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(54) Name of Invention

ELECTROLYTE AND LITHIUM SECONDARY BATTERY CONTAINING THE SAME

(57) Abstract

The present invention belongs to the field of lithium secondary batteries and discloses an electrolyte and a lithium secondary battery containing the same. The electrolyte comprises an electrolyte substance, an organic solvent, an additive, and a functional compound, the functional compound being at least one selected from the group consisting of a tricyanophosphite compound and a tricyanophosphate compound. The tricyanophosphite compound or the tricyanophosphate compound contained in the electrolyte of the present invention can form films on the surfaces of the positive and negative electrodes and can complex with metal ions to prevent metal ions at the positive electrode from detaching and dissolving into the electrode and to prevent the metal ions from depositing at the negative electrode, thereby stabilizing the structure of the positive electrode, improving the SEI film at the negative electrode, and improving the cycling performance and high-temperature performance of the lithium secondary battery. At the same time, the functional compound of the present invention can reduce the film impedance in a low-temperature environment and mitigate the issue of lithium precipitation during low-temperature charging.

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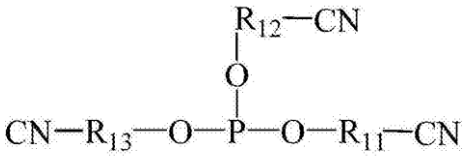
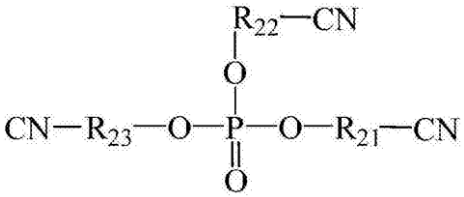
1. An electrolyte, wherein the electrolyte comprises an electrolyte substance, an organic solvent, an additive, and a functional compound, the functional compound being at least one selected from the group consisting of a tricyanophosphite compound and a tricyanophosphate compound, and the tricyanophosphite compound and the tricyanophosphate compound having, respectively, structural formulas as shown in formula (I) and formula (II) below:



formula (I),



formula (II); and

R_{11}, R_{12}, R_{13}, R_{21}, R_{22}, and R_{23} in the formulas are each independently selected from the group consisting of C1-C5 alkylene groups and fluoroalkylene groups.

2. The electrolyte of claim 1, wherein the mass percentage of the functional compound in the electrolyte is 0.05%-10%.

3. The electrolyte of claim 2, wherein the mass percentage of the functional compound in the electrolyte is 0.2%-5%.

4. The electrolyte of claim 1, wherein the electrolyte substance is at least one selected from the group consisting of $LiPF_6$, $LiBF_4$, $LiSO_3CF_3$, LiBOB, LiDFOB, LiTFSI, LiFSI, and $LiPO_2F_2$.

5. The electrolyte of claim 1, wherein the organic solvent comprises at least two selected from the group consisting of EC, PC, DMC, DEC, EMC, GBL, MA, EA, PA, BA, MP, EP, PP, BP, MB, EB, and PB.

6. The electrolyte of claim 5, wherein the organic solvent is at least two selected from the group consisting of EC, PC, EMC, DEC, PA, MP, EP, PP, and EB.

7. The electrolyte of claim 1, wherein the additive is at least one selected from the group consisting of FEC, VC, VEC, PS, BS, DTD, MMDS, PES, propylene sulfate, ethylene sulfite, SN, ADN, PN, HTCN, DENE, succinic anhydride, maleic anhydride, 2-methylmaleic anhydride, 2,3-dimethylmaleic anhydride, and itaconic anhydride.

8. A lithium secondary battery, comprising a positive electrode containing a positive electrode active material, a negative electrode containing a negative electrode active material, a separator, and an electrolyte; the positive electrode comprising a positive electrode active material for lithium ion intercalation or deintercalation, a conductive agent, a current collector, and a binder that binds the positive electrode active material, the conductive agent, and the current collector; and the negative electrode comprising a negative electrode active material that allows for lithium ion intercalation or deintercalation, a conductive agent, a current collector, and a binder that binds the negative electrode active material, the conductive agent, and the current collector, wherein the electrolyte is the electrolyte of any of claims 1 through 7.

ELECTROLYTE AND LITHIUM SECONDARY BATTERY CONTAINING THE SAME

TECHNICAL FIELD

[0001] The present invention belongs to the field of lithium secondary batteries and more particularly relates to an electrolyte and a lithium secondary battery containing the same.

