(19) DANMARK

(10) **DK/EP 3772129 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: ***H 01 M 10/0563 (2010.01)*** *H 01 M 4/505 (2010.01)* *H 01 M 4/587 (2010.01)* *H 01 M 4/80 (2006.01)* ***H 01 M 10/0525 (2010.01)*** *H 01 M 4/525 (2010.01)* *H 01 M 4/62 (2006.01)* *H 01 M 10/054 (2010.01)* ***H 01 M 10/0568 (2010.01)*** *H 01 M 4/58 (2010.01)* *H 01 M 4/74 (2006.01)* *H 01 M 10/0567 (2010.01)*

(45) Oversættelsen bekendtgjort den: **2021-07-26**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2021-06-30**

(86) Europæisk ansøgning nr.: **19189435.1**

(86) Europæisk indleveringsdag: **2019-07-31**

(87) Den europæiske ansøgnings publiceringsdag: **2021-02-03**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(73) Patenthaver: **Innolith Technology AG, Hirzbodenweg 95, 4052 Basel, Schweiz**

(72) Opfinder: **ZINCK, Laurent, 28, Rue de la vallée, 67470 Mothern, Frankrig**
BUSCH, Rebecca, Silberhölle 51, 76646 Bruchsal, Tyskland
Pszolla, Christian, Rheinstraße 105, 76185 Karlsruhe, Tyskland

(74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**

(54) Benævnelse: **SO2-BASERET ELEKTROLYT TIL EN GENOPLADELIG BATTERICELLE OG GENOPLADELIG BATTERICELLE OMFATTENDE DENNE**

(56) Fremdragne publikationer:
WO-A1-2017/178543
JP-A- 2001 143 750
JP-B2- 4 306 858
US-A- 4 891 281

Description

The invention relates to an SO_2-based electrolyte for a rechargeable battery cell, and a rechargeable battery cell.

Rechargeable battery cells are of great importance in many technical fields. They are often used for applications, which require only small rechargeable battery cells with relatively low current intensities, for example for the operation of cell phones. However, there is also a great need for larger rechargeable battery cells for high-energy applications, with mass storage of energy in the form of battery cells being of particular importance for the electric drive of vehicles.

High energy density is an important requirement for these types of rechargeable battery cells. This means that the rechargeable battery cell should contain as much electrical energy as possible per unit weight and volume. Lithium as an active metal has proven to be particularly advantageous for this purpose. The active metal of a rechargeable battery cell is the metal whose ions within the electrolyte migrate to the negative or positive electrode during cell charging or discharging, where they participate in electrochemical processes. These electrochemical processes lead directly or indirectly to the release of electrons into the external circuit or to the absorption of electrons from the external circuit. Rechargeable battery cells containing lithium as an active metal are also referred to as lithium-ion cells. The energy density of these lithium-ion cells can be increased either by expanding the specific capacity of the electrodes or by increasing the cell voltage.

Both the positive and negative electrodes of lithium-ion cells are designed as insertion electrodes. The term “insertion electrode” in the sense of this invention refers to electrodes which have a crystalline structure that ions of the active material can be stored in and removed from during operation of the lithium-ion cell. This means that the electrode processes can take place not only on the surface of the electrodes, but also within the crystalline structure. The negative electrode of lithium-ion cells consists of a carbon coating, which is applied to a conducting element made of copper. The conducting element provides the electronically conductive connection required between the carbon coating and the external circuit. The positive electrode consists of lithium cobalt oxide ($LiCoO_2$), which is applied to a conducting element made of aluminium. Both

electrodes typically have a thickness of less than 100 µm and are therefore very thin. When charging the lithium-ion cell, the ions of the active metal are removed from the positive electrode and stored in the negative electrode. The reverse process takes place when the lithium-ion cell is discharged.

The electrolyte is an important functional element of any rechargeable battery cell. It usually contains a solvent or solvent mixture and at least one conducting salt. Solid electrolytes or ionic liquids, for example, contain no solvent, rather only a conducting salt. The electrolyte is in contact with the positive and negative electrodes of the battery cell. At least one ion of the conducting salt (anion or cation) is mobile in the electrolyte such that a charge transport between the electrodes, required for the functioning of the rechargeable battery cell, can take place through ionic conduction. The electrolyte is oxidatively electrochemically decomposed from a certain upper cell voltage of the rechargeable battery cell. This process often leads to an irreversible destruction of components of the electrolyte, and thus to a failure of the rechargeable battery cell. Reductive processes can also decompose the electrolyte from a certain lower cell voltage. In order to avoid these processes, the positive and negative electrodes are selected such that the cell voltage is below or above the decomposition voltage of the electrolyte. The electrolyte thus determines the voltage window, i.e. the range within which a rechargeable battery cell can be operated reversibly.

Lithium-ion cells known from the prior art contain an electrolyte consisting of an organic solvent or solvent mixture and a conducting salt dissolved therein. The conducting salt is a lithium salt such as lithium hexafluorophosphate ($LiPF_6$). The solvent mixture can, for example, contain ethylene carbonate. Due to the organic solvent or solvent mixture, these kinds of lithium-ion cells are also referred to as organic lithium-ion cells.

In addition to lithium hexafluorophosphate ($LiPF_6$), commonly used in the prior art as conducting salt, other conducting salts are described for organic lithium-ion cells. Thus, for example, JP 4 306858 B2 describes conducting salts in the form of tetraalkoxyborate or tetraaryloxyborate salts, which may be fluorinated or partially fluorinated. JP 2001 143750 A teaches fluorinated or partially fluorinated tetraalkoxyborate salts and tetraalkoxyaluminate salts as conducting salts. In JP 4 306858 B2 and JP 2001 143750 A, the conducting salts described are dissolved in solvents or solvent mixtures and used in organic lithium-ion cells.

It has long been known that unintentional overcharging of organic lithium-ion cells leads to the irreversible decomposition of electrolyte components. The oxidative decomposition of the organic solvent and/or the conducting salt takes place on the surface of the positive electrode. The reaction heat generated during this decomposition and the resulting gaseous products are responsible for the subsequent "thermal runaway" and the resulting destruction of the organic lithium-ion cell. The vast majority of charging protocols for these organic lithium-ion cells use cell voltage as an indicator of the end of charging. Accidents caused by a thermal runaway are particularly likely to occur when using multi-cell battery packs in which multiple organic lithium-ion cells with dissimilar capacities are connected in series.

Therefore, organic lithium-ion cells are problematic in terms of their stability and long-term operational safety. Safety risks are in particular also caused by the combustibility of the organic solvent or solvent mixture. When an organic lithium-ion cell catches fire or even explodes, the organic solvent of the electrolyte forms a combustible material. Additional measures must be taken in order to avoid these safety risks. These measures include, in particular, very precise regulation of the charging and discharging processes of the organic lithium-ion cell as well as optimized battery design. Furthermore, the organic lithium-ion cell contains components that may melt in the event of an unintentional increase in temperature, and in this case the organic lithium-ion cell may be flooded with molten plastic. A further uncontrolled increase in temperature is thus prevented. However, these measures lead to higher manufacturing costs when producing the organic lithium-ion cells as well as to increased volume and weight. These measures also reduce the energy density of the organic lithium-ion cell.

A further disadvantage of organic lithium-ion cells is that any hydrolysis products forming in the presence of residual amounts of water are very aggressive towards the cell components of the rechargeable battery cell. For example, the conducting salt $LiPF_6$, which is frequently used in organic cells, reacts with traces of water and produces highly reactive, aggressive hydrogen fluoride (HF). For the production of these types of rechargeable battery cells with an organic electrolyte, it must therefore be ensured that the residual water contained in the electrolyte and the cell components is minimized. This is why production takes place in costly dry rooms under extremely low air humidity. The problems described above regarding stability and long-term operational safety are of particular importance for the development of organic lithium-ion cells, which on the one

hand have very good electrical energy and power characteristics, and on the other hand by a very high degree of operational safety and a very long service life; in particular, a high number of usable charging and discharging cycles.

A further development known from the prior art therefore provides for the use of an electrolyte based on sulphur dioxide (SO_2) instead of an organic electrolyte for rechargeable battery cells. Rechargeable battery cells, which contain an electrolyte based on SO_2, exhibit, *inter alia*, a high level of ionic conductivity. The term "SO_2-based electrolyte" refers to an electrolyte which contains SO_2 not merely as an additive at low concentrations, but for which the mobility of the ions in the conducting salt which is contained in the electrolyte and which causes the charge transport, is at least in part, largely or even completely provided by SO_2. The SO_2 therefore serves as a solvent for the conducting salt. The conducting salt and the gaseous SO_2 can form a liquid solvate complex, whereby the SO_2 is bound and the vapor pressure is noticeably reduced compared to pure SO_2. This produces electrolytes that have a low vapor pressure. Compared to the organic electrolytes described above, these SO_2-based electrolytes offer the advantage that they are non-combustible. Safety risks, which might occur due to the electrolyte's combustibility, can thus be excluded.

For example, document US 4 891 281 A describes a nonaqueous electrochemical battery cell having an electrolyte which conducts well. This electrolyte has a low vapor pressure and contains sulphur dioxide and an alkali metal or alkaline earth metal salt dissolved therein as conducting salt. As an example of an alkali metal salt, mention is made, *inter alia*, of $LiAlCl_4$ (cf. examples 1-11 of US 4 891 281 A).

EP 1 201 004 B1 describes an SO_2-based electrolyte composed of $LiAlCl_4$ * SO_2 in combination with a positive electrode made of $LiCoO_2$. EP 1 201 004 B1 proposes the use of an additional salt to avoid interfering decomposition reactions when overcharging the rechargeable battery cell from a potential of 4.1 to 4.2 volts, such as the undesired formation of chlorine (Cl_2) from lithium tetrachloroaluminate ($LiAlCl_4$).

EP 2534719 B1 also discloses an SO_2-based electrolyte having, *inter alia*, $LiAlCl_4$ as conducting salt. This $LiAlCl_4$ and the SO_2 form, for example, complexes of the formula $LiAlCl_4$ * 1.5 mol SO_2 or $LiAlCl_4$ * 6 mol SO_2. Lithium iron phosphate ($LiFePO_4$) is used as positive electrode. $LiFePO_4$ has a lower charge potential (3.7 V) compared to $LiCoO_2$ (4.2 V). Undesired overcharging reactions do not occur in this rechargeable battery cell, as potentials of 4.1 volts, which are harmful to the electrolyte, are not reached.

Document WO 2017/178543 A1 also discloses an electrolyte containing sulphur dioxide for a rechargeable battery cell. Here, the conducting salt comprises a compound having the stoichiometric formula $K(ASX_2)_p$, with K being a cation from the group of the alkali metals with p = 1, the alkaline earth metals with p = 2 or the zinc group with p = 2, A being an element from the third main group, S being sulphur and X being a halogen. The conducting salt is dissolved in sulphur dioxide (cf. page 5, lines 16-33 of WO 2017/178543 A1).

A disadvantage that also occurs *inter alia* with these SO_2-based electrolytes is that any hydrolysis products formed in the presence of residual amounts of water react with the cell components of the rechargeable battery cell and as a result lead to the formation of undesired by-products. Because of this, when producing these types of rechargeable battery cells with an SO_2-based electrolyte, it is important to ensure that the residual water contained in the electrolyte and the cell components is minimized.

