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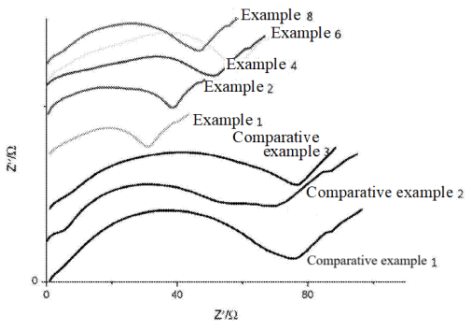
(54) Invention Name

Fast charging lithium-ion battery electrolyte

(57) Abstract

The present invention relates to the field of lithium-ion battery technology, and specifically, to a fast charging lithium-ion battery electrolyte, which is composed of a solvent, a lithium salt and an additive, wherein the solvent includes a mixture of two or more of a low-boiling-point linear carbonate and a linear carboxylic acid ester, fluorobenzene and hydrofluoroether; the additive includes a first additive for negative electrode film formation, a second additive for improving battery cycle performance, and a third additive for improving battery high temperature performance. Compared with the prior art, the combined use of the organic solvent and the three additives of the present invention produces a synergistic effect, which can meet the fast charging requirements of a fast charging system battery of above 2C with voltage of 4.35V, a negative electrode compaction density of 1.6g/cm^3 or more, a high potential and a high compaction density, and has good cycle performance and high and low temperature performance.



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Claims

1. A fast charging lithium-ion battery electrolyte, composed of a solvent, a lithium salt and an additive, characterized in that: the solvent includes a mixture of two or more of a low-boiling-point linear carbonate and a linear carboxylic acid ester, fluorobenzene and hydrofluoroether: the additive includes a first additive for negative electrode film formation, a second additive for improving battery cycle performance, and a third additive for improving battery high temperature performance.

2. The fast charging lithium-ion battery electrolyte according to claim 1, characterized in that: the solvent accounts for 70%-88% of the total mass of the lithium-ion battery electrolyte.

3. The fast charging lithium-ion battery electrolyte according to claim 1, characterized in that: the linear carbonate is dimethyl carbonate and/or ethyl methyl carbonate;

the linear carboxylic acid ester is at least one of propyl propionate, ethyl propionate, propyl acetate, butyl propionate, ethyl acetate, isopropyl propionate, ethyl butyrate, and methyl acetate.

4. The fast charging lithium-ion battery electrolyte according to claim 1, characterized in that: the hydrofluoroether is at least one of fluoromethyl-1,1,1,3,3,3-hexafluoroisopropyl ether, 1,1,2,2-tetrafluoroethyl ethyl ether, 2,6-difluoroanisole, 1,1,1,3,3,3-hexafluoroisopropyl methyl ether, tetrafluoromethyl butyl ether, 1,1,3,3,3-pentafluoro-2-trifluoromethylpropyl methyl ether, 1,1,2,2-tetrafluoroethyl-2,2,2-trifluoroethyl ether, 1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether, and 1,1,2,2-tetrafluoroethyl-4-methylphenyl ether.

5. The fast charging lithium-ion battery electrolyte according to claim 1, characterized in that: the additive accounts for 0.1%-20% of the total mass of the lithium-ion battery electrolyte.

6. The fast charging lithium-ion battery electrolyte according to claim 1, characterized in that: the first additive is at least one of vinylene carbonate, fluoroethylene carbonate, and 1,3-propane sultone, and the first additive accounts for 0.5%-10% of the total mass of the lithium-ion battery electrolyte.

7. The fast charging lithium-ion battery electrolyte according to claim 1, characterized in that: the second additive is at least one of lithium difluorooxalatoborate, lithium bisoxalatoborate, lithium bisfluorosulfonyl imide, lithium bistrifluoromethanesulfonyl imide, ethylene sulfate, 4-methyl ethylene sulfate, 4-ethyl ethylene sulfate, and 4-propyl ethylene sulfate, and the second additive accounts for 0.1%-5% of the total mass of the lithium-ion battery electrolyte.

8. The fast charging lithium-ion battery electrolyte according to claim 1, characterized in that: the third additive is a nitrile compound containing 2 or 3 nitrile functional groups, and the third additive accounts for 0.5%-5% of the total mass of the lithium-ion battery electrolyte.

