Claims:

1. A nonaqueous electrolyte solution for a lithium battery, which solution comprises

i) a liquid electrolyte medium;

ii) a lithium-containing salt; and

iii) at least one brominated flame retardant selected from

a) a brominated thiophene having two or more bromine atoms bound to the same thiophene ring, in which

the brominated thiophene has one or two substituents on the thiophene ring in addition to the bromine atoms, which substituents are selected from ether groups, ester groups, or carbonate groups, with the proviso that the ether oxygen atom is not bound directly to the thiophene ring, and which brominated thiophene has about six to about twelve carbon atoms, or

the brominated thiophene is 2,3-dibromothiophene, 2,4-dibromothiophene, 2,5-dibromothiophene, 3,4-dibromothiophene, 2,3,4-tribromothiophene, or 2,3,5-tribromothiophene,

b) a brominated thiazole having one or two bromine atoms bound to the thiazole ring, wherein when the brominated thiazole has two bromine atoms bound to the thiazole ring and the bromine atoms are in the 2 and 5 positions on the ring, a carbon atom of the thiazole ring has an oxygen-containing substituent bound thereto, and

c) a brominated thiadiazole having one bromine atom bound to the thiadiazole ring and an oxygen-containing substituent bound to a carbon atom of the thiadiazole ring.

2. A nonaqueous electrolyte solution as in Claim 1 wherein the brominated flame retardant is

I) a brominated thiophene which has four to about twelve carbon atoms, two to about four bromine atoms bound to the thiophene ring, and/or a bromine content of about 40 wt% or more relative to the total weight of the brominated flame retardant;

a brominated thiazole which contains three to about twelve carbon atoms and has one bromine atom bound to the thiazole ring;

a brominated thiazole which contains four to about twelve carbon atoms and has two bromine atoms bound to the thiazole ring, and/or has a bromine content of about 30 wt% or more relative to the total weight of the brominated flame retardant; or

o

a brominated thiadiazole which has three to about twelve carbon atoms and/or a bromine content of about 22 wt% or more, relative to the total weight of the brominated flame retardant; or

II) a brominated thiophene which has four to about ten carbon atoms, two to about three bromine atoms bound to the thiophene ring, and a bromine content of about 45 wt% or more relative to the total weight of the brominated flame retardant;

a brominated thiazole which contains three to about ten carbon atoms and has one bromine atom bound to the thiazole ring, and a bromine content of about 30 wt% or more relative to the total weight of the brominated flame retardant; or

a brominated thiazole which contains four to about ten carbon atoms and has two bromine atoms bound to the thiazole ring, and a bromine content of about 30 wt% or more relative to the total weight of the brominated flame retardant; or

a brominated thiadiazole which has three to about ten carbon atoms, two bromine atoms bound to the thiazole ring, and a bromine content of about 22 wt% or more, relative to the total weight of the brominated flame retardant.

3. A nonaqueous electrolyte solution as in Claim 1 wherein the brominated flame retardant is

a brominated thiazole wherein the oxygen-containing substituent is selected from hydrocarbyloxy groups and ether groups; or

a brominated thiadiazole which has which has a bromine content of about 22 wt% to about 45 wt%, relative to the total weight of the brominated flame retardant.

4. A nonaqueous electrolyte solution as in any of Claims 1-2 or 3 wherein

the brominated thiazole is a 1,3-thiazole, optionally wherein the 1,3-thiazole is 2-bromothiazole, 4-bromothiazole, 5-bromothiazole, 2,4-dibromothiazole, 4,5-dibromothiazole, 4,5-dibromo-2-methoxythiazole, or 4,5-dibromo-2-(2-methoxyethoxy)thiazole; or

the brominated thiadiazole is a 1,3,4-thiadiazole, optionally wherein the 1,3,4-thiadiazole is 2-bromo-5-methoxy-1,3,4-thiadiazole, 2-bromo-5-(2-methoxyethoxy)-1,3,4-thiadiazole, or 2-bromo-5-(2-ethoxyethoxy)-1,3,4-thiadiazole.