Another problem in SO_2-based electrolytes is that many conducting salts, especially those known for organic lithium-ion cells, are not soluble in SO_2. Measurements have shown that SO_2 is a poor solvent for many salts, for example Lithium fluoride (LiF), lithium bromide (LiBr), lithium sulphate (Li_2SO_4), lithium bis(oxalato)borate (LiBOB), lithium hexafluoroarsenate ($LiAsF_6$), lithium tetrafluoroborate ($LiBF_4$), trilithium hexafluoroaluminate (Li_3AlF_6), lithium hexafluoroantimonate ($LiSbF_6$), lithium difluoro(oxalato)borate ($LiBF_2C_2O_4$), lithium bis(trifluoromethanesulphonyl)imide (LiTFSI), lithium metaborate ($LiBO_2$), lithium aluminate ($LiAlO_2$), lithium triflate ($LiCF_3SO_3$) and lithium chlorosulphonate ($LiSO_3Cl$). The solubilities of these salts in SO_2 are approx. 10^{-2} – 10^{-4} mol/l (Table 1). At these low concentrations, it can be assumed that at best only low conductivities are present, which are not sufficient for the efficient operation of a rechargeable battery cell.

Table 1: Solubility of different salts in SO_2

Salt	Solubility / mol/l in SO_2	Salt	Solubility / mol/l in SO_2
LiF	$2.1 \cdot 10^{-3}$	$LiPF_6$	$1.5 \cdot 10^{-2}$
LiBr	$4.9 \cdot 10^{-3}$	$LiSbF_6$	$2.8 \cdot 10^{-4}$
Li_2SO_4	$2.7 \cdot 10^{-4}$	$LiBF_2(C_2O_4)$	$1.4 \cdot 10^{-4}$
$LiB(C_2O_4)_2$	$3.2 \cdot 10^{-4}$	$CF_3SO_2NLiSO_2CF_3$	$1.5 \cdot 10^{-2}$

Li_3PO_4	-	$LiBO_2$	$2.6 \cdot 10^{-4}$
Li_3AlF_6	$2.3 \cdot 10^{-3}$	$LiAlO_2$	$4.3 \cdot 10^{-4}$
$LiBF_4$	$1.7 \cdot 10^{-3}$	$LiCF_3SO_3$	$6.3 \cdot 10^{-4}$
$LiAsF_6$	$1.4 \cdot 10^{-3}$		

In order to further improve the possible applications and the properties of SO_2-based electrolytes and rechargeable battery cells containing this electrolyte, the object of the present invention is to specify an SO_2-based electrolyte, which, compared to the electrolytes known from the prior art,

- has a wide electrochemical window, so that no oxidative electrolyte decomposition occurs at the positive electrode;
- forms a stable covering layer on the negative electrode, wherein the covering layer capacity should be low and no further reductive electrolyte decomposition occurs on the negative electrode during further operation;
- allows for operating rechargeable battery cells with high-voltage cathodes due to a wide electrochemical window;
- exhibits good solubility for conducting salts and is therefore a good ionic conductor and electronic insulator, by means of which ion transport can be facilitated and self-discharge can be restricted to a minimum;
- is also inert to other components of the rechargeable battery cell, such as separators, electrode materials and cell packaging materials,
- is resistant to various misuses, such as electrical, mechanical or thermal misuse, and
- exhibits increased stability against residual amounts of water in the cell components of rechargeable battery cells.

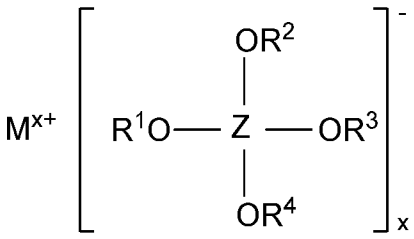
These types of electrolytes are intended in particular to be used in rechargeable battery cells which at the same time exhibit very good energy and power characteristics, a high degree of operational safety and a long service life, in particular a high number of usable charging and discharging cycles, without causing electrolyte decomposition during operation of the rechargeable battery cell.

Another object of the invention is to provide a rechargeable battery cell which contains an SO_2-based electrolyte and, in contrast to the rechargeable battery cells known from the prior art, has

- improved electrical performance, in particular a high energy density,
- improved overcharge capability and deep discharge capability,
- lower self-discharge,
- an increased service life, especially a high number of usable charging and discharging cycles,
- a reduced total weight,
- increased operational safety, even under more difficult environmental conditions in a vehicle, and
- reduced production costs.

The object is achieved by an SO_2-based electrolyte having the features of claim 1 and a rechargeable battery cell having the features of claim 14. Advantageous embodiments of the electrolyte according to the invention are defined in claims 2 to 13. Claims 15 to 24 describe advantageous further developments of the rechargeable battery cell according to the invention.

An SO_2-based electrolyte for a rechargeable battery cell according to the invention comprises at least one first conducting salt of the formula (I)



formula (I)

In formula (I), M is a metal selected from the group consisting of alkali metals, alkaline earth metals, metals of group 12 of the periodic table of the elements, and aluminium. x is an integer from 1 to 3. The substituents R^1, R^2, R^3 and R^4 are independently selected from the group consisting of C_1-C_{10} alkyl, C_2-C_{10} alkenyl, C_2-C10 alkynyl, C_3-C_{10} cycloalkyl, C_6-C_{14} aryl and C_5-C_{14} heteroaryl. The central atom Z is either aluminium or boron.

The SO_2-based electrolyte according to the invention not only contains SO_2 as an additive at low concentrations but also at concentrations, which ensure mobility of the ions of the first conducting salt which is contained in the electrolyte and causes the charge transport, at least in part, largely or even completely by means of SO_2. The first conducting salt is dissolved in the electrolyte and exhibits very good solubility therein. It can form a liquid solvate complex with the gaseous SO_2, in which complex the SO_2 is bound. In this case, the vapor pressure of the liquid solvate complex decreases significantly compared to the pure SO_2, leading to the production of electrolytes with low vapor pressure. However, it is also within the scope of the invention that, depending on the chemical structure of the first conducting salt according to formula (I), no reduction of the vapor pressure might occur during the production of the electrolyte according to the invention. In this case, it is preferable to work at low temperature or under pressure when producing the electrolyte according to the invention. The electrolyte may also contain several conducting salts of formula (I), which differ in their chemical structure.

The term "C_1-C_{10} alkyl", as used in the present invention, covers linear or branched saturated hydrocarbon groups with one to ten carbon atoms. These include in particular methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, n-pentyl, isopentyl, 2,2-dimethylpropyl, n-hexyl, isohexyl, 2-ethylhexyl, n-heptyl, isoheptyl, n-octyl, isooctyl, n-nonyl, n-decyl and the like.

The term "C_2-C_{10} alkenyl", as used in the present invention, covers unsaturated linear or branched hydrocarbon groups with two to ten carbon atoms, wherein the hydrocarbon groups have at least one C-C double bond. These include in particular ethenyl, 1-propenyl, 2-propenyl, 1-n-butenyl, 2-n-butenyl, isobutenyl, 1-pentenyl, 1-hexenyl, 1-heptenyl, 1-octenyl, 1-nonenyl, 1-decenyl and the like.

The term "C_2-C_{10} alkynyl", as used in the present invention, covers unsaturated linear or branched hydrocarbon groups with two to ten carbon atoms, wherein the hydrocarbon groups have at least one C-C triple bond. These include in particular ethynyl, 1-propynyl, 2-propynyl, 1-n-butynyl, 2-n-butynyl, isobutynyl, 1-pentynyl, 1-hexynyl,1-heptynyl, 1-octynyl, 1-nonynyl, 1-decynyl and the like.

The term "C_3-C_{10} cycloalkyl", as used in the present invention, covers cyclic, saturated hydrocarbon groups with three to ten carbon atoms. These include in particular cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, cyclohexyl, cyclonononyl and cyclodecanyl.

The term "C_6-C_{14} aryl", as used in the present invention, covers aromatic hydrocarbon groups with six to fourteen rings of carbon atoms. These include in particular phenyl (C_6H_5 group), naphthyl ($C_{10}H_7$ group) and anthracyl ($C_{14}H_9$ group).

The term "C_5-C_{14} heteroaryl", as used in the present invention, covers aromatic hydrocarbon groups with five to fourteen carbon atoms present in rings, in which at least one carbon atom has been replaced by or exchanged for a nitrogen, oxygen or sulphur-atom. These include in particular pyrrolyl, furanyl, thiophenyl, pyrridinyl, pyranyl, thiopyranyl and the like. All of the hydrocarbon groups mentioned above are in each case bonded via the oxygen atom to the central atom =according to formula (I).

The advantage of such an electrolyte over the electrolytes known from the prior art lies in the fact that the first conducting salt contained therein has a higher oxidation stability and consequently exhibits substantially no decomposition at higher cell voltages. This electrolyte is oxidation stable, preferably at least up to a potential of 4.0 volts, more preferably at least up to a potential of 4.2 volts, more preferably at least up to a potential of 4.4 volts, more preferably at least up to a potential of 4.6 volts, more preferably at least up to a potential of 4.8 volts and most preferably at least up to a potential of 5.0 volts. As a result, there is little or no electrolyte decomposition within the working potential of both electrodes of the rechargeable battery cell, when using such an electrolyte in a rechargeable battery cell. This significantly prolongs the service life of the electrolyte compared to the electrolytes known from the prior art. Such an electrolyte is also resistant to low temperatures. If there are small residual amounts of water (in the ppm range) in the electrolyte, the electrolyte or the first conducting salt forms, with the water, hydrolysis products that are significantly less aggressive towards the cell components compared to the SO_2-based electrolytes known from the prior art. As a result, the absence of water in the electrolyte is less critical than it is for the SO_2-based electrolytes known from the prior art. These advantages of the electrolyte according to the invention outweigh the disadvantage, which lies in the fact that the first conducting salt according to formula (I) has a significantly larger anion size compared to the conducting salts known from the prior art. This larger anion size leads to a lower conductivity of the first conducting salt according to formula (I) in comparison to the conductivity of $LiAlCl_4$.

A further aspect of the invention provides a rechargeable battery cell. This rechargeable battery cell contains the previously described electrolyte according to the invention or an electrolyte according to one of the advantageous embodiments of the

electrolyte according to the invention described below. Furthermore, the rechargeable battery cell according to the invention comprises an active metal, at least one positive electrode, at least one negative electrode and a housing.

In a first advantageous embodiment of the electrolyte according to the invention, the substituents R^1, R^2, R^3 and R^4 are independently selected from the group consisting of

- C_1-C_6 alkyl; preferably of C_2-C_4 alkyl; particularly preferably of the alkyl groups 2-propyl, methyl and ethyl;
- C_2-C_6 alkenyl; preferably of C_2-C_4 alkenyl; particularly preferably of the alkenyl groups ethenyl and propenyl;
- C_2-C_6 alkynyl; preferably of C_2-C_4 alkynyl;
- C_3-C_6 cycloalkyl;
- phenyl; and
- C_5-C_7 heteroaryl.

The term "C_1-C_6 alkyl", as used in this advantageous embodiment of the electrolyte according to the invention, covers linear or branched saturated hydrocarbon groups with one to six hydrocarbon groups, in particular methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, n-pentyl, isopentyl, 2,2-dimethylpropyl, n-hexyl and isohexyl. C_2-C_4 alkyls are preferred here. The C_2-C_4 alkyls 2-propyl, methyl and ethyl are particularly preferred.