BACKGROUND

[0002] Lithium secondary batteries provide a number of advantages, such as high operating voltage, high energy density, long cycle life, low self-discharge rate, no memory effects, and low pollution to the environment, and have been widely used in consumer electronic products, energy storage products, and power products. In recent years, as portable electronic products trend toward lighter weight and better performance, a higher demand is placed on the energy density of lithium secondary batteries. At present, in response to the continuous pursuit of higher energy density of batteries, a widely used strategy in the industry is to further compact the positive and negative electrodes and improve the cut-off voltage of the batteries. This is accompanied by deterioration of battery performance, and, in particular, it is easy for the SEI film formed on the surface of a battery's electrode to be damaged under a high voltage or a high temperature; during low-temperature charging [*sic*], as the kinetic performance of the battery is less than optimal, it is easy for lithium precipitation to occur during low-temperature charging and discharging, and thus the safety performance of the battery is affected.

[0003] Patent CN201510564696 discloses the use of a dicyano compound NC-R-CN as an additive to the electrolyte of a lithium-ion battery, which is capable of improving the battery's performance for high-temperature storage and cycling. Similarly, Patent CN201510964662 discloses the use of a compound having both an unsaturated carbon-carbon bond and a cyano group as an additive to the electrolyte of a lithium-ion battery; this enables polymerization on an electrode surface to form a compound containing a plurality of cyano groups, and this compound can complex with metal ions on the surface of the positive electrode material, thereby inhibiting the decomposition of the electrolyte at the surface of the electrode and improving the battery's performance for high-temperature storage and cycling. However, researchers in the art have discovered that film formation by a compound containing an unsaturated carbon-carbon double bond or triple bond increases the impedance, which causes lithium precipitation to occur more easily when the battery is charged at a low temperature and thereby lowers the battery's safety performance.

[0004] Therefore, it is of significant importance to develop a lithium secondary battery electrolyte for better high-temperature storage performance, cycling performance, and low-temperature charging performance.

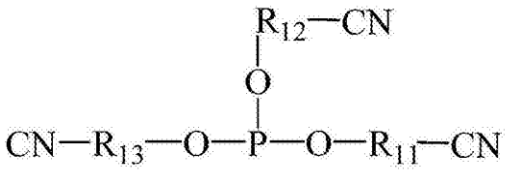
SUMMARY

[0005] The purpose of the present invention is to address the aforementioned technical issue, i.e., to provide an electrolyte and a lithium secondary battery containing the same for better high-temperature storage performance, cycling performance, and low-temperature charging performance.

[0006] The purpose of the present invention is achieved through the following technical solution:

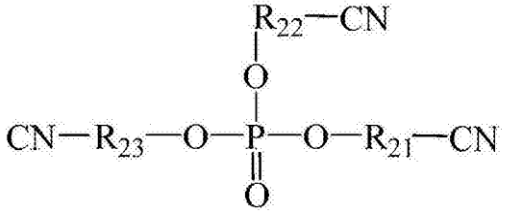
[0007] an electrolyte comprising an electrolyte substance, an organic solvent, an additive, and a

functional compound, the functional compound being at least one selected from the group consisting of a tricyanophosphite compound and a tricyanophosphate compound, and the tricyanophosphite compound and the tricyanophosphate compound having, respectively, structural formulas as shown in formula (I) and formula (II) below:



formula (I),

[0008]



formula (II); and

[0009] R_{11}, R_{12}, R_{13}, R_{21}, R_{22}, and R_{23} in the formulas are each independently selected from the group consisting of C1-C5 alkylene groups and fluoroalkylene groups.

[0010] Preferably, the mass percentage of the functional compound in the electrolyte is 0.05%-10%; when the percentage is less than 0.05%, the positive and negative electrodes are not well protected so it is difficult to adequately improve the battery's high-temperature storage performance and cycling performance; when the percentage is greater than 10%, increased viscosity of the electrolyte leads to deterioration of the battery's performance. More preferably, the mass percentage of the functional compound in the electrolyte is 0.2%-5%.

[0011] Preferably, the electrolyte substance is at least one selected from the group consisting of lithium hexafluorophosphate ($LiPF_6$), lithium tetrafluoroborate ($LiBF_4$), lithium trifluoromethanesulfonate ($LiSO_3CF_3$), lithium bis(oxalato)borate (LiBOB), lithium difluoro(oxalato)borate (LiDFOB), lithium bis(trifluoromethylsulphonyl)imide (LiTFSI), lithium bis(fluorosulfonyl)imide (LiFSI), and lithium difluorophosphate

[0012] ($LiPO_2F_2$).