o

5. A nonaqueous electrolyte solution as in Claim 1 wherein the brominated flame retardant is

i) a brominated thiophene which has an ether group as substituent on the thiophene ring, wherein the ether group has a portion between the thiophene ring and the ether oxygen atom, which portion is a saturated hydrocarbylene group having one to about four carbon atoms, and wherein the other group attached to the ether oxygen atom is a saturated hydrocarbyl group having one to about four carbon atoms, optionally wherein the brominated thiophene is propyl 1,1-dimethyl-2-[4-(2,3,5-tribromothiophene)]ethyl ether; or

ii) a brominated thiophene which has an ester group as substituent on the thiophene ring, wherein the carbonyl moiety of the ester group is bound directly to the thiophene ring, and wherein the other portion of the ester group is a hydrocarbyl group having one to about four carbon atoms, optionally wherein the brominated thiophene is methyl 2,5-dibromothiophene-3-carboxylate, ethyl 2,5-dibromothiophene-3-carboxylate, methyl 4,5-dibromothiophene-2-carboxylate, ethyl 4,5-dibromothiophene-2-carboxylate, ethyl 4,5-dibromothiophene-3-carboxylate, dimethyl 3,4-dibromothiophene-2,5-dicarboxylate, or diethyl 3,4-dibromothiophene-2,5-dicarboxylate; or

iii) a brominated thiophene which has a carbonate group as substituent on the thiophene ring, wherein an oxygen atom of the carbonate group can be bound directly to the thiophene ring, or not bound directly to the thiophene ring, and wherein the group attached to the other carbonate oxygen atom is either a hydrocarbyl group having one to about four carbon atoms or an ether group having three to about six carbon atoms, and one to three oxygen atoms.

6. A nonaqueous electrolyte solution as in Claim 5 wherein in iii)

the carbonate group is not bound to the thiophene ring via an oxygen atom of the carbonate group, and the portion of the carbonate group between the thiophene ring and the carbonate oxygen atom is a saturated hydrocarbylene group having one to about four carbon atoms; or

the brominated flame retardant is ethyl 4-(2,3,5-tribromothiophene) carbonate or methyl 1,1-dimethyl-2-[4-(2,3,5-tribromothiophene)]ethyl carbonate.

7. A nonaqueous electrolyte solution as in any of Claims 1-2, 3-4, 5, or 6 wherein the brominated flame retardant is in an amount of about 12 wt% or more bromine relative to the total weight of the solution.

o

8. A nonaqueous electrolyte solution as in any of Claims 1-2, 3-4, 5, 6, or 7 wherein the liquid electrolyte medium is ethylene carbonate, ethyl methyl carbonate, or a mixture thereof, and/or wherein the lithium-containing salt is lithium hexafluorophosphate, lithium di(fluoro)(oxalato)borate, or lithium bis(oxalato)borate.

9. A nonaqueous electrolyte solution as in any of Claims 1-2, 3-4, 5, 6, or 7-8 further comprising at least one electrochemical additive selected from:

I)

a) unsaturated cyclic carbonates containing three to about six carbon atoms,
b) fluorine-containing saturated cyclic carbonates containing three to about five carbon atoms and one to about four fluorine atoms,
c) tris(trihydrocarbylsilyl) phosphites containing three to about nine carbon atoms,
d) trihydrocarbyl phosphates containing three to about twelve carbon atoms,
e) cyclic sultones containing three to about eight carbon atoms,
f) saturated cyclic hydrocarbyl sulfites having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
g) saturated cyclic hydrocarbyl sulfates having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
h) cyclic dioxadithio polyoxide compounds having a 6-membered, 7-membered, or 8-membered ring and containing two to about six carbon atoms,
i) another lithium-containing salt, and
j) mixtures of any two or more of the foregoing; or

II)

a) unsaturated cyclic carbonates containing three to about four carbon atoms,
b) fluorine-containing saturated cyclic carbonates containing three to about four carbon atoms and one to about two fluorine atoms,
c) tris(trihydrocarbylsilyl) phosphites containing three to about six carbon atoms,
d) trihydrocarbyl phosphates containing three to about nine carbon atoms,
e) cyclic sultones containing three to about four carbon atoms,
f) saturated cyclic hydrocarbyl sulfites having a 5-membered ring and containing two to about four carbon atoms,

o

g) saturated cyclic hydrocarbyl sulfates having a 5-membered ring and containing two to about four carbon atoms,
h) cyclic dioxadithio polyoxide compounds having a 6-membered or 7-membered ring and containing two to about four carbon atoms,
i) another lithium-containing salt, and
j) mixtures of any two or more of the foregoing.