The term "C_2-C_6 alkenyl", as used in this advantageous embodiment of the electrolyte according to the invention, covers unsaturated linear or branched hydrocarbon groups with two to six carbon atoms, wherein the hydrocarbon groups have at least one C-C double bond. These include in particular ethenyl, 1-propenyl, 2- propenyl, 1-n-butenyl, 2-n-butenyl, isobutenyl, 1-pentenyl and 1-hexenyl, wherein C_2-C_4 alkenyls are preferred. Ethenyl and 1-propenyl are particularly preferred.

The term "C_2-C_6 alkynyl", as used in this advantageous embodiment of the electrolyte according to the invention, covers unsaturated linear or branched hydrocarbon groups with two to six carbon atoms, wherein the hydrocarbon groups have at least one C-C triple bond. These include in particular ethynyl, 1-propynyl, 2-propynyl, 1-n-butynyl, 2-n-butynyl, isobutynyl, 1-pentynyl and 1-hexynyl. Here, C_2-C_4-alkynyls are preferred.

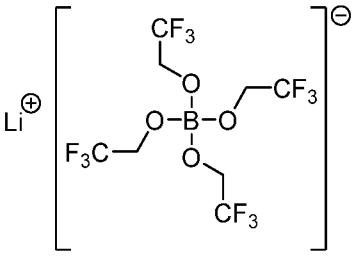
The term "C_3-C_6 cycloalkyl", as used in this advantageous embodiment of the electrolyte according to the invention, covers cyclic, saturated hydrocarbon groups with three to six carbon atoms. These include in particular cyclopropyl, cyclobutyl, cyclopentyl and cyclohexyl.

The term "C_5-C_7 heteroaryl", as used in this advantageous embodiment of the electrolyte according to the invention, covers phenyl und naphthyl.

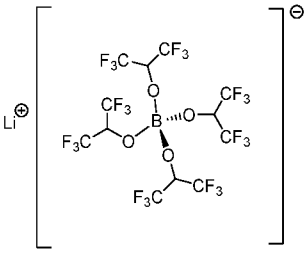
In order to improve solubility of the first conducting salt in the SO_2-based electrolyte, the substituents R^1, R^2, R^3 and R^4 are substituted by at least one fluorine atom and/or by at least one chemical group, said chemical group being selected from the group consisting of C_1-C_4 alkyl, C_2-C_4 alkenyl, C_2-C_4 alkynyl, phenyl and benzyl. The chemical groups C_1-C_4 alkyl, C_2-C_4 alkenyl, C_2-C_4 alkynyl, phenyl and benzyl have the same properties or chemical structures as the hydrocarbon groups described above. Substituted in this context means that individual atoms or atom groups of the substituents R^1, R^2, R^3 and R^4 are replaced by the fluorine atom and/or by the chemical group.

A particularly high solubility of the first conducting salt in the SO_2-based electrolyte can be achieved by at least one of the substituents R^1, R^2, R^3 and R^4 being a CF_3 group or an OSO_2CF_3 group.

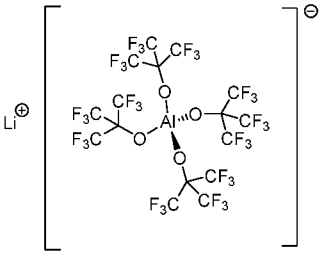
In another advantageous embodiment of the electrolyte according to the invention, the first conducting salt is selected from the group consisting of



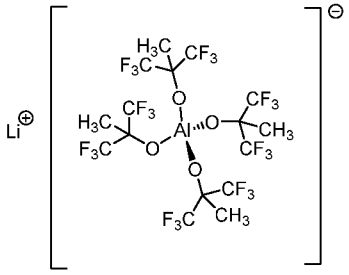
$Li[B(OCH_2CF_3)_4]$



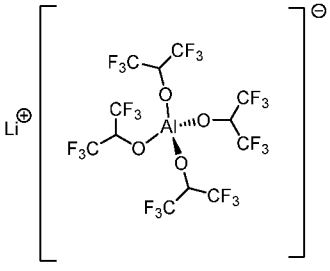
$Li[B(OCH(CF_3)_2)_4]$



$Li[Al(OC(CF_3)_3)_4]$



$Li[Al(OC(CH_3)(CF_3)_2)_4]$



$Li[Al(OCH(CF_3)_2)_4]$.

In order to adjust the conductivity and/or further properties of the electrolyte to a desired value, in another advantageous embodiment, the electrolyte has at least a second conducting salt, which differs from the first conducting salt according to formula (I). This means that in addition to the first conducting salt, the electrolyte may also contain one or several second conducting salts which differ from the first conducting salt in their chemical composition and their chemical structure.

In another advantageous embodiment of the electrolyte according to the invention, the second conducting salt is an alkali metal compound, in particular a lithium compound. The alkali metal compound or the lithium compound are selected from the group consisting of an aluminate, a halide, an oxalate, a borate, a phosphate, an arsenate and a gallate. Preferably, the second conducting salt is a lithium tetrahaloaluminate, especially $LiAlCl_4$.

In another advantageous embodiment, the electrolyte further contains at least one additive. This additive is preferably selected from the group formed by vinylene carbonate and its derivatives, vinyl ethylene carbonate and its derivatives, methyl ethylene carbonate and its derivatives, lithium (bisoxalato)borate, lithium difluoro(oxalato)borate, lithium tetrafluoro(oxalato)phosphate, lithium oxalate, 2-vinylpyridine, 4-vinylpyridine, cyclic exomethylenecarbonates, sultones, cyclic and acyclic sulfonates, acyclic sulphites, cyclic and acyclic sulfinates, organic esters of inorganic acids, acyclic and cyclic alkanes, which acyclic and cyclic alkanes have a boiling point of at least 36°C at 1 bar, aromatic compounds, halogenated cyclic and acyclic sulphonylimides, halogenated cyclic and acyclic phosphate esters, halogenated cyclic and acyclic phosphines, halogenated cyclic and acyclic phosphites, halogenated cyclic and acyclic phosphazenes, halogenated cyclic and acyclic silylamines, halogenated cyclic and acyclic halogenated esters, halogenated cyclic and acyclic amides, halogenated cyclic and acyclic anhydrides and halogenated organic heterocycles.

In another preferred embodiment, based on the total weight of the electrolyte composition, the electrolyte has the following composition

(i) 5 to 99.4% by weight of sulphur dioxide,

(ii) 0.6 to 95% by weight of the first conducting salt,

(iii) 0 to 25% by weight of the second conducting salt; and

(iv) 0 to 10% by weight of the additive.

As already mentioned above, the electrolyte may contain not only a first conducting salt according to formula (I) and a second conducting salt, but also in each case several first conducting salts according to formula (I) and several second conducting salts. In the latter case, the abovementioned percentages also include several first conducting salts and several second conducting salts. The molar concentration of the first conducting salt is in the range of 0.05 mol/l to 10 mol/l, preferably 0.1 mol/l to 6 mol/l and particularly preferably 0.2 mol/l to 3.5 mol/l based on the total volume of the electrolyte.

Another advantageous embodiment of the rechargeable battery cell according to the invention specifies that the electrolyte contains at least 0.1 mol SO_2, preferably at least 1 mol SO_2, more preferably at least 5 mol SO_2, more preferably at least 10 mol SO_2 and particularly preferably at least 20 mol SO_2 per mole of conducting salt. The electrolyte may also contain very high molar proportions of SO_2, the preferred upper limit being 2600 mol SO_2 per mole of conducting salt and upper limits of 1500, 1000, 500 and 100 mol SO_2 per mole of conducting salt being further preferred in this order. The term "per mole of conducting salt" refers to all conducting salts contained in the electrolyte. SO_2-based electrolytes with such a concentration ratio between SO_2 and the conducting salt offer the advantage that they can dissolve a larger amount of conducting salt than the electrolytes known from the prior art, which are based on an organic solvent mixture, for example. Within the scope of the invention, it was found that, surprisingly, an electrolyte with a relatively low concentration of conducting salt is advantageous despite the associated higher vapor pressure, particularly in terms of the stability thereof over many charging and discharging cycles of the rechargeable battery cell. The concentration of SO_2 in the electrolyte affects the conductivity thereof. By selecting the SO_2 concentration, the conductivity of the electrolyte can thus be adapted to the intended use of a rechargeable battery cell operated by means of this electrolyte.

The total amount of SO_2 and the first conducting salt may be greater than 50 percent by weight of the weight of the electrolyte, preferably greater than 60% by weight, more preferably greater than 70% by weight, more preferably greater than 80% by weight, more preferably greater than 85% by weight, more preferably greater than 90% by weight, more preferably greater than 95% by weight, or more preferably greater than 99% by weight.

The electrolyte may contain at least 5% by weight of SO_2 based on the total amount of the electrolyte contained in the rechargeable battery cell, with values of 20% by weight

of SO_2, 40% by weight of SO_2 and 60% by weight of SO_2 being further preferred. The electrolyte may also contain up to 95% by weight of SO_2, with maximum values of 80% by weight of SO_2 and 90% by weight of SO_2 being preferred in this order.

It is within the scope of the invention that the electrolyte preferably has only a small or even no percentage of at least one organic solvent. Preferably, the proportion of organic solvents in the electrolyte, which is for example in the form of a solvent or a mixture of several solvents, can be no more than 50% by weight of the weight of the electrolyte. Particular preference is given to lower proportions of no more than 40% by weight, no more than 30% by weight, no more than 20% by weight, no more than 15% by weight, no more than 10% by weight, no more than 5% by weight or no more than 1% by weight of the electrolyte. More preferably, the electrolyte is free of organic solvents. Due to the low proportion of organic solvents or even the complete absence thereof, the electrolyte is either hardly combustible or not combustible at all. This increases the operational safety of a rechargeable battery cell operating with this kind of SO_2-based electrolyte. Particularly preferably, the SO_2-based electrolyte is free of organic solvents.

Active metal

In the following, advantageous further embodiments of the rechargeable battery cell according to the invention are described with regard to the active metal:

In a first advantageous further embodiment of the rechargeable battery, the active metal is

- an alkali metal, in particular lithium or sodium;
- an alkaline earth metal, in particular calcium;
- a metal of group 12 of the periodic table of the elements, in particular zinc; or
- aluminium.

Negative electrode

In the following, advantageous further embodiments of the rechargeable battery cell according to the invention are described with regard to the negative electrode:

Another advantageous further embodiment of the rechargeable battery cell specifies that the negative electrode is an insertion electrode. This insertion electrode contains an insertion material as active material that the ions of the active metal are stored in during charging of the rechargeable battery cell and that the ions of the active metal can be removed from during discharging of the rechargeable battery cell. This means that the electrode processes can take place not only on the surface of the electrodes, but also inside the negative electrode. For example, if a conducting salt based on lithium is used, lithium ions can be stored in the insertion material during charging of the rechargeable battery cell and removed from the insertion material during discharging of the rechargeable battery cell. The negative electrode preferably contains carbon as active material or insertion material, in particular in the graphite modification. However, it is also within the scope of the invention that the carbon is present in the form of natural graphite (flake-form or rounded), synthetic graphite (mesophase graphite), graphitized mesocarbon microbeads (MCMB), with carbon-coated graphite or amorphous carbon.

