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(54) Title: NON-AQUEOUS ELECTROLYTE AND LITHIUM-ION BATTERY COMPRISING THE SAME

(57) Abstract: A lithium-ion battery may be provided. The battery may comprise: a battery core comprising a cathode, a silicon anode, and a separator interposed between the cathode and the silicon anode; a non-aqueous electrolyte comprising a lithium salt, a non-aqueous solvent, and an additive in which the additive comprises diallyl pyrocarbonate; and a housing for accommodating the battery core and the non-aqueous electrolyte. Furthermore, a non-aqueous electrolyte for a lithium-ion battery having a silicon anode may also be provided.

NON-AQUEOUS ELECTROLYTE AND LITHIUM-ION BATTERY COMPRISING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority to and benefits of the following applications:

1) Chinese Patent Application No.201010556261.3 filed with the State Intellectual Property Office of the People's Republic of China (SIPO) on Nov. 24, 2010; and

2) Chinese Patent Application No.201110078105.5 filed with the State Intellectual Property Office of the People's Republic of China (SIPO) on Mar. 30, 2011.

The above enumerated patent applications are incorporated by reference herein in their entirety.

FIELD

The present disclosure relates to the field of energy storage, more particularly to a lithium-ion battery having a silicon anode and a non-aqueous electrolyte for a lithium-ion battery having a silicon anode.

BACKGROUND

The statements in this section merely provide background information related to the present disclosure and may or may not constitute prior art.

Silicon is widely used for forming an anode for a lithium-ion battery, because of the high lithium storage capacity and high reserves in the earth thereof. However, the Li-Si alloy may have a large volume change with the reversible battery reaction; and after several charging-discharging cycles, the Li-Si alloy may be pulverized or have cracks, which may cause the electrode material to be flaked off and electrically disconnected as well as cause the performance of the lithium-ion battery to be reduced. Furthermore, because huge gases are generated during the charging and/or discharging due to side reaction thereof, the lithium-ion battery may be swollen.

SUMMARY

In viewing thereof, the present disclosure is directed to solve at least one of the problems existing in the prior art. Therefore, a lithium-ion battery may need to be provided, which may enhance the charging and discharging performance of the lithium-ion battery in addition to prolonged lifespan thereof. Further, a non-aqueous electrolyte for a lithium-ion battery having a silicon anode may also need to be provided.

According to an embodiment of the present disclosure, a lithium-ion battery having a silicon anode may be provided, comprising: a battery core comprising a cathode, a silicon anode, and a separator interposed between the cathode and the silicon anode; a non-aqueous electrolyte comprising a lithium salt, a non-aqueous solvent, and an additive in which the additive comprises diallyl pyrocarbonate; and a housing for accommodating the battery core and the non-aqueous electrolyte.

According to another embodiment of the present disclosure, a non-aqueous electrolyte for a lithium-ion battery having a silicon anode may be provided. The non-aqueous electrolyte may comprise a lithium salt, a non-aqueous solvent and an additive. The additive may comprise diallyl pyrocarbonate.

According to an embodiment of the present disclosure, the lithium-ion batteries may have better charging and discharging performance with enhanced residual capacity as well as reduced thickness change. The effects thereof may be brought by forming a stable SEI (solid electrolyte interphase) film between the non-aqueous electrolyte and the Li ions by using the diallyl pyrocarbonate, thus alleviating or inhibiting the reaction between the Li-Si alloy and the organic solvent and effectively enhancing the charging/discharging performance of the battery in addition to reduction of side reactions. In addition, battery swelling is reduced dramatically, thus enhancing the cycling lifespan of the battery accordingly.

Additional aspects and advantages of the embodiments of the present disclosure will be given in part in the following descriptions, become apparent in part from the following descriptions, or be learned from the practice of the embodiments of the present disclosure.

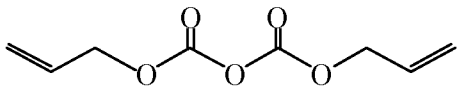
DETAILED DESCRIPTION

It will be appreciated by those of ordinary skill in the art that the disclosure may be embodied in other specific forms without departing from the spirit or essential character

thereof. The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restrictive.