[0013] The organic solvent comprises at least two selected from the group consisting of ethylene carbonate (EC), propylene carbonate (PC), dimethyl carbonate (DMC), diethyl carbonate (DEC), ethyl methyl carbonate (EMC), γ-butyrolactone (GBL), methyl acetate (MA), ethyl acetate (EA), propyl acetate (PA), butyl acetate (BA), methyl propionate (MP), ethyl propionate (EP), propyl propionate (PP), butyl propionate (BP), methyl butyrate (MB), ethyl butyrate (EB), and propyl butyrate (PB).

[0014] Preferably, the organic solvent is at least two selected from the group consisting of EC, PC, EMC, DEC, PA, MP, EP, PP, and EB.

[0015] The additive is a common additive used in the art; for example, the additive is at least one selected from the group consisting of fluoroethylene carbonate (FEC), vinylene carbonate (VC), vinyl ethylene carbonate (VEC), 1,3-propane sultone (PS), 1,4-butane sultone (BS), ethylene sulfate (DTD), methylene methanedisulfonate (MMDS), prop-1-ene-1,3-sultone (PES), propylene sulfate, ethylene sulfite, succinonitrile (SN), adiponitrile (ADN), pimelonitrile (PN), 1,3,6-hexanetricarbonitrile (HTCN), ethylene glycol bis(propionitrile) ether (DENE), succinic anhydride, maleic anhydride, 2-methylmaleic anhydride, 2,3-dimethylmaleic anhydride, and itaconic anhydride.

[0016] The present invention also relates to a lithium secondary battery containing the aforementioned electrolyte, the lithium secondary battery comprising a positive electrode containing a positive electrode active material, a negative electrode containing a negative electrode active material, a separator, and the aforementioned electrolyte; the positive electrode comprising a positive electrode active material for lithium ion intercalation or deintercalation, a conductive agent, a current collector, and a binder that binds the positive electrode active material, the conductive agent, and the current collector; and the negative electrode comprising a negative electrode active material that allows for lithium ion intercalation or deintercalation, a conductive agent, a current collector, and a binder that binds the negative electrode active material, the conductive agent, and the current collector.

[0017] The electrolyte of the present invention provides the following advantages and benefits:

[0018] the tricyanophosphite compound or the tricyanophosphate compound contained in the electrolyte of the present invention can form films on the surfaces of the positive and negative electrodes and can complex with metal ions to prevent metal ions at the positive electrode from detaching and dissolving into the electrode and to prevent the metal ions from depositing at the negative electrode, thereby stablizing the structure of the positive electrode, improving the SEI film at the negative electrode, and improving the cycling performance and high-temperature performance of the lithium secondary battery. At the same time, the functional compound of the present invention can reduce the film impedance in a low-temperature environment, mitigate the issue of lithium precipitation during low-temperature charging, and thereby significantly improve the safety performance of the battery.

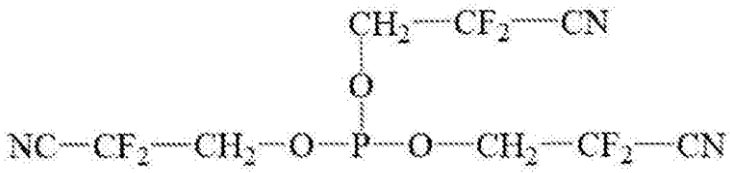
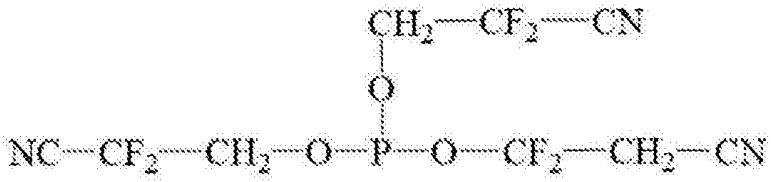
DETAILED DESCRIPTION