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9. The fast charging lithium-ion battery electrolyte according to claim 8, characterized in that: the nitrile compound is at least one of succinonitrile, glutaronitrile, 2-methylglutaronitrile, hexanedinitrile, 1,3,6-hexanetrinitrile, and pimelonitrile.

10. The fast charging lithium-ion battery electrolyte according to claim 1, characterized in that: the lithium salt accounts for 8%-20% of the total mass of the lithium-ion battery electrolyte.

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FAST CHARGING LITHIUM-ION BATTERY ELECTROLYTE

Technical field

[0001] The present invention relates to the field of lithium-ion battery technology, and specifically, to a fast charging lithium-ion battery electrolyte.

Background technology

[0002] Lithium-ion batteries are widely used in 3C digital products, electric vehicles, military, aerospace and other fields due to their high operating voltage, high energy density, long cycle life and environmental friendliness. With the popularization of smart digital products, the application of new energy vehicles has become more and more extensive, and people's demand for fast charging has become more urgent. Shortening the charging time can improve user experience, and fast charging technology is an important direction for the development of battery cells in the future.

[0003] The development of fast charging technology is affected by many aspects. From the perspective of the battery cell itself, battery design, positive and negative electrode materials and electrolytes are the key factors affecting battery fast charging technology, among which, the impact of fast charging electrolytes on fast charging technology is particularly obvious. During the fast charging process of the battery, lithium-ions quickly escape from the positive electrode into the electrolyte, then pass through the diaphragm and enter the negative electrode for lithium insertion. The rapid migration of a large number of lithium-ions requires the electrolyte to have higher kinetic properties and smaller mass transfer resistance during the mass transfer process. Therefore, the electrolyte needs to meet better wettability, lower viscosity, and lower lithium-ion transmission resistance.

[0004] In the prior art, low-boiling-point organic solvents are commonly used to improve the kinetic properties of the electrolyte. For example, linear dimethyl carbonate, ethyl methyl carbonate, ethyl acetate, propyl acetate and other organic solvents have lower viscosity and can provide a more suitable channel for lithium-ion transmission. However, the use of these solvents will cause the high temperature performance of the battery to be challenged. At the same time, the poor compatibility of carboxylic acid ester organic solvents with the negative electrode graphite of the battery will cause the battery cycle performance to deteriorate.

[0005] Therefore, in the current needs of high energy density, high voltage, and high negative electrode compaction density, the development of a combination of solvents and additives that matches the fast charging electrolyte is the key to solving the above problems. In addition, the fast charging technology requires the electrolyte to have higher kinetic performance. Improving battery kinetics, high temperature performance, and cycle performance are the main goals of the fast charging electrolyte.

Content of the invention

[0006] The purpose of the present invention is to provide a fast charging lithium-

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ion battery electrolyte in view of the deficiencies of the prior art. The electrolyte can meet the requirements of fast charging requirements of a fast charging system battery above 2C with voltage of 4.35V, a negative electrode compaction density of 1.6g/cm^3 or more, a high potential and a high compaction density, and has good cycle performance and high and low temperature performance.

[0007] In order to achieve the above-mentioned purpose, the present invention adopts the following technical scheme:

[0008] A fast charging lithium-ion battery electrolyte is provided, which is composed of a solvent, a lithium salt and an additive. The non-aqueous organic solvent includes a mixture of two or more of a low-boiling-point linear carbonate and a linear carboxylic acid ester, fluorobenzene and hydrofluoroether; the additive includes a first additive for negative electrode film formation, a second additive for improving battery cycle performance, and a third additive for improving battery high temperature performance.

[0009] Preferably, the solvent accounts for 70%-88% of the total mass of the lithium-ion battery electrolyte.

[0010] Preferably, the linear carbonate is dimethyl carbonate or ethyl methyl carbonate;

[0011] The linear carboxylic acid ester is at least one of propyl propionate, ethyl propionate, propyl acetate, butyl propionate, ethyl acetate, isopropyl propionate, ethyl butyrate, and methyl acetate.

[0012] Preferably, the hydrofluoroether is at least one of fluoromethyl-1,1,1,3,3,3-hexafluoroisopropyl ether, 1,1,2,2-tetrafluoroethyl ethyl ether, 2,6-difluoroanisole, 1,1,1,3,3,3-hexafluoroisopropyl methyl ether, tetrafluoromethyl butyl ether, 1,1,3,3,3-pentafluoro-2-trifluoromethylpropyl methyl ether, 1,1,2,2-tetrafluoroethyl-2,2,2-trifluoroethyl ether, 1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether, and 1,1,2,2-tetrafluoroethyl-4-methylphenyl ether.

