comprising a mixture of a LiI and I_2, wherein the mixture is dissolved in the mixed-solvent solution, the LiI to I_2 molar concentration ratio is in the range of 1.0 to 2.3, and the active cathode material is in contact with the cathode current collector, and an oxidizing gas dissolved in the solvent

[0009] In one aspect, the present invention relates to a method of preparing an electrolyte for a metal halide rechargeable battery, the method comprising: dissolving a mixture of a metal halide and its corresponding halogen in a solvent comprising a nitrile-based compound and/or a heterocyclic-based compound, wherein the metal halide to halogen molar concentration ratio is greater than 0.5; and introducing an oxidizing gas into the mixed-solvent solution.

[0009a] In a further aspect, the present disclosure provides method of preparing an electrolyte for a metal halide rechargeable battery, the method comprising dissolving a metal halide and its corresponding halogen in a solvent comprising a nitrile-based compound and/or a heterocyclic-based compound, wherein the metal halide to halogen molar concentration ratio is 1.0 to 2.3; and introducing an oxidizing gas into the solvent.

[0010] In another aspect, the present invention relates to a method of fabricating a metal halide rechargeable battery, the method comprising: dissolving a mixture of LiI and I_2 in a solvent to form an electrolyte solution, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound, and the LiI to I_2 molar concentration ratio is in the range of 0.5 to 8; forming a soaked separator by soaking a separator in the electrolyte

solution; forming a stack comprising an anode, the soaked separator, and a cathode current collector, wherein the soaked separator is place between the anode and the cathode current collector; and introducing an oxidizing gas into the stack.

[0010a] In another aspect, there is provided a method of fabricating a metal halide rechargeable battery, the method comprising dissolving LiI and I_2 in a solvent to form an electrolyte solution, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound, and the LiI to I_2 molar concentration ratio is in the range of 1.0 to 2.3; soaking a separator in the electrolyte solution; forming a stack comprising an anode, the soaked separator, and a cathode current collector, wherein the soaked separator is placed between the anode and the cathode current collector; and introducing an oxidizing gas into the stack.

[0011] In a further aspect, the present invention relates to a method of preparing an electrolyte for a metal halide rechargeable battery, the method comprising: combining a metal halide, the metal halide's corresponding halogen, an oxidizing gas, and a solvent, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound and the metal halide to halogen molar concentration ratio is greater than 0.5.

[0011a] In yet another aspect, the present disclosure provides a method of preparing an electrolyte for a metal halide rechargeable battery, the method comprising combining a metal halide, the metal halide's corresponding halogen, an oxidizing gas, and a solvent, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound and the metal halide to halogen molar concentration ratio is 1.0 to 2.3.

[0012] In another aspect, the present invention relates to a method of fabricating a metal halide rechargeable battery, the method comprising: forming an electrolyte solution comprising LiI, I_2, an oxidizing gas, and a solvent, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound, and the LiI to I_2 molar concentration ratio is in the range of 0.5 to 8; soaking a separator in the electrolyte solution; and forming a stack comprising an anode, the soaked separator, and a cathode current collector, wherein the soaked separator is placed between the anode and the cathode current collector.

[0012a] In a further aspect, there is provided a method of fabricating a metal halide rechargeable battery, the method comprising forming an electrolyte solution comprising LiI, I_2, an oxidizing gas, and a solvent, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound, and the LiI to I_2 molar concentration ratio is in the range of 1.0 to 2.3; soaking a separator in the electrolyte solution; and forming a stack comprising an anode, the soaked separator, and a cathode current collector, wherein the soaked separator is placed between the anode and the cathode current collector

CLAIMS

1. A battery, comprising:

an anode;

a cathode current collector; and

an electrolyte that facilitates transport of ions between the anode and cathode, wherein the electrolyte includes:

a solvent comprising one or more organic liquid compounds,

an active cathode material comprising a mixture of a metal halide and its corresponding halogen, wherein the metal halide to halogen molar concentration ratio is 1.0 to 2.3, the mixture is dissolved in the solvent, and the active cathode material is in contact with the cathode current collector, and

an oxidizing gas dissolved in the solvent.

2. The battery of claim 1, wherein the metal halide comprises a salt that dissociates into (i) an ion selected from the group consisting of I^-, Br^-, Cl^-, and F^- and (ii) an ion selected from the group consisting of Li^+, Mg^{2+}, $Al^{3+}$and Na^+.

3. The battery of claim 1, wherein the halogen is a molecular halogen comprising at least one of I_2, Br_2, Cl_2, and F_2.

4. The battery of claim 1, wherein the one or more organic liquid compounds comprise a nitrile and/or a heterocyclic compound.

5. The battery of claim 4, wherein the one or more organic liquid compounds comprise a glyme.

6. The battery of claim 1, wherein the anode comprises one or more alkali metals and/or one or more alkali earth metals.

7. The battery of claim 2, wherein the anode comprises at least one of Li, Mg, Al, and Na.

8. The battery of claim 1, wherein the cathode current collector comprises a porous carbon material and/or a metal.

9. The battery of claim 1, wherein the oxidizing gas is selected from the group consisting of oxygen, air, nitric oxide, nitrogen dioxide, and mixtures and combinations thereof.

10. An electrolyte for a rechargeable metal halide battery comprising:

a solvent comprising one or more organic liquid compounds,

an active cathode material comprising a mixture of a metal halide and its corresponding halogen, wherein the metal halide to halogen molar concentration ratio is 1.0 to 2.3 and the mixture is dissolved in the solvent; and

an oxidizing gas dissolved in the solvent.