In some embodiments, a lithium-ion battery may comprise: a battery core comprising a cathode, a silicon anode, and a separator interposed between the cathode and the silicon anode; a non-aqueous electrolyte comprising a lithium salt, a non-aqueous solvent, and an additive in which the additive comprises diallyl pyrocarbonate; and a housing for accommodating the battery core and the non-aqueous electrolyte.

In one embodiment, diallyl pyrocarbonate has a formula of:



. Diallyl pyrocarbonate may promote the formation of a stable SEI (solid electrolyte interphase) film between the non-aqueous solvent and the Li ions, and the SEI film may alleviate or inhibit the reaction of Li-Si alloy with the organic solvent, thus enhancing the charging/discharging performance of the battery. Furthermore, the C=C double bond in the allyl group may reduce water and HF in the electrolyte, which may avoid the reaction of HF with the SEI film, reduce the side reactions and avoid the swelling of the battery. Therefore, the charging/discharging performance and the cycling lifespan of the battery may be effectively enhanced.

In the non-aqueous electrolyte of the lithium-ion battery of the present disclosure, small amount of diallyl pyrocarbonate may enhance the charging-discharging performance and the cycling performance of the lithium-ion battery, because the diallyl pyrocarbonate may inhibit the reaction of the Li-Si alloy with the organic solvent. In one embodiment, based on the total weight of the non-aqueous electrolyte, the amount of diallyl pyrocarbonate is from about 0.1 wt. % to about 10 wt. %. For the lithium-ion battery without using silicon materials as the anode, diallyl pyrocarbonate does not have notable influence on the charging/discharging performance of the battery.

There are no special limitations on the contents of the lithium salt and the non-aqueous solvent in the non-aqueous electrolyte. In one embodiment, based on the total weight of the non-aqueous electrolyte, the amount of the lithium salt is from about 1 wt. % to about 10 wt. %, and the amount of the non-aqueous solvent is from about 80 wt. % to about 98.9 wt. %.

The lithium salt may be any known in the art, for example, at least one selected from a group consisting of $LiClO_4$ (lithium perchlorate), $LiPF_6$ (lithium hexafluorophosphate), $LiBF_4$ (lithium tetrafluoroborate), $LiAsF_6$ (lithium hexafluoroarsenate), $LiSO_3F$, and $LiCF_3SO_3$.

The non-aqueous solvent may be any known in the art, for example, at least one selected from a group consisting of ethylene carbonate (EC), dimethyl carbonate (DMC), ethyl methyl carbonate (EMC), fluoroethylene carbonate (FEC), and diethyl carbonate (DEC).

In one embodiment, the additive may further comprise at least one of diethyl pyrocarbonate and di-tert-butyl pyrocarbonate. In one embodiment, based on the total weight of the non-aqueous electrolyte, the amount of diethyl pyrocarbonate is from about 0.1 wt. % to about 10 wt. %, and the amount of di-tert-butyl pyrocarbonate is from about 0.1 wt. % to about 10 wt. %.

In the lithium-ion battery, the cathode, the separator and the battery package structure are well known in the art, so the detailed description thereof is omitted here for clarity purpose.

In one embodiment, the silicon anode may be made from at least one of a silicon nanowire material and a carbon-coated silicon nanowire material. The anode of the lithium-ion battery according to the present disclosure may be a silicon anode. The carbon-coated silicon nanowire material may improve the conductivity of the silicon material, avoid high irreversible capacity loss generated when the surface of the silicon material reacts with the non-aqueous electrolyte.

The silicon anode battery will be described in detail hereinafter with reference to the following embodiments.

EXAMPLE 1

(1) Preparation of non-aqueous electrolyte

At room temperature, in a glove box with a water content of less than 5ppm, a non-aqueous solvent was prepared by mixing EC, DEC and EMC with a weight ratio of about 2:1:3. And then, a non-aqueous electrolyte was prepared by firstly dissolving 8

weight parts of $LiPF_6$ in 87 weight parts of the non-aqueous solvent, and then adding 5 weight parts of diallyl pyrocarbonate.

The non-aqueous electrolyte was labeled as S1.