[0013] Preferably, the additive accounts for 0.1%-20% of the total mass of the lithium-ion battery electrolyte.

[0014] Preferably, the first additive is at least one of vinylene carbonate, fluoroethylene carbonate, and 1,3-propane sultone, and the first additive accounts for 0.5%-10% of the total mass of the lithium-ion battery electrolyte.

[0015] Preferably, the second additive is at least one of lithium difluorooxalatoborate (DFOB), lithium bisoxalatoborate (BOB), lithium bisfluorosulfonyl imide (FSI), lithium bistrifluoromethanesulfonyl imide (TFSI), ethylene sulfate (DTD), 4-methy ethylene sulfate (4-methy DTD), 4-ethyl ethylene sulfate (4-ethyl DTD), 4-propyl ethylene sulfate (4-Propyl-DTD), the second additive accounts for 0.1%-5% of the total mass of the lithium-ion battery electrolyte.

[0016] Preferably, the third additive is a nitrile compound containing 2 or 3 nitrile

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functional groups, and the nitrile compound can eliminate the high temperature performance deterioration caused by low-boiling-point compounds, so that the electrolyte has better kinetic performance as a whole. The third additive accounts for 0.5%-5% of the total mass of the lithium-ion battery electrolyte.

[0017] Preferably, the nitrile compound is at least one of succinonitrile, glutaronitrile, 2-methylglutaronitrile, hexanedinitrile, 1,3,6-hexanetrinitrile, and pimelonitrile.

[0018] Preferably, the lithium salt accounts for 8%-20% of the total mass of the lithium-ion battery electrolyte. More preferably, in order to improve the ability of fast charging, the lithium salt concentration of the electrolyte is moderately increased, and the lithium salt accounts for 12%-18% of the total mass of the lithium-ion battery electrolyte.

[0019] The beneficial effects of the present invention are:

[0020] A fast charging lithium-ion battery electrolyte of the present invention improves the battery kinetic performance by changing the solvent system, and selects linear carbonates, linear carboxylates, fluorobenzene and hydrofluoroethers that are easy to diffuse, have good wettability, low viscosity and low melting and boiling points as solvents in the solvent system; on the other hand, additives with low impedance are used to improve the battery film-forming performance, cycle performance and high-temperature performance, while reducing the use of high-impedance additives in the prior art. The additives are composed of negative electrode film-forming additives, additives for improving battery cycle performance, and additives for improving battery high-temperature performance. Compared with the prior art, the present invention has the following advantages: on the one hand, by using the above-mentioned low-boiling-point organic solvent to adjust the wetting effect and mass transfer resistance of the electrolyte system, a good channel is provided for the lithium-ion deintercalation process; on the other hand, due to the low-boiling-point linear carbonate and carboxylate introduced into the above-mentioned solvent, it will lead to the problems of incompatibility with graphite, poor battery cycle performance, and high temperature resistance (i.e., problems that cannot be solved by the prior art), but the present invention effectively reduces the use of high-impedance compounds by using three additives in combination, and the additives used to improve the battery cycle performance can effectively solve the problem of incompatibility with graphite caused by the introduction of low-boiling-point linear carbonate and carboxylate organic solvents, and at the same time, the nitrile additive of the present invention can also eliminate the deterioration of high-temperature performance caused by the above-mentioned low-boiling-point organic solvent. Therefore, the low boiling point organic solvent used in the present invention in combination with the three additives produces a synergistic effect, forming a matching electrolyte system with good kinetic performance, so as to meet the requirements of fast charging requirements of a fast charging system battery above 2C with voltage of 4.35V, a negative electrode compaction density of $1.6g/cm^3$ or more, a high potential and a high compaction density. At the same time, the electrolyte has both good cycle performance and high and low temperature performance.

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Description of the drawings

[0021] Figure 1 is a 2C/1C cycle performance test diagram of a battery prepared by the electrolytes of Comparative Example 3 and Examples 3-8.

[0022] Figure 2 is a 3C/1C cycle performance test diagram of a battery prepared by the electrolytes of Comparative Examples 1 and 2 and Examples 1, 2, 4, and 5.