11. The electrolyte of claim 10, wherein the metal halide comprises a salt that dissociates into (i) an ion selected from the group consisting of I^-, Br^-, Cl^-, and F^- and (ii) an ion selected from the group consisting of Li^+, Mg^{2+}, Al^{3+}, and Na^+.

12. The electrolyte of claim 10, wherein the halogen is a molecular halogen comprising at least one of I_2, Br_2, Cl_2, and F_2.

13. The electrolyte of claim 10, wherein the organic solvent comprises a nitrile and/or a heterocyclic compound.

14. The electrolyte of claim 13, wherein the organic liquid compound comprises a glyme.

15. The electrolyte of claim 10, wherein the oxidizing gas is selected from the group consisting of oxygen, air, nitric oxide, nitrogen dioxide, and mixtures and combinations thereof.

16. A rechargeable battery, comprising:

an anode;

a cathode current collector; and

an electrolyte that facilitates transport of ions between the anode and the cathode current collector, wherein the electrolyte includes:

a mixed-solvent solution comprising a nitrile-based compound and/or a heterocyclic-based compound,

an active cathode material comprising a mixture of a LiI and I_2, wherein the mixture is dissolved in the mixed-solvent solution, the LiI to I_2 molar concentration ratio is in the range of 1.0 to 2.3, and the active cathode material is in contact with the cathode current collector, and

an oxidizing gas dissolved in the solvent.

17. The rechargeable battery of claim 16, wherein the nitrile-based compound is methoxypropionitrile and the heterocyclic-based compound is 1,3-dioxolane.

18. The rechargeable battery of claim 16, wherein the mixed-solvent solution comprises a glyme-based compound.

19. The rechargeable battery of claim 18, wherein the glyme-based compound is 1,2-dimethoxyethane.

20. The rechargeable battery of claim 16, wherein the electrolyte comprises an additional lithium salt selected from the group consisting of lithium nitrate ($LiNO_3$), lithium fluoride (LiF), lithium bis(trifluoromethanesulfonyl)imide (LiTFSI; $LiC_2F_6NO_4S_2$), lithium trifluoromethanesulfonate ($LiCF_3SO_3$), lithium hexafluorophosphate ($LiPF_6$), lithium hexafluoroarsenate ($LiAsF_6$), lithium perchlorate ($LiClO_4$), and lithium tetrafluoroborate ($LiBF_4$).

21. The rechargeable battery of claim 16, wherein the anode comprises Li.

22. The rechargeable battery of claim 16, wherein the cathode current collector comprises a porous carbon material and/or a metal.

23. The rechargeable battery of claim 16, wherein the oxidizing gas is selected from the group consisting of oxygen, air, nitric oxide, nitrogen dioxide, and mixtures and combinations thereof.

24. A method of preparing an electrolyte for a metal halide rechargeable battery, the method comprising:

dissolving a metal halide and its corresponding halogen in a solvent comprising a nitrile-based compound and/or a heterocyclic-based compound, wherein the metal halide to halogen molar concentration ratio is 1.0 to 2.3; and

introducing an oxidizing gas into the solvent.

25. The method of claim 24, wherein the metal halide comprises a salt that dissociates into (i) an ion selected from the group consisting of I^-, Br^-, Cl^-, and F^- and (ii) an ion selected from the group consisting of Li^+, Mg^{2+}, Al^{3+} and Na^+.

26. The method of claim 24, wherein the halogen is a molecular halogen comprising at least one of I_2, Br_2, Cl_2, and F_2.

27. The method of claim 24, wherein the nitrile-based compound is methoxypropionitrile and the heterocyclic-based compound is 1,3-dioxolane.

28. The method of claim 24, wherein the mixed-solvent solution comprises a glyme-based compound.

29. The method of claim 24, wherein the glyme-based compound is 1,2-dimethoxyethane.

30. The method of claim 24, wherein the oxidizing gas is selected from the group consisting of oxygen, air, nitric oxide, nitrogen dioxide, and mixtures and combinations thereof.

31. A method of fabricating a metal halide rechargeable battery, the method comprising:

dissolving LiI and I_2 in a solvent to form an electrolyte solution, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound, and the LiI to I_2 molar concentration ratio is in the range of 1.0 to 2.3;

soaking a separator in the electrolyte solution;

forming a stack comprising an anode, the soaked separator, and a cathode current collector, wherein the soaked separator is placed between the anode and the cathode current collector; and

introducing an oxidizing gas into the stack.

32. The method of claim 31, wherein the nitrile-based compound is methoxypropionitrile and the heterocyclic-based compound is 1,3-dioxolane.

33. The method of claim 31, wherein the solvent comprises a glyme-based compound.

34. The method of claim 33, wherein the glyme-based compound is 1,2-dimethoxyethane.

35. A method of preparing an electrolyte for a metal halide rechargeable battery, the method comprising:

combining a metal halide, the metal halide's corresponding halogen, an oxidizing gas, and a solvent, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound and the metal halide to halogen molar concentration ratio is 1.0 to 2.3.

36. A method of fabricating a metal halide rechargeable battery, the method comprising:

forming an electrolyte solution comprising LiI, I_2, an oxidizing gas, and a solvent, wherein the solvent comprises a nitrile-based compound and/or a heterocyclic-based compound, and the LiI to I_2 molar concentration ratio is in the range of 1.0 to 2.3;

soaking a separator in the electrolyte solution; and

forming a stack comprising an anode, the soaked separator, and a cathode current collector, wherein the soaked separator is placed between the anode and the cathode current collector.