(2) Preparation of lithium-ion battery having silicon anode

$LiCoO_2$, polyvinylidene fluoride (PVDF), and a conductive agent were mixed evenly and coated onto an aluminum foil to form a positive plate. A silicon nanowire material, carboxymethyl cellulose (CMC), and styrene-butadiene rubber (SBR) were mixed evenly and coated onto a copper foil to form a negative plate. The positive plate, a PE/PP composite separator, the negative plate, and the non-aqueous electrolyte S1 were used to form a lithium-ion button battery having a silicon anode in an argon glove box using a conventional battery manufacturing process.

The lithium-ion button battery having a silicon anode obtained above was labeled as A1.

COMPARATIVE EXAMPLE 1

(1) Preparation of non-aqueous electrolyte

This step is substantially similar to the step (1) in EXAMPLE 1, with the exception that: the non-aqueous electrolyte was prepared by directly dissolving 8 weight parts of $LiPF_6$ in 92 weight parts of the non-aqueous solvent.

The non-aqueous electrolyte was labeled as DS1.

(2) Preparation of lithium-ion battery having silicon anode

This step is substantially similar to the step (2) in EXAMPLE 1, with the exception that: the positive plate, the PE/PP composite separator, the negative plate, and the non-aqueous electrolyte DS1 were used to form a lithium-ion button battery having a silicon anode in an argon glove box using the conventional battery manufacturing process.

The lithium-ion button battery obtained above was labeled as DA1.

COMPARATIVE EXAMPLE 2

(1) Preparation of non-aqueous electrolyte

This step is substantially similar to the step (1) in EXAMPLE 1, with the exception that: the non-aqueous electrolyte was prepared by firstly dissolving the 8 weight parts of $LiPF_6$ in 89.50 weight parts of the non-aqueous solvent, and then adding 0.5 weight parts of diethyl pyrocarbonate and 2 weight parts of vinylene carbonate.

The non-aqueous electrolyte was labeled as DS2.

(2) Preparation of lithium-ion battery having silicon anode

This step is substantially similar to the step (2) in EXAMPLE 1, with the exception that: the positive plate, the PE/PP composite separator, the negative plate, and the non-aqueous electrolyte DS2 were used to form a lithium-ion button battery having a silicon anode in an argon glove box using the conventional battery manufacturing process.

The lithium-ion button battery obtained above was labeled as DA2.

EXAMPLE 2

(1) Preparation of non-aqueous electrolyte

This step is substantially similar to the step (1) in EXAMPLE 1, with the exception that: the non-aqueous electrolyte was prepared by firstly dissolving 9 weight parts of $LiPF_6$ in 91.9 weight parts of the non-aqueous solvent, and then adding 0.1 weight parts of diallyl pyrocarbonate.

The non-aqueous electrolyte was labeled as S2.

(2) Preparation of lithium-ion battery having silicon anode

This step is substantially similar to the step (2) in EXAMPLE 1, with the exception that: the positive plate, the PE/PP composite separator, the negative plate, and the non-aqueous electrolyte S2 were used to form a lithium-ion button battery having a silicon anode in an argon glove box using the conventional battery manufacturing process.

The lithium-ion button battery obtained above was labeled as A2.

EXAMPLE 3

(1) Preparation of non-aqueous electrolyte

This step is substantially similar to the step (1) in EXAMPLE 1, with the exception that: the non-aqueous electrolyte was prepared by firstly dissolving 4 weight parts of $LiPF_6$ in 86 weight parts of the non-aqueous solvent, and then adding 10 weight parts of diallyl pyrocarbonate.

The non-aqueous electrolyte was labeled as S3.

(2) Preparation of lithium-ion battery having silicon anode

This step is substantially similar to the step (2) in EXAMPLE 1, with the exception that: the positive plate, the PE/PP composite separator, the negative plate, and the

non-aqueous electrolyte S3 were used to form a lithium-ion button battery having a silicon anode in an argon glove box using the conventional battery manufacturing process.

The lithium-ion button battery obtained above was labeled as A3.