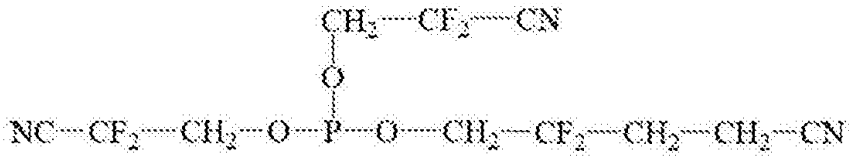
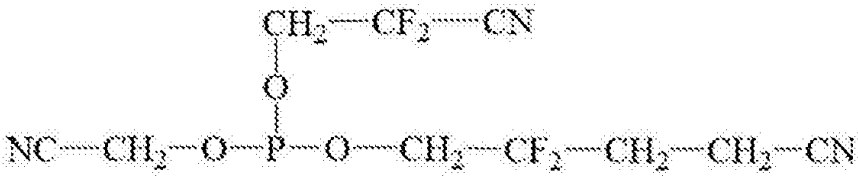
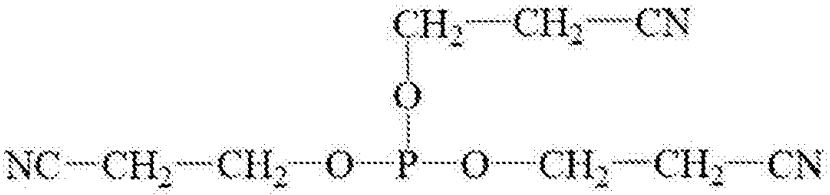
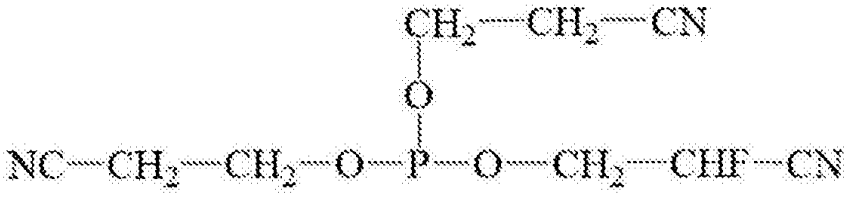
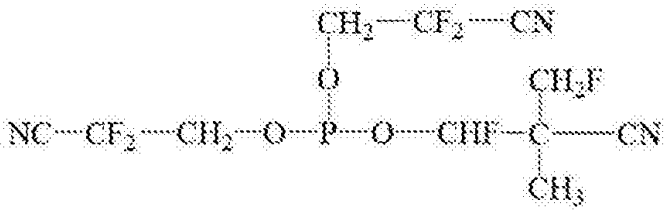
[0019] A more detailed description of the present invention is provided below in conjunction with embodiments; however, the present invention are not limited thereby.

[0020] The structures of the tricyanophosphite compounds and the tricyanophosphate compounds used in embodiments of the present invention are shown in Table 1 and Table 2, respectively.

[0021] Table 1 Tricyanophosphite compounds

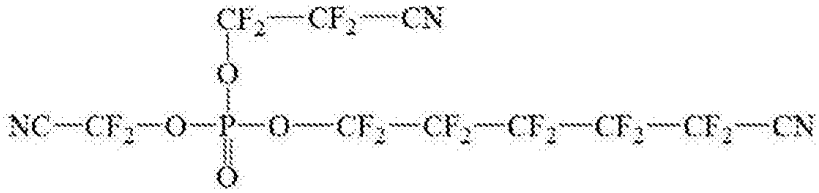
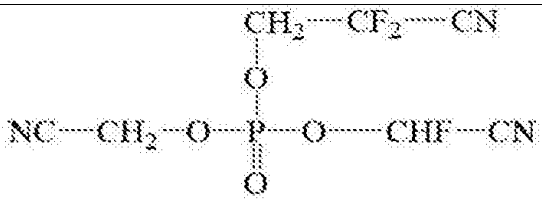
[0022]