In another advantageous further embodiment of the rechargeable battery cell according to the invention, the negative electrode comprises lithium intercalation anode active materials that contain no carbon, for example lithium titanate (e.g. $Li_4Ti_5O_{12}$).

Another advantageous further embodiment of the rechargeable battery cell according to the invention specifies that the negative electrode with lithium comprises alloy-forming anode active materials. These include lithium-storing metals and metal alloys (e.g. Si, Ge, Sn, $SnCo_xC_y$, $SnSi_x$ and the like) and oxides of the lithium-storing metals and metal alloys (e.g. SnO_x, SiO_x, oxide glasses of Sn, Si and the like).

In another advantageous further embodiment of the rechargeable battery cell according to the invention, the negative electrode contains conversion anode active materials. These conversion anode active materials can be, for example, transition metal oxides in the form of manganese oxides (MnO_x), iron oxides (FeO_x), cobalt oxides (CoO_x), nickel oxides (NiO_x, copper oxides (CuO_x) or metal hydrides in the form of magnesium hydride (MgH_2), titanium hydride (TiH_2), aluminium hydride (AlH_3) and boron-, aluminium- and magnesium-based ternary hydrides and the like.

In another advantageous further embodiment of the rechargeable battery cell according to the invention, the negative electrode comprises a metal, in particular metallic lithium.

Another advantageous further embodiment of the rechargeable battery cell according to the invention provides that the negative electrode is porous, wherein the maximum porosity is preferably no more than 50%, more preferably no more than 45%, more preferably no more than 40%, more preferably no more than 35%, more preferably no more than 30%, more preferably no more than 20% and particularly preferably no more than 10%. The porosity represents the cavity volume in relation to the total volume of the negative electrode, wherein the cavity volume is formed by so-called pores or cavities. This porosity enlarges leads to an enlargement of the inner surface of the negative electrode. The porosity further reduces the density of the negative electrode and thus also its weight. The individual pores of the negative electrode can preferably be completely filled with the electrolyte during operation.

Another advantageous further embodiment of the battery cell according to the invention provides that the negative electrode has a conducting element. This means that in addition to the active material or insertion material, the negative electrode also comprises a conducting element. This conducting element is used to enable the necessary electronically conductive connection of the active material of the negative electrode. For this purpose, the conducting element is in contact with the active material participating in the electrode reaction of the negative electrode. This conducting element can be planar shaped in the form of a thin metal sheet or a thin metal foil. The thin metal foil preferably has a perforated or mesh-like structure. The active material of the negative electrode is preferably applied to the surface of the thin metal sheet or the thin metal foil. Such planar conducting elements have a thickness in the range of 5 µm to 50 µm. A thickness of the planar conducting element in the range of 10 µm to 30 µm is preferred. When planar conducting elements are used, the negative electrode can have a total thickness of at least 20 µm, preferably of at least 40 µm and particularly preferably of at least 60 µm. The maximum thickness is no more than 200 µm, preferably no more than 150 µm and particularly preferably no more than 100 µm. The area-specific capacity of the negative electrode is preferably at least 0.5 mAh/cm^2 when a planar conducting element is used, with the following values being further preferred, in this order: 1 mAh/cm^2, 3 mAh/cm^2, 5 mAh/cm^2, 10 mAh/cm^2.

Furthermore, there is also the possibility that the conducting element may be in the form of a three-dimensional porous metal structure, in particular in the form of a metal foam. The term “three-dimensional porous metal structure” refers to any structure

consisting of metal that extends not only like the thin metal sheet or metal foil over the length and width of the planar electrode, but also over the thickness thereof. The three-dimensional porous metal structure is porous, such that the active material of the negative electrode can be incorporated into the pores of the metal structure. The amount of active material incorporated or applied is the loading of the negative electrode. If the conducting element is in the form of a three-dimensional porous metal structure, in particular in the form of a metal foam, then the negative electrode preferably has a thickness of at least 0.2 mm, preferably of at least 0.3 mm, more preferably of at least 0.4 mm, more preferably of at least 0.5 mm and particularly preferably of at least 0.6 mm. In this case, the electrodes are significantly thicker in comparison to negative electrodes which are used for organic lithium-ion cells. Another advantageous configuration provides that the area-specific capacity of the negative electrode, when using a three-dimensional conducting element in the form of a metal foam, in particular in the form of a metal foam, is preferably at least 2.5 mAh/cm^2, the following values being further preferred, in this order: 5 mAh/cm^2, 10 mAh/cm^2, 15 mAh/cm^2, 20 mAh/cm^2, 25 mAh/cm^2, 30 mAh/cm^2. If the conducting element is in the form of a three-dimensional porous metal structure, in particular in the form of a metal foam, the amount of the active material of the negative electrode, i.e. the loading of the electrode relative to its surface, is at least 10 mg/cm^2, preferably at least 20 mg/cm^2, more preferably at least 40 mg/cm^2, more preferably at least 60 mg/cm^2, more preferably at least 80 mg/cm^2 and particularly preferably at least 100 mg/cm^2. This loading of the negative electrode has a positive effect on the charging and discharging process of the rechargeable battery cell.

In a further advantageous further embodiment of the battery cell according to the invention, the negative electrode comprises at least one binder. This binder is preferably a fluorinated binder, in particular a polyvinylidene fluoride and/or a terpolymer formed from tetrafluoroethylene, hexafluoropropylene and vinylidene fluoride. However, it may also be a binder consisting of a polymer composed of monomeric structural units of a conjugated carboxylic acid or of the alkali metal, alkaline earth metal or ammonium salt of this conjugated carboxylic acid or of a combination thereof. The binder may also consist of a polymer based on monomeric styrene and butadiene structural units. In addition, the binder may also be a binder of the group of carboxymethylcelluloses. The binder is present in the negative electrode preferably in a concentration of no more than 20% by weight, more preferably no more than 15% by weight, more preferably no more than 10%

by weight, more preferably no more than 7% by weight, more preferably no more than 5% by weight and particularly preferably no more than 2% by weight relative to the total weight of the negative electrode.

Positive electrode

In the following, advantageous further embodiments of the rechargeable battery cell according to the invention are described with regard to the positive electrode:

In another advantageous further embodiment of the battery cell according to the invention, the positive electrode contains at least one intercalation compound as active material. For the purpose of this invention, the term “intercalation compound” means a subcategory of the insertion materials described above. This intercalation compound functions as a host matrix, with empty spaces that are interconnected. The ions of the active metal can diffuse into these empty spaces during the discharge process of the rechargeable battery cell and be stored there. During the deposition of the ions of the active metal, only minor or no structural changes occur in the host matrix. Preferably, the intercalation compound has the following composition $Li_xM'_yM''_zO_a$, wherein

- M' is at least one metal selected from the group consisting of the elements Ti, V, Cr, Mn, Fe, Co, Ni, Cu and Zn;
- M" is at least one element selected from the group consisting of elements of the groups 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and 16 of the periodic table of the elements;
- x and y are greater than 0;
- z is greater than or equal to 0; and
- a is greater than 0.

The indices y and z refer to the totality of metals and elements represented by M' and M" respectively. For example, if M' comprises two metals M'_1 and M'_2, the following applies for the index y: y=y1+y2, where y1 and y2 represent the indices of the metals M'_1 and M'_2. The indices x, y, z and a must be selected in such a way that charge neutrality prevails within the composition.

Compositions of the formula $Li_xM'_yM''_zO_4$ are preferred. In another advantageous further embodiment of the rechargeable battery cell according to the invention, M' is iron

and M'' is phosphorus in the composition $Li_xM'_yM''_zO_4$. In this case, the intercalation compound is lithium iron phosphate ($LiFePO_4$). Another advantageous further embodiment of the rechargeable battery cell according to the invention provides that M' is manganese and M'' is cobalt in the composition $Li_xM'_yM''_zO_4$. In this case, the intercalation compound is lithium cobalt manganese oxide ($LiCoMnO_4$). $LiCoMnO_4$ can be used to produce so-called high-voltage electrodes for high-energy cells with a cell voltage of over 5 volts. This $LiCoMnO_4$ is preferably free of Mn^{3+}.

Another advantageous further embodiment of the rechargeable battery cell according to the invention provides that M' consists of the metals nickel and manganese and M'' is cobalt. These are compositions of the formula $Li_xNi_{y1}Mn_{y2}Co_zO_2$ (NMC). Examples of these intercalation compounds of lithium nickel manganese cobalt oxide are $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$ (NMC111), $LiNi_{0.6}Mn_{0.2}Co_2O_2$ (NMC622) and $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (NMC811).

High-voltage electrodes can be cycled at least up to an upper potential of 4.0 volts, more preferably at least up to a potential of 4.2 volts, more preferably at least up to a potential of 4.4 volts, more preferably at least up to a potential of 4.6 volts, more preferably at least up to a potential of 4.8 volts and particularly preferably at least up to a potential of 5.0 volts in the rechargeable battery according to the invention.

Another advantageous further embodiment of the rechargeable battery cell according to the invention provides that the positive electrode contains at least one metal compound. This metal compound is selected from the group consisting of a metal oxide, a metal halide and a metal phosphate. Preferably, the metal of this metal compound is a transition metal with an atomic number of 22 to 28 in the periodic table of the elements, in particular cobalt, nickel, manganese or iron.

Another advantageous further embodiment of the battery cell according to the invention provides that the positive electrode has a conducting element. This means that in addition to the active material, the positive electrode also comprises a conducting element. This conducting element is used to enable the necessary electronically conductive connection of the active material of the positive electrode. For this purpose, the conducting element is in contact with the active material participating in the electrode reaction of the positive electrode.

This conducting element can be planar, in the form of a thin metal sheet or a thin metal foil. The thin metal foil preferably has a perforated or mesh-like structure. The

active material of the positive electrode is preferably applied to the surface of the thin metal sheet or the thin metal foil. Such planar conducting elements have a thickness in the range of 5 µm to 50 µm. A thickness of the planar conducting element in the range of 10 µm to 30 µm is preferred. When planar conducting elements are used, the positive electrode can have a total thickness of at least 20 µm, preferably of at least 40 µm and particularly preferably of at least 60 µm. The maximum thickness is no more than 200 µm, preferably no more than 150 µm and particularly preferably no more than 100 µm. The area-specific capacity of the positive electrode is preferably at least 0.5 mAh/cm^2 when a planar conducting element is used, with the following values being further preferred, in this order: 1 mAh/cm^2, 3 mAh/cm^2, 5 mAh/cm^2, 10 mAh/cm^2.

Furthermore, there is also the possibility that the conducting element of the positive electrode may be in the form of a three-dimensional porous metal structure, in particular in the form of a metal foam. The three-dimensional porous metal structure is porous, such that the active material of the positive electrode can be incorporated into the pores of the metal structure. The amount of active material incorporated or applied is the loading of the positive electrode. If the conducting element is in the form of a three-dimensional porous metal structure, in particular in the form of a metal foam, then the positive electrode preferably has a thickness of at least 0.2 mm, preferably of at least 0.3 mm, more preferably of at least 0.4 mm, more preferably of at least 0.5 mm and particularly preferably of at least 0.6 mm. Another advantageous embodiment provides that the area-specific capacity of the positive electrode, when using a three-dimensional conducting element in the form of a metal foam, in particular in the form of a metal foam, is preferably at least 2.5 mAh/cm^2, the following values being further preferred, in this order: 5 mAh/cm^2, 10 mAh/cm^2, 15 mAh/cm^2, 20 mAh/cm^2, 25 mAh/cm^2, 30 mAh/cm^2. If the conducting element is in the form of a three-dimensional porous metal structure, in particular in the form of a metal foam, the amount of the active material of the positive electrode, i.e. the loading of the electrode relative to its surface, is at least 10 mg/cm^2, preferably at least 20 mg/cm^2, more preferably at least 40 mg/cm^2, more preferably at least 60 mg/cm^2, more preferably at least 80 mg/cm^2 and particularly preferably at least 100 mg/cm^2. This loading of the positive electrode has a positive effect on the charging process and the discharging process of the rechargeable battery cell.