[0023] Figure 3 is a 1C/1C cycle performance test diagram of a battery prepared by the electrolytes of Comparative Examples 1, 2, 3 and Examples 1, 2, 5, and 6 at 45°C.

[0024] Figure 4 is the AC impedance spectrum of the electrolytes of Comparative Examples 1, 2, 3 and Examples 1, 2, 4, 6, and 8 at a low temperature of 10°C.

Specific embodiments

[0025] The present invention is further described in conjunction with the following examples and drawings.

[0026] Comparative Example 1

[0027] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate and ethyl methyl carbonate are uniformly mixed in a mass ratio of 25:75, 1.0% by mass of vinylene carbonate and 2% by mass of 1,3-propane sultone are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 1.

[0028] Comparative Example 2

[0029] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate and ethyl methyl carbonate are mixed uniformly in a mass ratio of 25:55:20, 1.0% by mass of vinylene carbonate and 2% by mass of 1,3-propane sultone are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 1.

[0030] Comparative Example 3

[0031] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate and ethyl methyl carbonate are mixed uniformly in a mass ratio of 25:55:20, 1.0% by mass of vinylene carbonate, 2% by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, and 1.5% by mass of succinonitrile are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 1.

[0032] Example 1

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[0033] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, and ethyl acetate are mixed uniformly in a mass ratio of 25:35:20:20, 0.5% by mass of vinylene carbonate, 2% by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, 1.0% by mass of lithium difluorooxalate borate, and 1.5% by mass of succinonitrile are added to the mixed solution, and then 13.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 1.

[0034] Example 2

[0035] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, ethyl propionate, and fluorobenzene are mixed uniformly in a mass ratio of 25:35:20:12:8, 0.5% by mass of vinylene carbonate, 2% by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, 1.0% by mass of lithium difluorooxalate borate, and 1.5% by mass of succinonitrile are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 2.

[0036] Example 3

[0037] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, ethyl propionate, and 1,1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether are mixed uniformly in a mass ratio of 25:35:20:15:5, 0.5% by mass of vinylene carbonate, 2% by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, 1.0% by mass of lithium difluorooxalate borate, and 1.5% by mass of succinonitrile are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 3.

[0038] Example 4

[0039] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, and ethyl acetate are mixed uniformly at a mass ratio of 25:40:15:20, 0.5% by mass of vinylene carbonate, 2% by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, 1.0% by mass of 4-propyl ethylene sulfate, 0.5% by mass of lithium difluorooxalate borate, and 1.5% by mass of 1,3,6-hexane trinitrile are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 6.

[0040] Example 5

[0041] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, ethyl propionate, and 1,1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether are mixed uniformly in a mass ratio of 25:35:20:15:5, 0.5% by mass of vinylene carbonate, 2%

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by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, 1.0% by mass of 4-propyl ethylene sulfate, and 1.5% by mass of succinonitrile are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 5.

[0042] Example 6

[0043] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, ethyl acetate, and fluorobenzene are mixed uniformly in a mass ratio of 25:30:15:25:5, 0.5% by mass of vinylene carbonate, 2% by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, 1.0% by mass of 4-propyl ethylene sulfate, 0.5% by mass of lithium difluorooxalate borate, 1.5% by mass of succinonitrile and 1% by mass of adiponitrile are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 7.

[0044] Example 7

[0045] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, ethyl propionate, and 1,1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether are mixed uniformly in a mass ratio of 25:35:20:15:5, 0.5% by mass of vinylene carbonate, 2% by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, 1.0% by mass of ethylene sulfate, and 1.5% by mass of succinonitrile are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 4.

[0046] Example 8

[0047] In a glove box filled with argon (water content <10ppm, oxygen content <1ppm), ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, ethyl acetate, and fluorobenzene are mixed uniformly in a mass ratio of 25:30:10:20:5, 0.5% by mass of vinylene carbonate, 2% by mass of 1,3-propane sultone, 5% by mass of fluoroethylene carbonate, 1.0% by mass of 4-propyl ethylene sulfate, 0.5% by mass of lithium difluorooxalate borate, 1.5% by mass of 1,3,6-hexane trinitrile and 1% by mass of adiponitrile are added to the mixed solution, and then 14.0% by mass of $LiPF_6$ is slowly added and stirred until it is completely dissolved to obtain the lithium-ion battery electrolyte of Comparative Example 8.