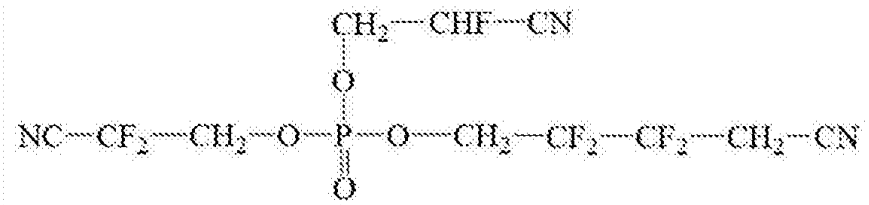
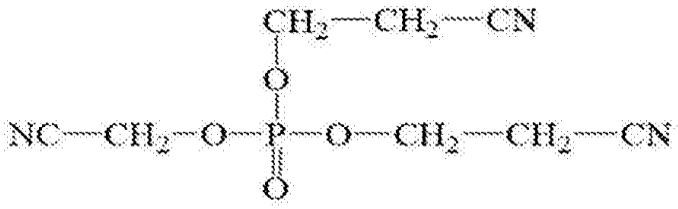
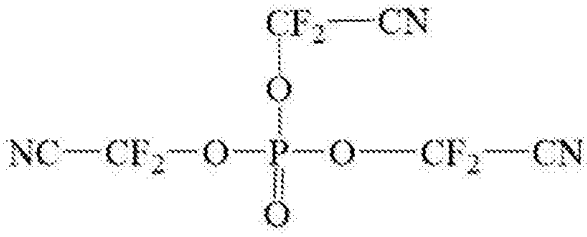
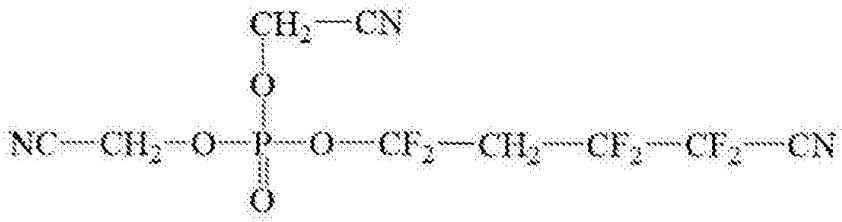
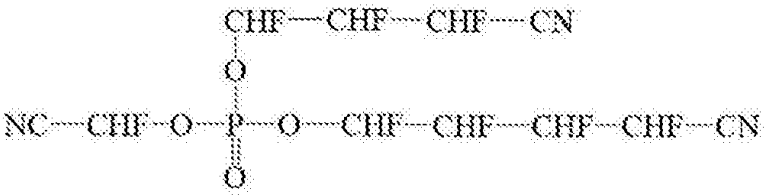
	Structural formula
Compound I_1	
Compound I_2	

Compound I_3	
Compound I_4	
Compound I_5	
Compound I_6	
Compound I_7	

[0023] Table 2 Tricyanophosphate compounds

[0024]

	Structural formula
Compound II_1	
Compound II_2	

Compound II_3	
Compound II_4	
Compound II_5	
Compound II_6	
Compound II_7	

[0025] Below are the steps for the manufacturing and performance testing of the lithium secondary battery according to embodiments of the present invention:

[0026] (1) Electrolyte preparation: mixing, in an argon atmosphere glove box, organic solvents according to a mass ratio; and then adding an additive, a tricyanophosphite compound or tricyanophosphate compound, and an electrolyte substance and stirring well to obtain the electrolyte of the present invention.

[0027] (2) Positive electrode preparation: dissolving polyvinylidene fluoride (PVDF) in 1-methyl-2-pyrrolidone (NMP) according to a mass ratio; then adding a positive electrode active material and a conductive agent to the aforementioned solution according to a mass ratio and mixing well; coating two surfaces of an aluminum foil with the mixed slurry; and performing drying and calendaring to obtain a positive electrode.

[0028] (3) Negative electrode preparation: dissolving a SBR binder and a CMC thickener in water according to a mass ratio; then adding a negative electrode material and a conductive agent to the aforementioned solution according to a mass ratio and mixing well; coating two surfaces of a copper foil with the mixed slurry; and performing drying and calendaring it to obtain a negative electrode.

[0029] (4) Lithium secondary battery manufacturing: making the positive electrode, the negative electrode, and the separator prepared above into a cell; injecting the electrolyte obtained in Step (1); and performing formation and other process steps to complete a lithium secondary battery.

[0030] (5) Battery performance testing

[0031] High-temperature cycle test: performing a charge/discharge cycle test on the battery at 0.5/0.5 C rate in a 45 °C temperature chamber. High-temperature storage performance test: performing charging and discharging of the battery once at 0.5/0.5 C rate in room temperature; then storing the battery at a high temperature after fully charging it at 0.5 C rate; performing a hot test on the thickness of the battery after it has been stored for a period of time; and performing a charge/discharge test at 0.5 C rate once the battery has cooled completely to calculate its capacity retention rate and capacity recovery rate. Low-temperature charge test: discharging the battery at 0.5 C rate in room temperature; fully charging the battery at 0.3 C rate after resting it in a high/low temperature chamber at 0 °C for 4 hours; and then disassembling the battery in an argon atmosphere glove box and observing whether lithium precipitation has occurred on the surface of the negative electrode.