In another advantageous further embodiment of the battery cell according to the invention, the positive electrode comprises at least one binder. This binder is preferably

a fluorinated binder, in particular a polyvinylidene fluoride and/or a terpolymer formed from tetrafluoroethylene, hexafluoropropylene and vinylidene fluoride. However, it may also be a binder consisting of a polymer composed of monomeric structural units of a conjugated carboxylic acid or of the alkali metal, alkaline earth metal or ammonium salt of this conjugated carboxylic acid or of a combination thereof. The binder may also consist of a polymer based on monomeric styrene and butadiene structural units. In addition, the binder may also be a binder of the group of carboxymethylcelluloses. The binder is present in the positive electrode preferably at a concentration of no more than 20% by weight, more preferably no more than 15% by weight, more preferably no more than 10% by weight, more preferably no more than 7% by weight, more preferably no more than 5% by weight and particularly preferably no more than 2% by weight relative to the total weight of the positive electrode.

Structure of the rechargeable battery cell

In the following, advantageous further embodiments of the rechargeable battery cell according to the invention are described with regard to their structure:

In order to further improve the function of the rechargeable battery cell, another advantageous further embodiment of the rechargeable battery cell according to the invention provides that the rechargeable battery cell comprises a plurality of negative electrodes and a plurality of positive electrodes arranged alternately stacked in the housing. The positive electrodes and the negative electrodes are preferably electrically separated from each other by separators.

The separator may consist of a non-woven material, a membrane, a woven or knitted material, an organic material, an inorganic material or a combination thereof. Organic separators may consist of unsubstituted polyolefins (e.g. polypropylene or polyethylene), partially to completely halogen-substituted polyolefins (e.g. partially to completely fluorine-substituted, in particular PVDF, ETFE, PTFE), polyesters, polyamides or polysulphones. Separators which contain a combination of organic and inorganic materials, include, for example, glass fibre textile materials in which the glass fibres are provided with a suitable polymeric coating. The coating preferably contains a fluorine-containing polymer such as polytetrafluoroethylene (PTFE), ethylene-tetrafluoroethylene (ETFE), perfluoroethylene propylene (FEP), THV (terpolymer of

tetrafluoroethylene, hexafluoroethylene and vinylidene fluoride) or a perfluoroalkoxy polymer (PFA), aminosilane, polypropylene (PP) or polyethylene (PE). The separator can also be folded in the housing of the rechargeable battery cell, for example in the form of a "z-folding". With z-folding, a strip-shaped separator is folded z-like through or around the electrodes. The separator can also be designed as a separator paper.

It is also within the scope of the invention that the separator can be designed as a sheath, wherein each positive electrode or each negative electrode is enveloped by the sheath. The sheath may be formed of a non-woven material, a membrane, a woven or knitted material, an organic material, an inorganic material or a combination thereof.

A sheath enveloping the positive electrode leads to a more uniform ion migration and ion distribution in the rechargeable battery cell. The more even the ion distribution is, especially in the negative electrode, the higher the possible loading of the negative electrode with active material and consequently the higher the usable capacity of the rechargeable battery cell. At the same time, risks associated with uneven loading and the resulting separation of the active metal can be avoided. These advantages are particularly effective when the positive electrodes of the rechargeable battery cell are enveloped with the sheath.

The surface dimensions of the electrodes and of the sheath can preferably be matched to each other in such a manner that the outer dimensions of the sheath of the electrodes and the outer dimensions of the unsheathed electrode coincide in at least one dimension.

The surface area of the sheath can preferably be greater than the surface area of the electrode. In this case, the sheath extends beyond a boundary of the electrode. Two layers of the sheath covering the electrode on both sides can therefore be joined together at the edge of the positive electrode by an edge connector.

In another advantageous configuration of the rechargeable battery cell according to the invention, the negative electrodes have a sheath, while the positive electrodes do not have a sheath.

Other advantageous properties of the invention are described and explained in more detail below using figures, examples and experiments.

Figure 1: shows a first embodiment example of a rechargeable battery cell according to the invention in a cross-sectional view;

Figure 2: shows a detailed electron microscope image of the three-dimensional porous structure of the metal foam of the first embodiment example from Figure 1;

Figure 3: shows a second embodiment example of a rechargeable battery cell according to the invention in a cross-sectional view;

Figure 4: shows a detail of the second embodiment example from Figure 3:

Figure 5: shows a third embodiment example of the rechargeable battery cell according to the invention in an exploded view;

Figure 6: shows the discharge capacity as a function of the number of cycles of full cells containing either a mixed electrolyte of compound 1 or compound 3 in a reference electrolyte or the reference electrolyte;

Figure 7: shows charge and discharge potential curves in volts [V] as a function of the percentage charge of full cells filled with either one of the three embodiment examples 1, 2 or 3 of an electrolyte according to the invention or the reference electrolyte;

Figure 8: shows a potential curve in volts [V] as a function of the percentage loading of a full cell filled with the first embodiment example 1 of the electrolyte according to the invention;

Figure 9: shows potential curves in volts [V] as a function of the cumulative loading of full cells filled with a third embodiment example 3 of an electrolyte according to the invention, depending on the charge/discharge current;

Figure 10: shows mean values for the discharge capacities of a reference full cell filled with the reference electrolyte and a test full cell filled with the first embodiment example 1 of the electrolyte according to the invention as a function of the cycle number;

Figure 11: shows the course of the internal resistance of the two full cells from Figure 10 across the cycle number;

Figure 12: shows the conductivity in [mS/cm] of the first embodiment example 1 of the electrolyte according to the invention depending on the concentration; and

Figure 13: shows the potential in [V] of a reference full cell and two test full cells when charging a negative electrode against lithium as a function of capacity, which is related to the theoretical capacity of the negative electrode, during covering layer formation on the negative electrode.

Figure 1 shows a first embodiment example of a rechargeable battery cell 2 according to the invention in a cross-sectional view. This rechargeable battery cell 2 is designed as a prismatic cell and, *inter alia*, has a housing 1. This housing 1 encloses an electrode array 3, comprising three positive electrodes 4 and four negative electrodes 5. The positive electrodes 4 and the negative electrodes 5 are arranged alternately stacked in the electrode array 3. The housing 1 can, however, also accommodate more positive electrodes 4 and/or negative electrodes 5. In general, it is preferred that the number of negative electrodes 5 is one greater than the number of positive electrodes 4. As a result, the outer front surfaces of the electrode stack are formed by the electrode surfaces of the negative electrodes 5. The electrodes 4, 5 are connected via electrode connections 6, 7 to corresponding contacts 9, 10 of the rechargeable battery cell 2. The rechargeable battery cell 2 is filled with an SO_2-based electrolyte in such a manner that the electrolyte penetrates as completely as possible into all pores or cavities, particularly within the electrodes 4, 5. The electrolyte is not visible in Figure 1. In this embodiment example, the positive electrodes 4 contain an intercalation compound as active material. This intercalation compound is $LiCoMnO_4$.

In this embodiment example, the electrodes 4, 5 have a flat design, i.e. are in the form of layers of low thickness in relation to their surface area. They are in each case separated from each other by separators 11. The housing 1 of the rechargeable battery cell 2 is substantially cuboid, the electrodes 4, 5 and the walls of the housing 1 shown in sectional view extending perpendicularly to the plane of the drawing and being essentially straight and flat. However, the rechargeable battery cell 2 can also be in the form of a winding cell in which the electrodes consist of thin layers wound together with a separator material. The separators 11 separate the positive electrode 4 and the negative electrode 5 spatially and electrically, and they are also, *inter alia*, permeable to the ions of the active metal. In this way, large electrochemically active surfaces are created, which enable a correspondingly high current efficiency.

The electrodes 4, 5 also have a conducting element, not depicted in Figure 1, which enables the necessary electronically conductive connection of the active material of the respective electrode. This conducting element is in contact with the active material participating in the electrode reaction of the respective electrode 4, 5 (not depicted in Figure 1). The conducting element is in the form of a porous metal foam. The metal foam extends over the thickness of the electrodes 4, 5. The active material of the positive

electrodes 4 and the negative electrodes 5 is incorporated into the pores of this metal foam so that it fills its pores uniformly over the entire thickness of the metal structure. To improve mechanical strength, the positive electrodes 4 contain a binder. This binder is a fluoropolymer. The negative electrodes 5 contain carbon as an active material in a form suitable, as insertion material, for the absorption of lithium ions. The structure of the negative electrode 5 is similar to that of the positive electrode 4.

Figure 2 shows an electron microscope image of the three-dimensional porous structure of the metal foam 18 of the first embodiment example from Figure 1. The scale shows that the pores P have an average diameter of more than 100 µm, i.e. they are relatively large.

Figure 3 shows a second embodiment example of the rechargeable battery cell 2 according to the invention in a cross-sectional view. This second embodiment example differs from the first embodiment example shown in Figure 1 in that the electrode arrangement 3 comprises one positive electrode 4 and two negative electrodes 5. The positive electrode 4 has a conducting element 34 in the form of a planar metal foil to which the active material 24 of the positive electrode 4 is applied on both sides. The negative electrodes 5 also comprise a conducting element 35 in the form of a planar metal foil to which the active material 25 of the negative electrode 4 is applied on both sides. Alternatively, the planar conducting elements of the edge electrodes, i.e. the electrodes that close off the electrode stack, may only be coated with active material on one side. The uncoated side faces the housing wall.

Figure 4 shows the planar metal foil, which serves in each case as a conducting element 34, 35 for the positive electrodes 4 and the negative electrodes 5 in the second embodiment example from Figure 3. This metal foil has a perforated or mesh-like structure with a thickness of 20 µm.

Figure 5 shows a third embodiment example of the rechargeable battery cell 2 according to the invention in an exploded view. This third embodiment example differs from the two previously described embodiment examples in that the positive electrode 4 is enveloped with a sheath 13. A surface area of the sheath 13 is greater than a surface area of the positive electrode 4, the boundary 14 of which is drawn as a dashed line in Figure 2. Two layers 15, 16 of the sheath 13, covering the positive electrode 4 on both sides, are connected to each other at the circumferential edge of the positive electrode 4 via an edge connector 17.

Example 1: Preparation of a reference electrolyte

A reference electrolyte used for the examples described below was prepared according to the process described in patent specification EP 2 954 588 B1. Lithium chloride (LiCl) was first dried under vacuum at 120°C for three days. Aluminium particles (Al) were dried under vacuum at 450°C for two days. LiCl, aluminium chloride ($AlCl_3$) and Al were mixed at a molar ratio of $AlCl_3$:LiCl:Al of 1:1.06:0.35 in a glass bottle with an opening allowing gas to escape. This mixture was then heat-treated in stages to produce a molten salt. After cooling, the molten salt formed was filtered, then cooled to room temperature, and finally SO_2 was added until the desired molar ratio of SO_2 to $LiAlCl_4$ was formed. The reference electrolyte thus formed had the composition $LiAlCl_4$ * x SO_2, where x depends on the amount of SO_2 added.