[0048] The lithium-ion electrolyte prepared in the above Comparative Examples 1-3 and Examples 1-8 is respectively injected into a lithium-ion battery whose positive electrode active material is lithium cobalt oxide $LiCoO_2$ and whose negative electrode active material is LA-1 (compaction density is 1.65 g/cm^3). The battery after injection is packaged, shelved, formed, aged, repackaged, and divided into different volumes to obtain a lithium-ion battery to be tested.

[0049] Room temperature 2C/1C cycle experiment: the battery is charged at 2.0C

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to a limiting voltage of 4.35V and then changed to constant voltage charging until the charging current is no greater than the cut-off current, and then stood for 5 minutes, and then discharged at 1.0C to a cut-off voltage of 3.0V, and stood for 5 minutes. The charging and discharging experiment is carried out for more than 200 cycles according to the above steps, and the results are shown in Figure 1.

[0050] Room temperature 3C/1C cycle experiment: the battery is charged at 3.0C to a limiting voltage of 4.35V and then changed to constant voltage charging until the charging current is no greater than the cut-off current, and then stood for 5 minutes, and then discharged at 1.0C to a cut-off voltage of 3.0V, and stood for 5 minutes. The charging and discharging experiment is carried out for more than 200 cycles according to the above steps, and the results are shown in Figure 2.

[0051] 45℃-1C/1C cycle experiment: the battery is placed in a 45℃ constant temperature box, charged at 1.0C to a limiting voltage of 4.35V and then changed to constant voltage charging until the charging current is no greater than the cut-off current, and then stood for 5 minutes, and then discharged at 1.0C to a cut-off voltage of 3.0V, and stood for 5 minutes. The charging and discharging experiment is carried out for more than 300 cycles according to the above steps, and the results are shown in Figure 3.

[0052] The melting and boiling point data of some solvents used in Examples 1-8 are shown in Table 1:

[0053] Table 1. Melting and boiling point data of solvents used in Examples 1-8

[0054]

Solvent	Melting point/℃	Boiling point℃
Dimethyl carbonate	4.6	90
Ethyl methyl carbonate	-55	108
Ethyl acetate	-84	77.1
Ethyl propionate	-73.8	99
Butyl butyrate	-98	121.6
Fluorobenzene	-42	85

[0055] From the melting and boiling point data of some solvents in Examples 1-8 listed in Table 1, it can be seen that the melting and boiling points of the linear carbonate and carboxylate solvents used in the present invention are both low, providing a more suitable channel for lithium-ion transmission and reducing the impedance of the battery system.

[0056] Principle analysis:

[0057] Figure 4 is the AC impedance spectrum of the electrolytes of Comparative Examples 1-3 and Examples 1, 2, 4, 6, and 8 at a low temperature of 10°C. It can be seen from Figure 4 that the carbonate organic solvents used in Comparative Examples 1 to 3 and the commonly used vinylene carbonate additives have a large impedance, while in Examples 1 to 8 of the present invention, carboxylate or fluorobenzene

compounds are used as a replacement in the solvent system, reducing the amount of vinylene carbonate used, and the impedance has been significantly reduced.

[0058] The present invention systematically adjusts the battery solvent system and the additive composition, and the overall impedance of the electrolyte is reduced to a certain extent. The impedance sources of lithium-ions in the battery process have three components: the migration impedance of lithium-ions in the electrolyte, the impedance of lithium-ions passing through the SEI film, and the impedance of lithium-ions passing through the positive and negative electrodes, separating film and other materials. Usually, the impedance of lithium-ions passing through the SEI film is one of the characterization bases for studying the kinetic performance of lithium-ions in the battery system transmission process. From Figure 4, it can be found that the corresponding semicircle in the AC impedance curve can characterize the impedance behavior of lithium-ions in the SEI film. The larger the radius of the arc, the worse the kinetic performance, and the smaller the radius, the better the kinetic performance of the battery. The carboxylic acid esters, fluorobenzenes and fluoroether are used in the present invention have this property. First, these components often do not participate in the formation of the SEI film, and mainly provide a better channel for the transmission of lithium-ions. When using the carboxylic acid esters, fluorobenzenes and fluoroethers of the present invention, SEI film-forming additives are particularly important for the performance of the battery. On the one hand, the cycle performance of fast charging must be guaranteed, and on the other hand, other performance of the battery must not be affected. As for the selection of the above-mentioned carboxylic acid esters, fluorobenzene and fluoroethers, the applicant believes that non-methyl carboxylates at the end can be used in large quantities (accounting for up to 30% of the solvent system), while the amount of fluorobenzene and fluoroether compounds is relatively low, which is more conducive to the fast charging of the system under high voltage and high compaction conditions. This is largely related to the viscosity of fluorobenzene and fluoroethers; In addition, the boiling point of carboxylates is lower and the molecular weight is smaller, while the groups in fluorobenzene or fluoroethers are often larger, which is not conducive to the improvement of the kinetic performance of the electrolyte. The addition of fluorobenzene and fluoroether as auxiliary solvents can improve the comprehensive performance of the present invention.