EXAMPLE 4

(1) Preparation of non-aqueous electrolyte

This step is substantially similar to the step (1) in EXAMPLE 1, with the exception that: the non-aqueous electrolyte was prepared by firstly dissolving 5 weight parts of $LiPF_6$ in 85 weight parts of the non-aqueous solvent, and then adding 4 weight parts of diallyl pyrocarbonate, 3 weight parts of diethyl pyrocarbonate, and 3 weight parts of di-tert-butyl pyrocarbonate.

The non-aqueous electrolyte was labeled as S4.

(2) Preparation of lithium-ion battery having silicon anode

This step is substantially similar to the step (2) in EXAMPLE 1, with the exception that: the positive plate, the PE/PP composite separator, the negative plate, and the non-aqueous electrolyte S4 were used to form a lithium-ion button battery having a silicon anode in an argon glove box using the conventional battery manufacturing process.

The lithium-ion button battery obtained above was labeled as A4.

EXAMPLE 5

The EXAMPLE 5 is substantially similar to EXAMPLE 1, with the exception that: in the step (2), a carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate.

The lithium-ion button battery obtained above was labeled as A5.

EXAMPLE 6

The EXAMPLE 6 is substantially similar to EXAMPLE 2, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate.

The lithium-ion button battery obtained above was labeled as A6.

EXAMPLE 7

The EXAMPLE 7 is substantially similar to EXAMPLE 3, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate.

The lithium-ion button battery obtained above was labeled as A7.

EXAMPLE 8

The EXAMPLE 8 is substantially similar to EXAMPLE 4, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate.

The lithium-ion button battery obtained above was labeled as A8.

COMPARATIVE EXAMPLE 3

The COMPARATIVE EXAMPLE 3 is substantially similar to COMPARATIVE EXAMPLE 1, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate.

The lithium-ion button battery was labeled as DA3.

COMPARATIVE EXAMPLE 4

The COMPARATIVE EXAMPLE 4 is substantially similar to COMPARATIVE EXAMPLE 2, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate.

The lithium-ion button battery was labeled as DA4.

EXAMPLE 9

The EXAMPLE 9 is substantially similar to EXAMPLE 1, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate, and a lithium-ion square-shaped battery having a silicon anode with an aluminum housing was formed instead of a lithium-ion button battery having a silicon anode.

The lithium-ion square-shaped battery having a silicon anode obtained above was labeled as A9.

EXAMPLE 10

The EXAMPLE 10 is substantially similar to EXAMPLE 2, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate, and a lithium-ion square-shaped battery having a silicon anode with an aluminum housing was formed instead of a lithium-ion button battery having a silicon anode.

The lithium-ion square-shaped battery having a silicon anode obtained above was labeled as A10.

EXAMPLE 11

The EXAMPLE 11 is substantially similar to EXAMPLE 3, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate, and a lithium-ion square-shaped battery having a silicon anode with an aluminum housing was formed instead of a silicon anode lithium-ion button battery.

The lithium-ion square-shaped battery having a silicon anode obtained above was labeled as A11.

EXAMPLE 12

The EXAMPLE 12 is substantially similar to EXAMPLE 4, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate, and a lithium-ion square-shaped battery having a silicon anode with an aluminum housing was formed instead of a silicon anode lithium-ion button battery.

The lithium-ion square-shaped battery having a silicon anode obtained above was labeled as A12.

COMPARATIVE EXAMPLE 5

The COMPARATIVE EXAMPLE 5 is substantially similar to COMPARATIVE EXAMPLE 1, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate, and a lithium-ion square-shaped battery having a silicon anode with an aluminum housing was formed instead of a silicon anode lithium-ion button battery.

The lithium-ion square-shaped battery having a silicon anode obtained above was labeled as DA5.

COMPARATIVE EXAMPLE 6

The COMPARATIVE EXAMPLE 6 is substantially similar to COMPARATIVE EXAMPLE 2, with the exception that: in the step (2), the carbon-coated silicon nanowire material was used instead of the silicon nanowire material to form the negative plate, and

a lithium-ion square-shaped battery having a silicon anode with an aluminum housing was formed instead of a silicon anode lithium-ion button battery.

The lithium-ion square-shaped battery having a silicon anode obtained above was labeled as DA6.