Example 2: Preparation of three embodiment examples 1, 2 and 3 of the electrolyte according to the invention

For the experiments described below, three embodiment examples 1, 2 and 3 of the electrolyte according to the invention were prepared (hereinafter referred to as electrolytes 1, 2 and 3). For this purpose, first three different initial conducting salts according to formula (I) were prepared according to a manufacturing process described in the following documents:

"I. Krossing, *Chem. Eur. J.* **2001**, *7*, 490;

S. M.Ivanova et al., *Chem. Eur. J.* **2001**, *7*, 503;

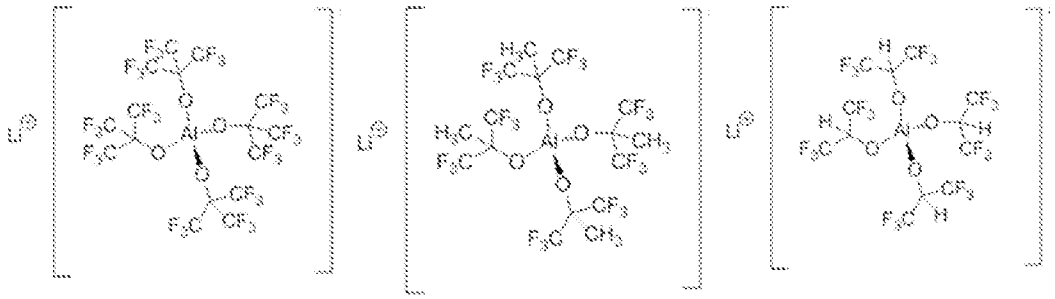
Tsujioka et al., *J. Electrochem. Soc.*, **2004**, *151*, A1418"

These three different, initial conducting salts according to formula (I) are hereinafter referred to as compounds 1, 2 and 3. They originate from the family of polyfluoroalkoxyaluminates and were prepared in hexane according to the following reaction equation starting with $LiAlH_4$ and the corresponding alcohol R-OH with $R^1=R^2=R^3=R^4$.

$$LiAlH_4 + 4\ HO\text{-}R \xrightarrow{\text{Hexan}} LiAl(OR)_4 + 4\ H_2$$

[Hexan = hexane]

As a result, compounds 1, 2 and 3 depicted below with the chemical and structural formulas were formed:



Li [Al(OC(CF$_3$)$_3$)$_4$] Compound 1

Li [Al(OC(CH$_3$)(CF$_3$)$_2$)$_4$] Compound 2

Li [Al(OCH(CF$_3$)$_2$)$_4$] Compound 3

For purification, compounds 1, 2 and 3 were first recrystallized. This removed residues of the educt $LiAlH_4$ from the first conducting salt, since this educt could possibly lead to spark formation with any traces of water present in SO_2.

Subsequently, compounds 1, 2 and 3 were dissolved in SO_2. It was found that compounds 1, 2 and 3 dissolve well in SO_2.

The preparation of electrolytes 1, 2 and 3 was carried out at low temperature or under pressure according to process steps 1 to 4 listed below:

1) Initial charging of the respective compound 1, 2 and 3 in each case in a pressure vessel with riser pipe,

2) Evacuation of the pressure vessels,

3) Inflow of liquid SO_2 and

4) Repetition of steps 2 + 3 until the target amount of SO_2 has been added.

The respective concentration of compounds 1, 2 and 3 in electrolytes 1, 2 and 3 was 1 mol/l (molar concentration based on 1 litre of the electrolyte), unless stated otherwise in the experiment description. The experiments described below were carried out with electrolytes 1, 2 and 3 and the reference electrolyte.

Example 3: Production of full cells

The full cells used in the experiments described below are rechargeable battery cells with two negative electrodes and one positive electrode, which were each separated by a separator. The positive electrodes contained $LiFePO_4$ as an active material, a conductivity promoter and a binder. The negative electrodes contained graphite as active material and also a binder. The full cells were each filled with the electrolyte required for the experiments, i.e. either with the reference electrolyte or electrolytes 1, 2 or 3.

Several, i.e. two to four identical full cells were produced for each experiment. The results presented in the experiments are in each case mean values of the measurement values obtained for the identical full cells.

Experiment 1: Investigation of possible negative effects of electrolytes 1 and 3 on the cycling behaviour of full cells

In order to test whether the electrolyte according to the invention has no negative effects on the cycling behaviour of full cells, mixed electrolytes were first prepared which contained a small proportion of either compound 1 or compound 3 in the reference electrolyte.

To this end, mixed electrolytes consisting of 95% by weight reference electrolyte and 5% by weight compound 1 or 5% by weight compound 3 were prepared. The two mixed electrolytes were compared with a pure reference electrolyte (100% by weight). For this purpose, experiments were carried out in full cells according to example 3. To this end, full cells each were filled with the different electrolytes. The full cells were charged with 50 mA up to a potential of 3.6 V. The potential of 3.6 volts was maintained until the current dropped to a value of 40 mA. The discharge was performed with a current of 50 mA up to a potential of 2.5 V. 500 charge/discharge cycles were performed. Figure 6 shows three discharge curves, i.e. the discharge capacities as a function of the cycle number. All electrolytes show nearly the same progression of the discharge capacity.

It can be concluded from this that electrolytes 1 and 3, as well as the first conducting salt according to formula (I), have no serious negative effects on cycling behaviour.

Experiment 2: Function of the electrolytes according to the invention in a battery cell

With the reference electrolyte prepared in example 1 and the electrolytes 1, 2 or 3 prepared in example 2, experiments were carried out in full cells according to example 3. The reference electrolyte and the electrolytes 1, 2 and 3 each had a concentration of 0.6 mol/l of conducting salt. Four full cells were filled with the electrolytes. The full cells were charged with 50 mA up to a potential of 3.6 V. The potential of 3.6 volts was maintained until the current had dropped to a value of 40 mA. The discharge was performed with a current of 50 mA up to a potential of 2.5 V. In the upper part, Figure 7 shows the charging curves with reference to the scale of the left y-axis and in the lower part, it shows the discharging curves with reference to the scale of the right y-axis. With electrolytes 1, 2 and 3 the full cells could be charged and discharged again.

Experiment 3: Verification of high voltage capability of electrolytes 1, 2 and 3

To demonstrate the high voltage capability of electrolytes 1, 2 and 3, an experiment was carried out in full cells according to example 3. The full cell was filled with electrolyte 1 as described in example 2, which contained compound 1 as the first conducting salt in a molar concentration of 1 mol/l, based on 1 litre of the electrolyte.

Figure 8 shows the potential curve of the previously described full cell in volts [V] above the percentage loading which is based on the maximum loading of the full cell. The full cell was charged with an amperage of 50 mA up to a potential of 5 V. The potential was maintained until the charging current had dropped to 40 mA. Afterwards the discharge took place with an amperage of 50 mA to a discharge potential of 2.5 V. Figure 6 shows the charge/discharge curve of the full cell obtained in this experiment 3. Cycling efficiency was greater than 99.5%. This means that no capacity was used for secondary or overcharging reactions of the electrolyte. The electrolyte 1 is stable in this potential range. From this it can be concluded that the electrolyte according to the invention which contains the first conducting salt can also be used for high-energy cells in which high cell voltages occur, without the first conducting salt decomposing.

Experiment 4: Cycling efficiency

The charge/discharge experiment 3 was repeated, with the difference that the upper potential limit for charging was increased from 3.6 volts to 5.0 volts in 0.2-volt

steps. This means that eight cycles were performed. Table 2 shows the cycling efficiencies achieved in each case.

Table 2: Cycling efficiency as a function of charge potential

Charge potential	Cycling efficiency
3.60	99.7%
3.80	99.6%
4.00	99.7%
4.20	99.7%
4.40	99.7%
4.60	99.7%
4.80	99.7%
5.00	99.7%

The achieved cycling efficiencies are identical for each charge potential and show a stable behaviour of electrolyte 1 in the entire potential range up to 5.0 volts.

Experiment 5:

The electrolyte 3 according to the invention was compared with the reference electrolyte in a cycling experiment. Three full cells, as described in example 3, were used for this purpose. One full cell each was filled with the reference electrolyte and two full cells with electrolyte 3. The full cell was charged up to a potential of 3.6 volts and discharged to 2.5 volts. The full cell with the reference electrolyte was operated with a current of 100 mA, the two full cells with electrolyte 3, adapted to the lower conductivity, were charged or discharged once with 10 mA and once with 5 mA, respectively. Figure 9 shows the charge/discharge curves obtained. All full cells show a stable charge and a stable discharge. At lower currents, the attainable capacity for electrolyte 3 increases.

Experiment 6: Comparison of discharge capacities and internal resistance of full cells with reference electrolyte and electrolyte 1

In this experiment, the use of the electrolyte according to the invention as an alternative to the reference electrolyte used in the prior art was investigated.

The experiment was also carried out in the full cells described in example 3. The full cells were filled either with reference electrolyte (hereinafter referred to as reference full cell) or with the previously described electrolyte 1 according to the invention (hereinafter referred to as test full cell). Thus, the reference full cell and the test full cell differed only in the type of electrolyte used.

Several cycling experiments were performed, starting with a formation cycle. Table 3 shows the charging and discharging currents used in each case and the final charging and discharging voltages during charging and discharging of the two full cells. In addition, the limit of the charge current (I_{cutoff}) at the final charging voltage is 3.6 volts. There was a break of ten minutes between charging and discharging each of the two full cells.

Table 3: Data of the cycling experiments

- Formation: Charge / Discharge	- 1 cycle: 15 mA to 125 mAh / 15 mA to 2.5 V
- Cycling: Charge / Discharge	- 90 cycles: 50 mA to 3.6 V (I_{cutoff} = 40 mA) / 50 mA to 2.5 V
- 24 h Rest	- 1 cycle: 50 mA to 3.6 V (I_{cutoff} = 40 mA) / 24 h Rest / 50 mA to 2.5 V
- Cycling: Charge / Discharge	- 410 cycles: 50 mA to 3.6 V (I_{cutoff} = 40 mA) / 50 mA to 2.5 V

Figure 10 shows mean values for the discharge capacities of the two full cells as a function of the cycle number. The dashed line with long dashes shows the mean values obtained for discharge capacities of the test full cell. For this purpose, mean values obtained from three identical measurements were used. The dashed line with short lines shows the discharge capacities of the reference full cell. For this purpose, mean values obtained from two identical measurements were used.

These mean discharge capacity values are each expressed as a percentage of the nominal capacity. The nominal capacity is obtained by subtracting from the theoretical capacity of the positive electrode the capacity consumed in the first cycle to form a

covering layer on the negative electrode. This covering layer is formed on the negative electrode when the full cell is charged for the first time. Lithium ions are irreversibly consumed for this covering layer formation, so that the respective full cell has less cycling capacity available for the subsequent cycles.