[0059] In the above solvent system, the present invention improves the battery cycle performance with the help of certain special film-forming additives to make up for the incompatibility of the other negative electrodes. For the second additive for improving the battery cycle performance, lithium difluorooxalate borate, ethylene sulfate (DTD) and substituted ethylene sulfate have the best cycle stability. For the improvement of high temperature performance under high voltage of the fast charging system, among the nitrile compounds containing 2 or 3 nitrile functional groups in the third additive used in the present invention to improve the high temperature performance of the battery, 1,3,6-hexane trinitrile is particularly preferred. This is related to the poor compatibility of nitrile compounds with the negative electrode. The high temperature performance is often challenged when using the solvent system of the present invention. An efficient high temperature additive is the best choice. Nitrile compounds containing 2 or 3 nitrile functional groups, such as 1,3,6-hexane trinitrile, contain three nitrile groups, and the density of nitrile groups per unit volume is higher. It has better compatibility with the negative electrode and is easier to protect the positive

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electrode. The high temperature improvement effect of other dinitrile compounds or mononitrile compounds is relatively poor. This requires more nitrile to compensate. However, excessive addition of nitrile has a negative effect on the cycle performance, especially in the case of fast charging, this phenomenon is more obvious, and the cycle performance will drop rapidly.

[0060] Conclusion:

[0061] Figure 1 is a 2C/1C cycle performance test diagram of the battery prepared by the electrolyte of Comparative Example 3 and Examples 3-8. It can be seen from Figure 1 that the battery discharge capacity has a significant decrease in the initial stage. This is because after the positive electrode lithium-ions migrate to the vicinity during the fast charging process of the battery, a part of the lithium-ions cannot return to the positive electrode during discharge. The electrolyte of Comparative Example 3 began to drop after 50 cycles, and the cycle performance deteriorated rapidly, while the electrolyte of the present invention did not drop, and maintained a high discharge capacity in the later stage of the cycle.

[0062] Figure 2 is a 3C/1C cycle performance test diagram of the battery prepared by the electrolytes of Comparative Examples 1, 2 and Examples 1, 2, 4, and 5. It can be seen from Figure 2 that the electrolyte of the present invention can meet the requirements of 3C/1C cycle performance. After some formulations are cycled to 400 cycles, the capacity retention rate can still be as high as about 88%, showing that the electrolyte of the present invention has good fast charging ability and cycle performance.

[0063] Figure 3 is a 1C/1C cycle performance test diagram of the battery prepared by the electrolytes of Comparative Examples 1, 2, 3 and Examples 1, 2, 5, and 6 at 45°C. In order to further investigate the cycle performance of the battery at high temperature, a 1C/1C cycle performance test was conducted at 45°C. It can be seen from Figure 3 that the electrolytes of Comparative Examples 1, 2, 3 and Examples 1, 2, 5, and 6 all have good cycle performance. Although the present invention uses some low-boiling-point organic solvents, the synergistic effect between the additives prevents the battery from producing gas under high temperature conditions. The electrolyte also has good high-temperature cycle performance and can meet the use requirements of a higher temperature range.

[0064] In summary, the low boiling point organic solvent used in the present invention is used in combination with the three additives to produce a synergistic effect, forming a matching electrolyte system with good dynamic performance, which can meet the requirements of fast charging requirements of a fast charging system battery above 2C with voltage of 4.35V, a negative electrode compaction density of 1.6g/cm^3 or more, a high potential and a high compaction density. At the same time, the electrolyte also has good cycle performance and high and low temperature performance.

[0065] Finally, it should be noted that the above examples are only used to illustrate the technical solution of the present invention rather than to limit the scope of protection of the present invention. Although the present invention is described in detail with reference to the preferred examples, ordinary technicians in the field should understand that the technical solution of the present invention can be modified or

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replaced by equivalents without departing from the essence and scope of the technical solution of the present invention.