TESTING

The lithium-ion button batteries A1 to A8 and DA1 to DA4 were charged and discharged under a current of about 0.1mA at a voltage of about 0.005V to 1.5V, the charge capacity and the discharge capacity of the button batteries A1 to A8 and DA1 to DA4 were recorded, and the discharge efficiency of the button batteries A1 to A8 and DA1 to DA4 were calculated respectively. The testing results thereof were shown in Table 1.

Discharge efficiency (%) = (charge capacity /discharge capacity) × 100%.

Table1

Battery	Charge Capacity /mAh	Discharge Capacity /mAh	Discharge Efficiency /%	Battery	Charge Capacity /mAh	Discharge Capacity /mAh	Discharge Efficiency /%
A1	3804	3215	84.52	A5	629	587	93.32
A2	3786	3106	82.04	A6	632	582	92.09
A3	3874	3225	83.25	A7	619	577	93.22
A4	3904	3279	83.99	A8	640	599	93.59
DA1	3386	847	25.02	DA3	558	261	46.77
DA2	3593	1693	47.12	DA4	571	417	73.03

The lithium-ion batteries A9 to A12, DA5 and DA6 were charged and discharged under a current of about 200mA at a voltage of about 3.0V to 4.2V, the initial charge capacity and the initial discharge capacity of the lithium-ion batteries A9 to A12, DA5 and DA6 were recorded, and the discharge efficiency of the lithium-ion batteries A9 to A12, DA5 and DA6 were calculated respectively. After 100 cycles, the residual charge capacity or remaining charge capacity and the discharge capacity of the lithium-ion batteries A9 to A12, DA5 and DA6 were recorded, the capacity residual rate of the lithium-ion batteries A9 to A12, DA5 and DA6 were calculated, and the thickness of the lithium-ion batteries A9 to A12, DA5 and DA6 before and after the 100 cycles were recorded. The results were shown in Table 2.

Capacity residual rate = (residual discharge capacity after 100 cycles / initial discharge capacity) × 100%.

Table 2

Battery	Initial Charge Capacity /mAh	Initial Discharge Capacity /mAh	Discharge Efficiency /%	Capacity residual Rate /%	Battery Thickness Before 100 Cycles /mm	Battery Thickness After 100 Cycles /mm
A9	984	980	99.59	62.7	5.3	6.2
A10	966	958	99.17	61.2	5.6	6.2
A11	974	969	99.49	60.7	5.4	6.1
A12	979	971	99.18	61.8	5.8	6.3
DA5	935	893	95.51	35.3	6.5	9.3
DA6	954	930	97.48	46.7	6.1	7.8

As shown in Table 1, compared with the lithium-ion button batteries DA1 to DA4, the lithium-ion button batteries A1 to A8 have better charging and discharging performance. As shown in Table 2, compared with the lithium-ion batteries DA5 and DA6, the lithium-ion batteries A9 to A12 have better charging and discharging performance, higher residual capacity after 100 cycles, and less thickness change with prolonged battery lifespan.

Although explanatory embodiments have been shown and described, it would be appreciated by those skilled in the art that changes, alternatives, and modifications can be made in the embodiments without departing from spirit and principles of the invention. Such changes, alternatives, and modifications all fall into the scope of the claims and their equivalents.

WHAT IS CLAIMED IS:

1. A lithium-ion battery, comprising:

a battery core comprising a cathode, a silicon anode, and a separator interposed between the cathode and the silicon anode;

a non-aqueous electrolyte comprising a lithium salt, a non-aqueous solvent, and an additive in which the additive comprises diallyl pyrocarbonate; and

a housing for accommodating the battery core and the non-aqueous electrolyte.

2. The lithium-ion battery according to claim 1, wherein based on the total weight of the non-aqueous electrolyte, the amount of diallyl pyrocarbonate is from about 0.1 wt. % to about 10 wt. %.

3. The lithium-ion battery according to claim 1, wherein based on the total weight of the non-aqueous electrolyte, the amount of the lithium salt is from about 1 wt. % to about 10 wt. %.

4. The lithium-ion battery according to claim 1, wherein based on the total weight of the non-aqueous electrolyte, the amount of the non-aqueous solvent is from about 80 wt. % to about 98.9 wt. %.