The starting value of the discharge capacity of both full cells is approx. 90% of the nominal capacity. Both full cells show a discharge capacity drop across the cycle number. The capacity drop for the reference full cell was 19% up to the 500th cycle and the remaining capacity was then 71%. The test full cell had a discharge capacity drop of 22% and a remaining capacity of 68% after 500 cycles. Capacity progression in both curves is almost parallel from the 300th cycle onwards and suggests further stable progression. The behaviour of the full cells is similar and shows that the electrolyte according to the invention can be used as an alternative to the reference electrolyte.

During experiment 6, progression of the internal resistance of the two full cells was also recorded via the cycle number. Figure 11 shows the results for the reference full cell and for the test full cell. The internal resistance is a loss factor inside the full cell due to its design. The internal resistance of the reference full cell is slightly above 0.2 Ohm. The test full cell shows a higher internal resistance of initially approx. 0.95 Ohm, which is stable at a value of 0.8 Ohm from approx. cycle 200 onwards.

These results are in line with the applicant's expectations, as the lithium ionic conductivity in an electrolyte with large anions used according to the present invention is somewhat more difficult.

Experiment 7: Determining conductivities

The conductivity was determined by preparing the electrolyte 1 with different concentrations of compound 1. For each concentration of compound 1, the conductivity of electrolyte 1 was determined using a conductive measurement method. After temperature control, a two-electrode sensor was held in contact with the solution and measurement was carried out in a measurement range of 0 - 50 mS/cm. Table 4 shows the different concentrations, the corresponding SO_2 contents and the conductivity values determined.

Table 4: Conductivity as a function of the concentration of compound 1 in the electrolyte 1

c of compound 1 in mol/l	wt% SO_2	Conductivity in mS/cm
1.00	34%	13.6
0.60	60%	24.7
0.40	75%	20.8
0.20	87%	11.7

Figure 12 shows the conductivity of electrolyte 1 as a function of the concentration of compound 1. A maximum conductivity of 24.7 mS/cm is depicted at a concentration of compound 1 of 0.6 mol/l. In comparison, the organic electrolytes known from the prior art, such as LP30 (1 M LiPF6 / EC-DMC (1:1 weight)) have a conductivity of only approx. 10 mS/cm.

Experiment 8: Determination of a capacity consumed for the formation of a coating layer on the negative electrode

In this experiment, the capacity consumed in the first cycle for the formation of a covering layer on the negative electrode was investigated. This covering layer is formed on the negative electrode when the full cell is charged for the first time. Lithium ions are irreversibly consumed for this coating formation, so that the full cell has less cycling capacity available for the subsequent cycles.

The reference electrolyte, electrolyte 1 and electrolyte 3 were each examined in a full cell for this experiment. The structure corresponded to the structure described in example 3. The composition of the reference electrolyte used in a first experiment was LiAlCl4 * x SO_2 with x > 1.5. In a second and third experiment, electrolytes 1 and 3 were examined.

Figure 13 shows the potential in volts of the full cells when charging the negative electrode against lithium as a function of capacity, which is related to the theoretical capacity of the negative electrode. The dotted line shows the results for the reference electrolyte and the dotted or solid line shows the results for the electrolytes 1 and 3 according to the invention. The three curves show averaged results of several experiments each with the full cells described above. First, the full cells were charged with

a current of 15 mA until a capacity of 125 mAh (Q_{cha}) was reached. The full cells were then discharged at 15 mA until a potential of 2.5 volts was reached. This is when the discharge capacity (Q_{dis}) was determined.

The capacity in % of theory consumed to form the covering layer on the negative electrode is calculated according to the following formula:

$$\text{Covering layer capacity} = (Q_{cha}\ (125\ \text{mAh}) - Q_{dis}\ (x\ \text{mAh})) / Q_{NEL}$$

Q_{NEL} is the theoretical capacity of the negative electrode used. In the case of graphite, the theoretical capacity calculated is 372 mAh/g. The absolute capacity losses are 7.58% and 11.51% respectively for electrolytes 1 and 3 and 6.85% for the reference electrolyte. The capacity for the formation of the covering layer is slightly higher for both electrolytes according to the invention than for the reference electrolyte. Values in the range of 7.5% - 11.5% for absolute capacity losses are good results in combination with the possibility of using high-voltage cathodes of up to 5 volts.

Experiment 9: Low-temperature behaviour

In order to determine the low-temperature behaviour of an electrolyte according to the invention in comparison to the reference electrolyte, two full cells, as described in experiment 1, were filled with reference electrolyte on the one hand and electrolyte 1 on the other hand. Both full cells were charged at 20°C and discharged again. The discharge capacity achieved was rated 100%. In temperature steps of 10°C, the temperature of the full cells was lowered, and in each case a charge/discharge cycle was carried out again. The discharge capacity obtained was described in % of the discharge capacity at 20°C. Table 5 shows the results.

Table 5: Discharge capacities as a function of temperature

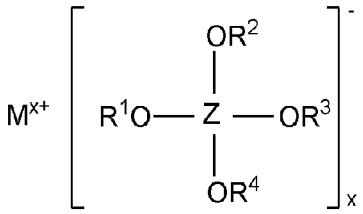
Temperature	Discharge capacity of electrolyte 1	Discharge capacity of reference electrolyte
20°C	100%	100%
10°C	87%	99%
0°C	72%	46%
-10°C	61%	21%
-20°C	31%	n/a

-30°C	3%	n/a
-40°C	0%	n/a

The full cell with electrolyte 1 shows an excellent low-temperature behaviour. At -10°C, 61% of the capacity is still reached. At -20°C the capacity reached is still 31%. Even at -30°C, a small amount can still be discharged. In contrast, the full cell with the reference electrolyte only shows a discharge capacity down to -10°C. There, a capacity of 21% is achieved.

Patentkrav

1. SO_2-baseret elektrolyt til en genopladelig battericelle indeholdende mindst et første ledende salt med formlen (I),



Formel (I)

hvor

- M er et metal, som er valgt fra gruppen bestående af alkalimetaller, jordalkalimetaller, metaller fra gruppe 12 i det periodiske system og aluminium;
- x er et heltal fra 1 til 3;
- substituenterne R^1, R^2, R^3 og R^4 uafhængigt af hinanden er valgt fra gruppen bestående af C_1-C_{10} alkyl, C_2-C_{10} alkenyl, C_2-C_{10} alkynyl, C_3-C_{10} cycloalkyl, C_6-C_{14} aryl og C_5-C_{14} heteroaryl; og
- hvor Z er aluminium eller bor.

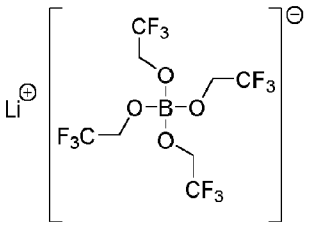
2. Elektrolyt ifølge krav 1,
hvor substituenterne R^1, R^2, R^3 og R^4 uafhængigt af hinanden er valgt fra gruppen bestående af

- C_1-C_6 alkyl; fortrinsvis af C_2-C_4 alkyl; især fortrinsvis af alkylgrupperne 2-propyl, methyl og ethyl;
- C_2-C_6 alkenyl; fortrinsvis C_2-C_4 alkenyl; især fortrinsvis af alkenylgrupperne ethenyl og propenyl;
- C_2-C_6 alkynyl; fortrinsvis af C_2-C_4 alkynyl;
- C_3-C_6 cycloalkyl;
- phenyl; og
- C_5-C_7 heteroaryl.

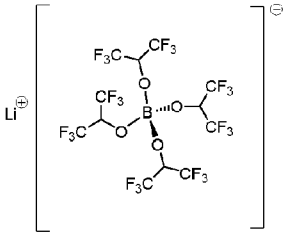
3. Elektrolyt ifølge krav 1 eller 2,
hvor mindst en af substituenterne R^1, R^2, R^3 og R^4 er substitueret med mindst et fluoratom og/eller med mindst en kemisk gruppe, hvor den kemiske gruppe er valgt fra gruppen bestående af C_1-C_4 alkyl, C_2-C_4 alkenyl, C_2-C_4 alkynyl, phenyl og benzyl.

4. Elektrolyt ifølge et af kravene 1 til 3,
hvor mindst en af substituenterne R^1, R^2, R^3 og R^4 er en CF_3-gruppe eller en OSO_2CF_3-gruppe.

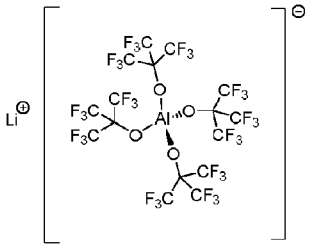
5. Elektrolyt ifølge et af kravene 1 til 4,
hvor det første ledende salt er valgt fra gruppen bestående af



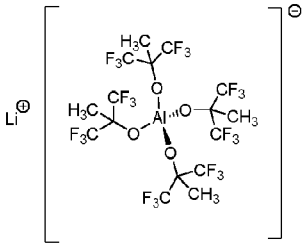
$Li[B(OCH_2CF_3)_4]$



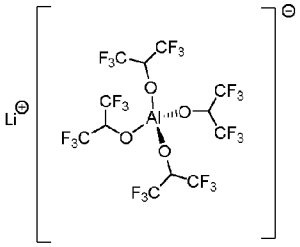
$Li[B(OCH(CF_3)_2)_4]$



$Li[Al(OC(CF_3)_3)_4]$



$Li[Al(OC(CH_3)(CF_3)_2)_4]$



$Li[Al(OCH(CF_3)_2)_4]$.

6. Elektrolyt ifølge et af kravene 1 til 5,
der indeholder mindst et andet ledende salt, der adskiller sig fra det første ledende salt ifølge formlen (I).

7. Elektrolyt ifølge krav 6,
hvor det andet ledende salt er en alkalimetalforbindelse, især en lithiumforbindelse valgt fra gruppen bestående af et aluminat, et halogenid, et oxalat, et borat, et phosphat, et arsenat og et gallat.

8. Elektrolyt ifølge krav 6 eller 7,
hvor det andet ledende salt er et lithiumtetrahalogenoaluminat, især lithiumtetrachloraluminat.

9. Elektrolyt ifølge et af kravene 1 til 8,
som indeholder mindst et tilsætningsstof.

10. Elektrolyt ifølge krav 9,
hvor tilsætningsstoffet er valgt fra gruppen bestående af vinylencarbonat og dets derivater, vinylethylencarbonat og dets derivater, methylethylencarbonat og dets derivater, lithium(bisoxalato)borat, lithiumdifluor(oxalato)borat, lithiumtetrafluor(oxalato)phosphat, lithiumoxalat, 2-vinylpyridin, 4-vinylpyridin, cykliske exomethylencarbonater, sultoner, cykliske og acykliske sulfonater, acykliske sulfitter, cykliske og acykliske sulfinater, organiske estere, uorganiske syrer, acykliske og cykliske alkaner, hvor de acykliske og cykliske alkaner har et kogepunkt ved 1 bar på mindst 36°C, aromatiske forbindelser, halogenerede cykliske og acykliske sulfonylimider, halogenerede cykliske og acykliske phosphatestere, halogenerede cykliske og acykliske phosphiner, halogenerede cykliske og acykliske phosphitter, halogenerede cykliske og acykliske phosphazener, halogenerede cykliske og acykliske silylaminer, halogenerede cykliske og acykliske halogenerede estere, halogenerede cykliske og acykliske amider, halogenerede cykliske og acykliske anhydrider og halogenerede organiske heterocykler.