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Drawings

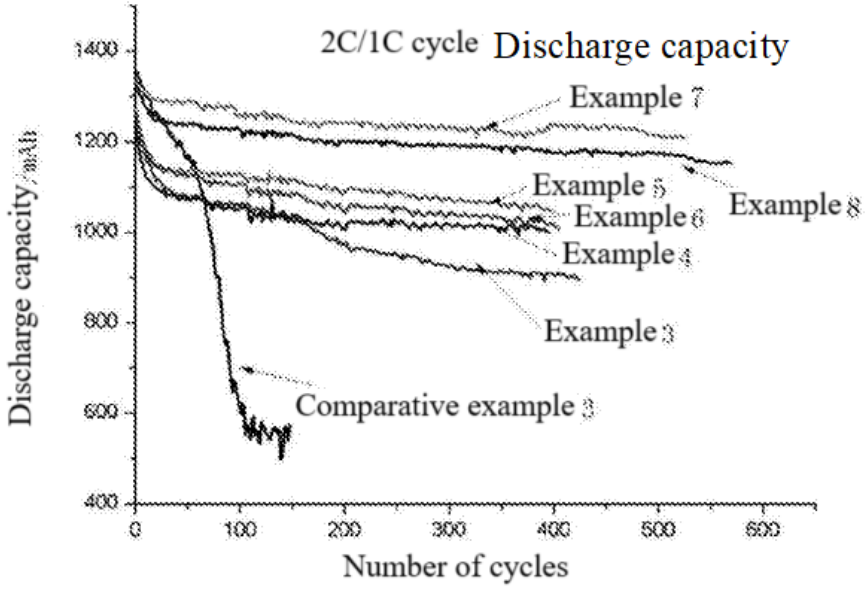

FIG. 1

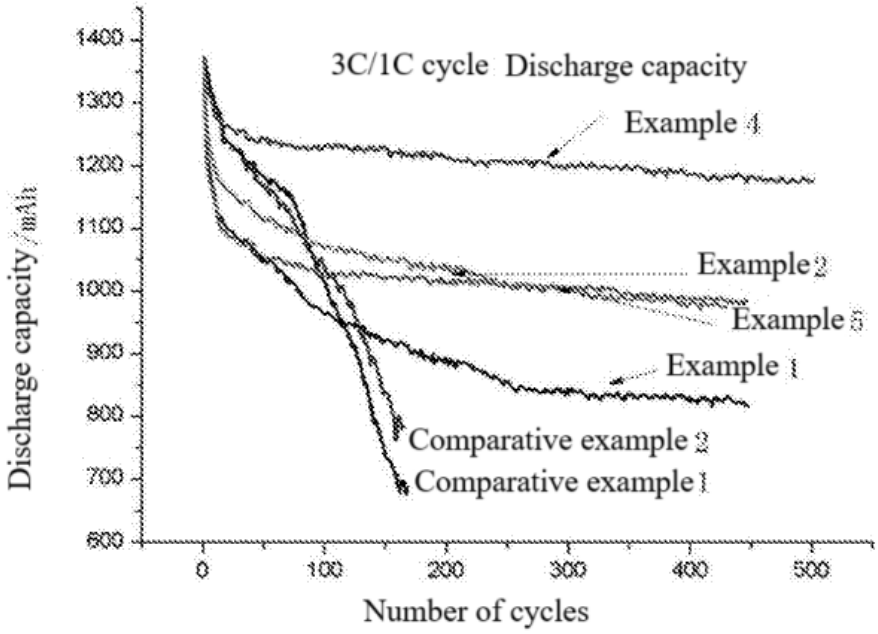

FIG. 2

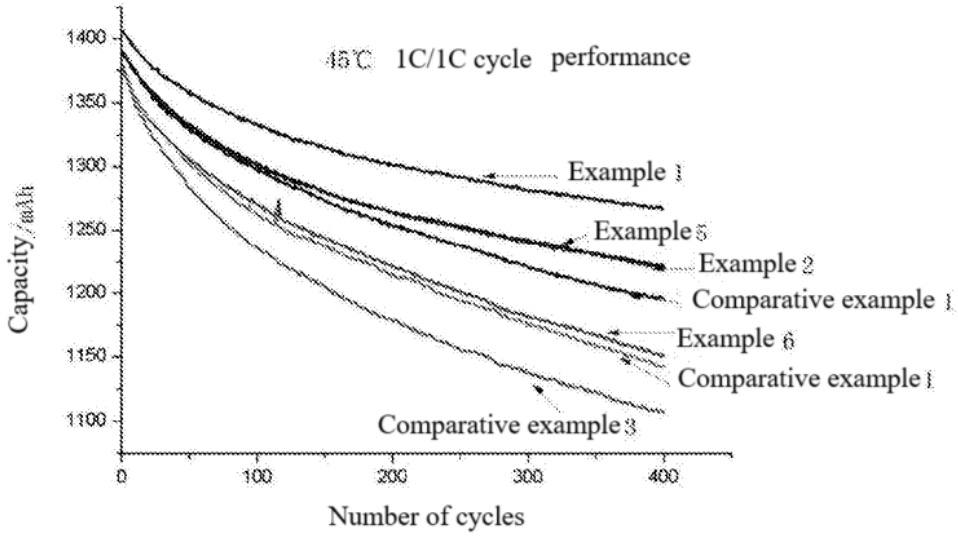
45℃ 1C/1C cycle performance
Capacity/mAh
1400
1350
1300
1250
1200
1150
1100
0
100
200
300
400
Number of cycles
Example 1
Example 5
Example 2
Comparative example 1
Example 6
Comparative example 1
Comparative example 3

FIG. 3

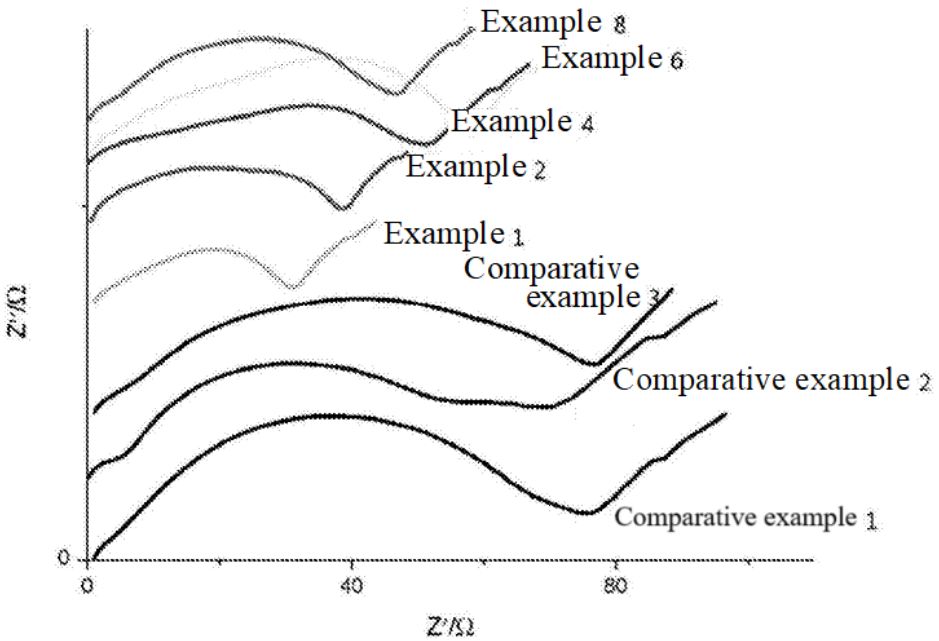
Example 8
Example 6
Example 4
Example 2
Example 1
Comparative example 3
Comparative example 2
Comparative example 1
Z''/Ω
0
0
40
80
Z'/Ω

FIG. 4

DECLARATION OF TRANSLATOR

I, Fengci Yao, hereby declare as follows:

1. I personally performed the attached translation from Chinese into English of the patent number CN105552439A that is entitled "一种快速充电的锂离子电池电解液" in Chinese and "Fast charging lithium-ion battery electrolyte " in English (also attached).

2. The attached translation is, to the best of my knowledge, a true, full and accurate translation of the attached Chinese document.

3. I am competent to perform this translation, because I have 20 years experiences of translation work in the related industry.

4. I declare under the penalty of perjury under the laws of the United States that the foregoing is true and correct; and further declare that I am aware that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 1001 of Title 18 of the United States Code.

Dated: 1/15/2025

Fengci Yao

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