Title: SEPARATION OF ELECTROLYTES IN LITHIUM BATTERIES

Abstract: Methods and articles relating to separation of electrolyte compositions within lithium batteries are provided. The lithium batteries described herein may include an anode having lithium as the active anode species and a cathode having sulfur as the active cathode species. Suitable electrolytes for the lithium batteries can comprise a heterogeneous electrolyte including a first electrolyte solvent (e.g., diolefin glycol (DOL)) that partitions towards the anode and is favorable towards the anode (referred to herein as an "anode-side electrolyte solvent") and a second electrolyte solvent (e.g., 1,2-dimethoxyethane (DME)) that partitions towards the cathode and is favorable towards the cathode (referred to herein as a "cathode-side electrolyte solvent"). By separating the electrolyte solvents during operation of the battery such that the anode-side electrolyte solvent is present disproportionately at the anode and the cathode-side electrolyte solvent is present disproportionately at the cathode, the battery can benefit from desirable characteristics of both electrolyte solvents (e.g., relatively low lithium reactivity of the anode-side electrolyte solvent and relatively high polysulfide solubility of the cathode-side electrolyte solvent).
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. H01M2/16 H01M4/02

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)

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 practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
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<tbody>
<tr>
<td>X</td>
<td>US 5 961 672 A (SKOTHEIM TERJE A [US] ET AL) 5 October 1999 (1999-10-05)</td>
<td>1,2,6,8, 9,13,14, 17, 19-21, 37-39,44</td>
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<td>examples 3-5</td>
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<td>X</td>
<td>EP 1 178 555 A (SAMSUNG SDI CO LTD [KR]) 6 February 2002 (2002-02-06)</td>
<td>1,2,6,8, 9,13,14, 17, 19-21, 37-39,44</td>
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<tr>
<td></td>
<td>paragraph [0031]; examples 1-7</td>
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</table>

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:
  
* A* document defining the general state of the art which is not considered to be of particular relevance
* E* earlier document but published on or after the international filing date
* L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
* O* document referring to an oral disclosure, use, exhibition or other means
* P* document published prior to the international filing date but later than the priority date claimed

* T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

* X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

* Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

* &* document member of the same patent family

Date of the actual completion of the International search: 20 May 2008

Date of mailing of the International search report: 03/06/2008

Name and mailing address of the ISA:

European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 apn nl, Fax: (+31-70) 340-3018

Authorized officer: Fitzpatrick, John
INTERNATIONAL SEARCH REPORT

Box No. II  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☑ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
   see FURTHER INFORMATION sheet PCT/ISA/210

3. □ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest  
☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)
Continuation of Box II.2

Claims Nos.:

The subject matter of the current application refers to a lithium battery including an electrolyte comprising at least two solvents. Theses solvents should be such that in use there is a partitioning of the solvents to respective electrodes and whereby the the solvent which partitions to the cathode reacts adversely with the anode. The prior art however abounds with lithium batteries comprising an electrolyte including multiple solvents. These solvents by virtue of simply being different always have different physical, chemical and electrochemical characteristics including, and merely by way of example, different dielectric constants. In use, i.e. when current flows, there will thus invariably be a certain partitioning i.e. one solvent will preferentially be attracted toward a specific electrode. Moreover, all lithium battery solvents react to a greater or lesser degree with the Li anode in view of the latter’s high oxidative potential. This is indeed necessary to form a protective layer which protects lithium from spontaneous dissolution. This protective layer does however influence the response characteristics of the battery and as such can also be considered to be an adverse reaction. This is the reason indeed that the lithium battery field is littered with attempts to alleviate the effects of this layer, by providing, for example, specific coatings which moderate the lithium electrode dissolution but which allow lithium ion passage therethrough.

With the above in mind, the initial phase of the search revealed a very large number of documents relevant to the issue of novelty. So many documents were retrieved that it is impossible to determine which parts of the claims may be said to define subject-matter for which protection might legitimately be sought (Article 6 PCT). For these reasons, the search was performed taking into consideration the non-compliance in determining the extent of the search.

The search was thus limited to the specific manners in which this partitioning phenomenon is enhanced in the current application, namely via:

(i) The type of polymer gel layer of claim 7
(ii) The type of separator of claim 10
(iii) The solubility ratio of claim 13
(iv) The immiscible solvents of claims 15
(v) The type of anode and/or cathode polymer layer of claims 17, 18 or 21

The applicant’s attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO
policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.2), should the problems which led to the Article 17(2)PCT declaration be overcome.
<table>
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<th>Patent document cited in search report</th>
<th>Publication date</th>
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<td>US 5961672</td>
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<td>US 2002045102 A1</td>
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