5. The lithium-ion battery according to claim 1, wherein the lithium salt is at least one selected from a group consisting of $LiClO_4$, $LiPF_6$, $LiBF_4$, $LiAsF_6$, $LiSO_3F$, and $LiCF_3SO_3$.

6. The lithium-ion battery according to claim 1, wherein the non-aqueous solvent is at least one selected from a group consisting of ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, fluoroethylene carbonate, and diethyl carbonate.

7. The lithium-ion battery according to claim 1, wherein the additive further comprises at least one of diethyl pyrocarbonate and di-tert-butyl pyrocarbonate.

8. The lithium-ion battery according to claim 7, wherein based on the total weight of the non-aqueous electrolyte, the amount of diethyl pyrocarbonate is from about 0.1 wt. % to about 10 wt. %, and the amount of di-tert-butyl pyrocarbonate is from about 0.1 wt. % to about 10 wt. %.

9. The lithium-ion battery according to claim 1, wherein the silicon anode is made from at least one of a silicon nanowire material and a carbon-coated silicon nanowire material.

10. A non-aqueous electrolyte for a lithium-ion battery having a silicon anode, comprising a lithium salt, a non-aqueous solvent and an additive, wherein the additive comprises diallyl pyrocarbonate.

11. The non-aqueous electrolyte according to claim 10, wherein based on the total weight of the non-aqueous electrolyte, the amount of diallyl pyrocarbonate is from about 0.1 wt. % to about 10 wt.%.

12. The non-aqueous electrolyte according to claim 10, wherein based on the total weight of the non-aqueous electrolyte, the amount of the lithium salt is from about 1 wt. % to about 10 wt. %.

13. The non-aqueous electrolyte according to claim 10, wherein based on the total weight of the non-aqueous electrolyte, the amount of the non-aqueous solvent is from about 80 wt. % to about 98.9 wt. %.

14. The non-aqueous electrolyte according to claim 10, wherein the lithium salt is at least one selected from a group consisting of $LiClO_4$, $LiPF_6$, $LiBF_4$, $LiAsF_6$, $LiSO_3F$, and $LiCF_3SO_3$.

15. The non-aqueous electrolyte according to claim 10, wherein the non-aqueous solvent is at least one selected from a group consisting of ethylene carbonate, dimethyl carbonate, ethyl methyl carbonate, fluoroethylene carbonate, and diethyl carbonate.

16. The non-aqueous electrolyte according to claim 10, wherein the additive further comprises at least one of diethyl pyrocarbonate and di-tert-butyl pyrocarbonate.

17. The non-aqueous electrolyte according to claim 16, wherein based on the total weight of the non-aqueous electrolyte, the amount of diethyl pyrocarbonate is from about 0.1 wt. % to about 10 wt. %.

18. The non-aqueous electrolyte according to claim 17, wherein based on the total weight of the non-aqueous electrolyte, the amount of di-tert-butyl pyrocarbonate is from about 0.1 wt. % to about 10 wt. %.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2011/082113

A. CLASSIFICATION OF SUBJECT MATTER

See Extra Sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI;EPODOC;CNKI;CNPAT: pyrocarbonate, electrolyte, silicon, nanowire, carbon, coat, core

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN1992420A(SAMSUNG SDI CO LTD) 04 Jul.2007(04.07.2007) the whole document	1-18
A	CN101684548A(ZHENJIANG KEJIE LITHIUM BATTERY CO LTD) 31 Mar.2010 (31.03.2010) the whole document	1-18
A	CN101719543A(UNIV QINGHUA) 02 Jun.2010(02.06.2010) the whole document	1-18
A	US6511769B1(SAMSUNG SDI CO LTD) 28 Jan.2003(28.01.2003) the whole document	1-18
A	EP0627780B1(SONY CORP) 04 Sep.1996(04.09.1996) the whole document	1-18
A	JP9245831A(TOMIYAMA YAKUHIN KOGYO KK) 19 Sep.1997(19.09.1997) the whole document	1-18
A	JP2001057230A(SONY CORP) 27 Feb.2001(27.02.2001) the whole document	1-18

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 Jan.2012(11.01.2012)	**16 Feb. 2012 (16.02.2012)**
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer LI,Hua Telephone No. (86-10)62411623

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Information on patent family members

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