10. A nonaqueous electrolyte solution as in Claim 9 wherein the electrochemical additive is selected from:

a) an unsaturated cyclic carbonate in an amount of about 0.5 wt% to about 12 wt%, relative to the total weight of the nonaqueous electrolyte solution,
b) a fluorine-containing saturated cyclic carbonate in an amount of about 0.5 wt% to about 8 wt%, relative to the total weight of the nonaqueous electrolyte solution,
c) a tris(trihydrocarbylsilyl) phosphite in an amount of about 0.1 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,
d) a trihydrocarbyl phosphate in an amount of about 0.5 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,
e) a cyclic sultone in an amount of about 0.25 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,
f) a saturated cyclic hydrocarbyl sulfite in an amount of about 0.5 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,
g) a saturated cyclic hydrocarbyl sulfate in an amount of about 0.25 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,
h) a cyclic dioxadithio polyoxide compound in an amount of about 0.5 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,
i) another lithium-containing salt in an amount of about 0.5 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution, and
j) mixtures of any two or more of the foregoing.

11. A nonaqueous electrolyte solution as in any of Claims 7-9 or 10 wherein each electrochemical additive is not used with other electrochemical additives.

o

12. A nonaqueous electrolyte solution as in any of Claims 1-2, 3-4, 5, 6, 7-9, or 10 wherein the solution further comprises a nitrile compound, optionally wherein the nitrile compound is succinonitrile, or wherein the solution further comprises a nitrile compound and another lithium-containing salt, optionally wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.

13. A nonaqueous electrolyte solution for a lithium battery as in Claim 1, in which the solution comprises

at least one brominated flame retardant is selected from the group consisting of 2,3-dibromothiophene, 2,4-dibromothiophene, 2,5-dibromothiophene, 3,4-dibromothiophene, 2,3,4-tribromothiophene, 2,3,5-tribromothiophene, propyl 1,1-dimethyl-2-[4-(2,3,5-tribromothiophene)]ethyl ether, ethyl 4-(2,3,5-tribromothiophene) carbonate, methyl 1,1-dimethyl-2-[4-(2,3,5-tribromothiophene)]ethyl carbonate, methyl 2,5-dibromothiophene-3-carboxylate, ethyl 2,5-dibromothiophene-3-carboxylate, methyl 4,5-dibromothiophene-2-carboxylate, ethyl 4,5-dibromothiophene-2-carboxylate, ethyl 4,5-dibromothiophene-3-carboxylate, dimethyl 3,4-dibromothiophene-2,5-dicarboxylate, diethyl 3,4-dibromothiophene-2,5-dicarboxylate, 2-bromothiazole, 4-bromothiazole, 5-bromothiazole, 2,4-dibromothiazole, 4,5-dibromothiazole, 4,5-dibromo-2-methoxythiazole, 4,5-dibromo-2-(2-methoxyethoxy)thiazole, 2-bromo-5-methoxy-1,3,4-thiadiazole, 2-bromo-5-(2-methoxyethoxy)-1,3,4-thiadiazole, and 2-bromo-5-(2-ethoxyethoxy)-1,3,4-thiadiazole.

14. A nonaqueous electrolyte solution as in Claim 13 wherein the brominated flame retardant is 2,5-dibromothiophene, optionally wherein the brominated flame retardant is in an amount of about 12 wt% or more bromine relative to the total weight of the solution.

15. A nonaqueous electrolyte solution as in Claim 13 wherein the brominated flame retardant is 2,3-dibromothiophene, optionally wherein the brominated flame retardant is in an amount of about 13 wt% or more bromine relative to the total weight of the solution.

o

16. A nonaqueous electrolyte solution as in Claim 13 wherein the brominated flame retardant is 2-bromothiazole, 4-bromothiazole, 5-bromothiazole, 2,4-dibromothiazole, 4,5-dibromothiazole, 4,5-dibromo-2-methoxythiazole or 4,5-dibromo-2-(2-methoxyethoxy)thiazole.

17. A nonaqueous electrolyte solution as in any of Claims 13-15 or 16 wherein the liquid electrolyte medium is ethylene carbonate, ethyl methyl carbonate, or a mixture thereof, and/or wherein the lithium-containing salt is lithium hexafluorophosphate, lithium di(fluoro)(oxalato)borate, or lithium bis(oxalato)borate.

18. A nonaqueous electrolyte solution as in any of Claims 13-15 or 16 wherein the solution further comprises a nitrile compound or a nitrile compound and another lithium-containing salt, optionally wherein the nitrile compound is succinonitrile or wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.

19. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims 1-2, 3-4, 5, 6, 7-9, 10-12, 13-15, 16, or 17-18.