[0032] The composition of the electrolyte in Embodiments 1-25 and Comparison Cases 1-6 of the present invention are shown in Table 3.

[0033] Table 3 Electrolyte composition in embodiments and comparison cases

[0034]

	Organic solvent	Additive	Functional compound	Electrolyte substance
Embodiment 1	EC:EMC:DEC:PC = 25:25:40:10	5% FEC	3% Compound I_1	1.1 M $LiPF_6$
Embodiment 2	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound I_1	1.1 M $LiPF_6$
Embodiment 3	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound I_2	1.1 M $LiPF_6$

[0035]

Embodiment 4	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound I_3	1.1 M $LiPF_6$
Embodiment 5	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound I_4	1.1 M $LiPF_6$
Embodiment 6	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound I_5	1.1 M $LiPF_6$
Embodiment 7	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound I_6	1.1 M $LiPF_6$
Embodiment 8	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound I_7	1.1 M $LiPF_6$
Embodiment 9	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound II_1	1.1 M $LiPF_6$
Embodiment 10	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound II_2	1.1 M $LiPF_6$

Embodiment 11	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound II_3	1.1 M $LiPF_6$
Embodiment 12	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound II_4	1.1 M $LiPF_6$
Embodiment 13	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound II_5	1.1 M $LiPF_6$
Embodiment 14	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound II_6	1.1 M $LiPF_6$
Embodiment 15	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound II_7	1.1 M $LiPF_6$
Embodiment 16	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.05% Compound I_1	1.1 M $LiPF_6$
Embodiment 17	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.2% Compound I_1	1.1 M $LiPF_6$
Embodiment 18	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	5% Compound I_1	1.1 M $LiPF_6$
Embodiment 19	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	10% Compound I_1	1.1 M $LiPF_6$
Embodiment 20	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.4% Compound I_1, 0.4% Compound II_2	1.1 M $LiPF_6$
Embodiment 21	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.4% Compound I_2, 0.4% Compound II_5	1.1 M $LiPF_6$
Embodiment 22	EC:PA:EP:DEC:PC = 25:20:20:25:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.5% PES, 1% DENE, 0.5% itaconic anhydride	1.0% Compound II_4	1.0 M $LiPF_6$ +0.1 M $LiPO_2F_2$
Embodiment 23	EC:MP:EB:DEC:PC = 25:20:20:25:10	4% PS, 6% FEC, 1% DENE, 1% PN, 0.3% VEC, 1% DENE, 0.5% maleic anhydride	2.0% Compound I_7	0.9 M LiFSI
Embodiment 24	EC:EA:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	0.8% Compound I_1	1.1 M $LiPF_6$
Embodiment 25	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.5% DTD, 1% DENE, 0.5% HTCN	1.5% Compound II_6	1.0 M $LiPF_6$ +0.5 M LiTFSI
Comparison Case 1	EC:EMC:DEC:PC = 25:25:40:10	5% FEC	--	1.1 M $LiPF_6$
Comparison Case 2	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	--	1.1 M $LiPF_6$
Comparison Case 3	EC:PA:EP:DEC:PC = 25:20:20:25:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.5% PES, 1% DENE, 0.5% itaconic anhydride	--	1.0 M $LiPF_6$ +0.1 M $LiPO_2F_2$
Comparison Case 4	EC:MP:EB:DEC:PC = 25:20:20:25:10	4% PS, 6% FEC, 1% DENE, 1% PN, 0.3% VEC, 1% DENE, 0.5% maleic anhydride	--	0.9 M LiFSI
Comparison Case 5	EC:EA:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.3% VEC, 1% DENE	--	1.1 M $LiPF_6$
Comparison Case 6	EC:PP:DEC:PC = 25:25:40:10	3% PS, 5% FEC, 2% ADN, 1% SN, 0.5% DTD, 1% DENE, 0.5% HTCN	--	1.0 M $LiPF_6$ +0.5 M LiTFSI

[0038] In the table, percentage refers to the mass percentage in the final electrolyte, and concentration

refers to the concentration in the final electrolyte.