20. A process for producing a nonaqueous electrolyte solution for a lithium battery, which process comprises combining components comprising:

i) a liquid electrolyte medium;

ii) a lithium-containing salt; and

iii) at least one brominated flame retardant comprising

a) a brominated thiophene having two or more bromine atoms bound to the same thiophene ring, in which

the brominated thiophene has one or two substituents on the thiophene ring in addition to the bromine atoms, which substituents are selected from ether groups, ester groups, or carbonate groups, with the proviso that the ether oxygen atom is not bound directly to the thiophene ring, and which brominated thiophene has about six to about twelve carbon atoms, or

the brominated thiophene is is 2,3-dibromothiophene, 2,4-dibromothiophene, 2,5-dibromothiophene, 3,4-dibromothiophene, 2,3,4-tribromothiophene, or 2,3,5-tribromothiophene,

o

b) a brominated thiazole having one or two bromine atoms bound to the thiazole ring, wherein when the brominated thiazole has two bromine atoms bound to the thiazole ring and the bromine atoms are in the 2 and 5 positions on the ring, a carbon atom of the thiazole ring has an oxygen-containing substituent bound thereto, and

c) a brominated thiadiazole having one bromine atom bound to the thiadiazole ring and an oxygen-containing substituent bound to a carbon atom of the thiadiazole ring.

21. A process as in Claim 20 wherein the components further comprise at least one electrochemical additive selected from:

a) unsaturated cyclic carbonates containing three to about six carbon atoms,
b) fluorine-containing saturated cyclic carbonates containing three to about five carbon atoms and one to about four fluorine atoms,
c) tris(trihydrocarbylsilyl) phosphites containing three to about nine carbon atoms,
d) trihydrocarbyl phosphates containing three to about twelve carbon atoms,
e) cyclic sultones containing three to about eight carbon atoms,
f) saturated cyclic hydrocarbyl sulfites having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
g) saturated cyclic hydrocarbyl sulfates having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
h) cyclic dioxadithio polyoxide compounds having a 6-membered, 7-membered, or 8-membered ring and containing two to about six carbon atoms,
i) another lithium-containing salt, and
j) mixtures of any two or more of the foregoing; and/or

wherein the components further comprise a nitrile compound or a nitrile compound and another lithium-containing salt, optionally wherein the nitrile compound is succinonitrile or wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.

22. A process for producing a nonaqueous electrolyte solution for a lithium battery as in Claim 20, in which the at least one brominated flame retardant is selected from the group consisting of 2,3-dibromothiophene, 2,4-dibromothiophene, 2,5-dibromothiophene, 3,4-dibromothiophene, 2,3,4-tribromothiophene, 2,3,5-tribromothiophene, propyl 1,1-dimethyl-2-[4-(2,3,5-

o

tribromothiophene)]ethyl ether, ethyl 4-(2,3,5-tribromothiophene) carbonate, methyl 1,1-dimethyl-2-[4-(2,3,5-tribromothiophene)]ethyl carbonate, methyl 2,5-dibromothiophene-3-carboxylate, ethyl 2,5-dibromothiophene-3-carboxylate, methyl 4,5-dibromothiophene-2-carboxylate, ethyl 4,5-dibromothiophene-2-carboxylate, ethyl 4,5-dibromothiophene-3-carboxylate, dimethyl 3,4-dibromothiophene-2,5-dicarboxylate, diethyl 3,4-dibromothiophene-2,5-dicarboxylate, 2-bromothiazole, 4-bromothiazole, 5-bromothiazole, 2,4-dibromothiazole, 4,5-dibromothiazole, 4,5-dibromo-2-methoxythiazole, 4,5-dibromo-2-(2-methoxyethoxy)thiazole, 2-bromo-5-methoxy-1,3,4-thiadiazole, 2-bromo-5-(2-methoxyethoxy)-1,3,4-thiadiazole, and 2-bromo-5-(2-ethoxyethoxy)-1,3,4-thiadiazole.

23. A process as in Claim 22 wherein the components further comprise:

at least one electrochemical additive selected from vinylene carbonate, 4-fluoro-ethylene carbonate, tris(trimethylsilyl)phosphite, triallyl phosphate, 1,3-propane sultone, 1,3-propene sultone, ethylene sulfite, 1,3,2-dioxathiolane 2,2-dioxide, 1,5,2,4-dioxadithiane 2,2,4,4-tetroxide, lithium di(fluoro)(oxalato)borate, lithium bis(oxalato)borate, and mixtures of any two or more of these; and/or

a nitrile compound, optionally wherein the nitrile compound is succinonitrile; or wherein the components further comprise a nitrile compound and another lithium-containing salt, optionally wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.

24. A process as in any of Claims 22-23 wherein the brominated flame retardant is 2,3-dibromothiophene or 2,5-dibromothiophene.

o