[0039] Results from the performance testing of the lithium secondary battery made with the electrolyte according to Embodiments 1-25 and Comparison Cases 1-6 are shown in Table 4.

[0040] Table 4 Testing results for embodiments and comparison cases

[0041]

	45 ºC, 500 cycles		60 ºC, fully charged, stored for 30 days			Low-temperature charge at 0 ºC
	Capacity retention rate /%	Thickness change rate /%	Capacity retention rate /%	Capacity recovery rate /%	Thickness change rate /%	
Embodiment 1	86.9	4.9	78.2	87.5	8.6	No lithium precipitation
Embodiment 2	85.6	4.5	77.2	86.3	9.2	No lithium precipitation
Embodiment 3	84.5	4.1	78.1	85.2	9.5	No lithium precipitation
Embodiment 4	85.8	4.6	77.1	85.8	8.3	No lithium precipitation
Embodiment 5	83.1	4.9	76.5	86.9	7.6	No lithium precipitation
Embodiment 6	82.9	5.3	78.2	87.1	9.3	No lithium precipitation
Embodiment 7	83.5	4.8	77.5	87.8	7.1	No lithium precipitation
Embodiment 8	83.3	4.2	77.3	87.2	8.2	No lithium precipitation
Embodiment 9	86.2	3.8	76.5	85.3	9.8	No lithium precipitation
Embodiment 10	83.4	4.6	78.5	88.7	6.4	No lithium precipitation
Embodiment 11	82.1	4.6	76.1	85.8	9.2	No lithium precipitation
Embodiment 12	84.6	4.1	76.6	86.5	8.2	No lithium precipitation
Embodiment 13	84.8	4.5	78.1	89.4	6.1	No lithium precipitation
Embodiment 14	85.5	4.0	76.3	86.3	9.1	No lithium precipitation
Embodiment 15	85.2	4.3	76.1	86.8	9.5	No lithium precipitation
Embodiment 16	80.2	6.2	72.1	80.2	12.6	No lithium precipitation
Embodiment 17	83.9	5.3	75.3	84.5	10.5	No lithium precipitation

[0042]

Embodiment 18	85.6	4.1	77.8	87.9	7.4	No lithium precipitation
Embodiment 19	85.3	4.9	75.5	85.2	8.2	No lithium precipitation

Embodiment 20	86.2	4.2	78.8	89.6	6.3	No lithium precipitation
Embodiment 21	89.3	4.1	77.9	88.2	8.2	No lithium precipitation
Embodiment 22	86.6	3.6	78.3	88.5	8.9	No lithium precipitation
Embodiment 23	88.1	3.8	77.5	89.2	6.5	No lithium precipitation
Embodiment 24	78.9	9.2	69.1	75.2	13.5	No lithium precipitation
Embodiment 25	87.2	3.5	75.1	82.6	8.2	No lithium precipitation
Comparison Case 1	75.6	7.6	65.2	75.2	22.3	Lithium precipitation
Comparison Case 2	73.1	8.5	67.1	77.4	19.3	Lithium precipitation
Comparison Case 3	74.3	7.3	67.5	77.6	19.5	Lithium precipitation
Comparison Case 4	75.3	7.2	65.3	76.2	20.2	Lithium precipitation
Comparison Case 5	61.1	13.9	43.5	45.6	65.4	Slight lithium precipitation
Comparison Case 6	74.1	7.1	67.9	77.3	17.2	Slight lithium precipitation

[0043] By comparing Embodiments 1-25 and Comparison Cases 1-6, it is found that the addition of a tricyanophosphite compound or a tricyanophosphate compound can effectively improve the battery's cycling performance, significantly increase the battery's capacity retention rate after storage at a high temperature, suppress thickness expansion, and mitigate lithium precipitation during low-temperature charging.

[0044] The example embodiments above are better embodiments of the present invention; however, the present invention is not limited by the aforementioned embodiments, and any other alteration, modification, substitution, combination, and simplification made without deviating from the spirit, essence, and principle of the present invention shall be equivalent replacement and shall fall within the scope of protection of the present invention.

CERTIFICATE OF ACCURACY

I, Evelyn Garland, am competent to translate from Chinese into English and certify that the attached English language document(s) is a true and accurate translation of the original Chinese language document(s) CN106848381A to the best of my abilities.

I further declare that the statement in the preceding paragraph is true, and I understand that false statements and the like are punishable by fine and imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Date: January 17, 2023

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