11. Elektrolyt ifølge et af kravene 1 til 10,
omfattende en sammensætning af

(i) 5 til 99,4 vægtprocent svovldioxid,

(ii) 0,6 til 95 vægtprocent af det første ledende salt,

(iii) 0 til 25 vægtprocent af det andet ledende salt; og

(iv) 0 til 10 vægtprocent af tilsætningsstoffet

baseret på den samlede vægt af elektrolytsammensætningen.

12. Elektrolyt ifølge et af kravene 1 til 11,
hvor den molære koncentration af det første ledende salt er i området fra 0,05 mol/l til 10 mol/l, fortrinsvis fra 0,1 mol/l til 6 mol/l og især fortrinsvis fra 0,2 mol/l til 3,5 mol/l baseret på det samlede volumen af elektrolytten.

13. Elektrolyt ifølge et af kravene 1 til 12,
hvor elektrolytten indeholder mindst 0,1 mol SO_2, fortrinsvis mindst 1 mol SO_2, mere fortrinsvis mindst 5 mol SO_2, mere fortrinsvis mindst 10 mol SO_2 og især fortrinsvis mindst 20 mol SO_2 pr. mol ledende salt.

14. Genopladelig battericelle (2) indeholdende en elektrolyt ifølge mindst et af de ovennævnte krav, et aktivt metal, mindst en positiv elektrode (4), mindst en negativ elektrode (5) og et hus (1).

15. Genopladelig battericelle (2) ifølge krav 14,
hvor det aktive metal er

- et alkalimetal, især lithium eller natrium;
- et jordalkalimetal, især calcium;
- et metal fra gruppe 12 i det periodiske system, især zink; eller
- aluminium.

16. Genopladelig battericelle (2) ifølge krav 14 eller 15,
hvor den negative elektrode (5) er en indsættelseselektrode, fortrinsvis indeholdende carbon som et aktivt materiale, især i grafitmodifikationen.

17. Genopladelig battericelle (2) ifølge et af kravene 14 til 16,
hvor den positive elektrode (4) som aktivt materiale indeholder mindst en interkaleringsforbindelse, som fortrinsvis indeholder sammensætningen $Li_xM'_yM''_zO_a$, hvor

- M' er mindst et metal valgt fra gruppen bestående af grundstofferne Ti, V, Cr, Mn, Fe, Co, Ni, Cu og Zn;

- M" er mindst et grundstof valgt fra gruppen bestående af grundstofferne 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 og 16 i det periodiske system,
- x og y er større end 0,
- z er større end eller lig med 0, og
- a er større end 0.

18. Genopladelig battericelle (2) ifølge krav 17, hvor interkaleringsforbindelsen omfatter sammensætningen $Li_xM'_yM''_zO_a$, hvor M' er jern, og M" er phosphor, og hvor fortrinsvis x, y og z er lig med 1, og a er lig med 4.

19. Genopladelig battericelle (2) ifølge krav 17 eller 18, hvor interkaleringsforbindelsen har sammensætningen $Li_xM'_yM''_zO_a$, hvor M' er mangan, og M" er kobolt, og hvor fortrinsvis x, y og z er lig med 1, og a er lig med 4.

20. Genopladelig battericelle (2) ifølge krav 17 eller 18, hvor interkaleringsforbindelsen omfatter sammensætningen $Li_xM'_yM''_zO_a$, hvor M' omfatter nikkel og mangan, og M" er kobolt.

21. Genopladelig battericelle (2) ifølge et af kravene 14 til 20, hvor den positive elektrode (4) indeholder mindst en metalforbindelse valgt fra gruppen bestående af et metaloxid, et metalhalogenid og et metalphosphat, hvor metallet af metalforbindelsen fortrinsvis er et overgangsmetal med et atomnummer på 22 til 28 i det periodiske system, især kobolt, nikkel, mangan eller jern.

22. Genopladelig battericelle (2) ifølge et af kravene 14 til 21, hvor den positive elektrode (4) og/eller den negative elektrode (5) har et afledereelement (34, 35), som fortrinsvis er dannet af

- enten en planformet metalplade eller en metalfolie, eller

- en tredimensionel form af en porøs metalstruktur, især i form af et metalskum (18).

23. Genopladelig battericelle (2) ifølge et af kravene 14 til 22, hvor den positive elektrode (4) og/eller den negative elektrode (5) indeholder mindst et bindemiddel, fortrinsvis et fluoreret bindemiddel, især et polyvinylidenfluorid og/eller en terpolymer af tetrafluorethylen, hexafluorpropylen og vinylidenfluorid, eller
et bindemiddel bestående af en polymer sammensat af monomere strukturenheder af en konjugeret carboxylsyre eller af alkali-, jordalkali- eller ammoniumsalt af den konjugerede carboxylsyre eller af en kombination deraf, eller
et bindemiddel bestående af en polymer, der er baseret på monomere styren- og butadienstrukturenheder, eller et bindemiddel fra gruppen af carboxymethyl-celluloser,

hvor bindemidlet fortrinsvis er til stede i en koncentration på højst 20 vægtprocent, mere fortrinsvis højst 15 vægtprocent, mere fortrinsvis højst 10 vægtprocent, mere fortrinsvis højst 7 vægtprocent, mere fortrinsvis højst 5 vægtprocent og især fortrinsvis højst 2 vægtprocent baseret på den samlede vægt af den positive elektrode.

24. Genopladelig battericelle (2) ifølge et af kravene 14 til 23, som omfatter en flerhed af negative elektroder (4) og en flerhed af positive elektroder (5), som er skiftevis stablet i huset (1), hvor de positive elektroder (4) og de negative elektroder (5) fortrinsvis i hvert tilfælde er adskilt elektrisk fra hinanden ved hjælp af separatorer (11).

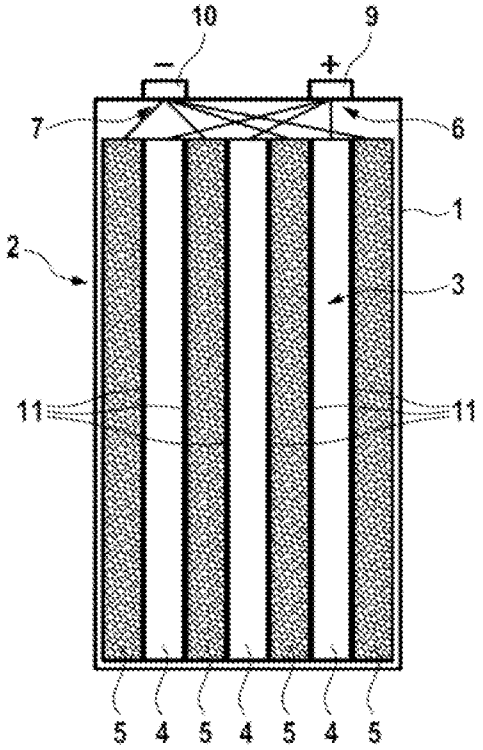


Fig. 1

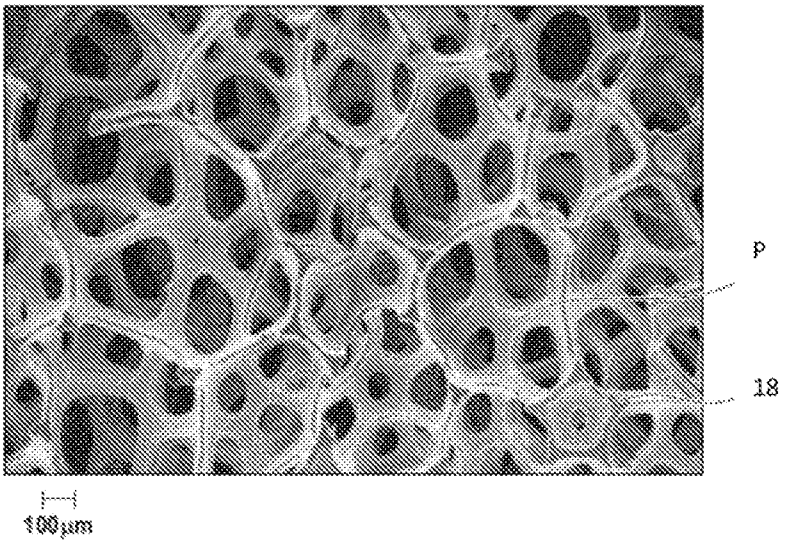


Fig. 2

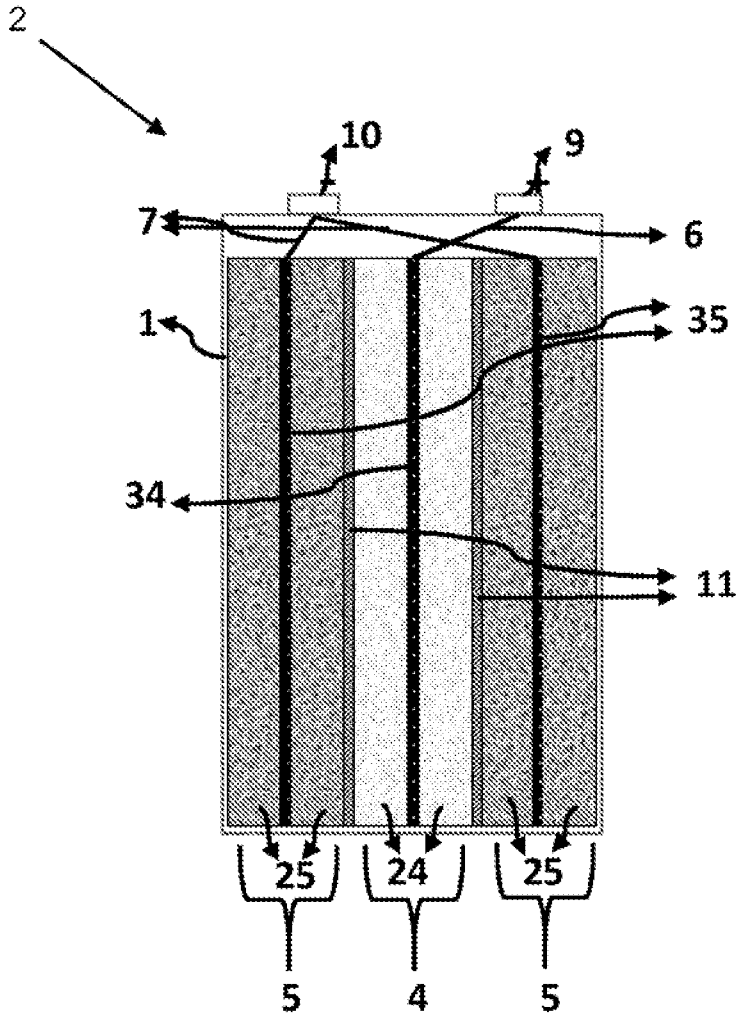


Fig. 3

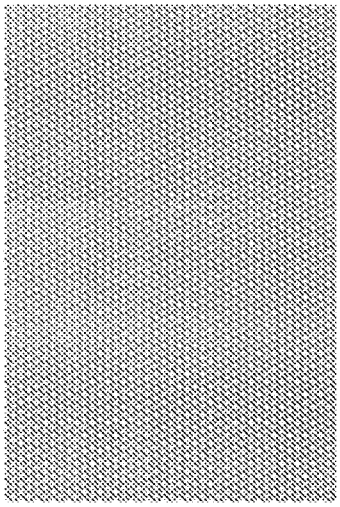


Fig. 4

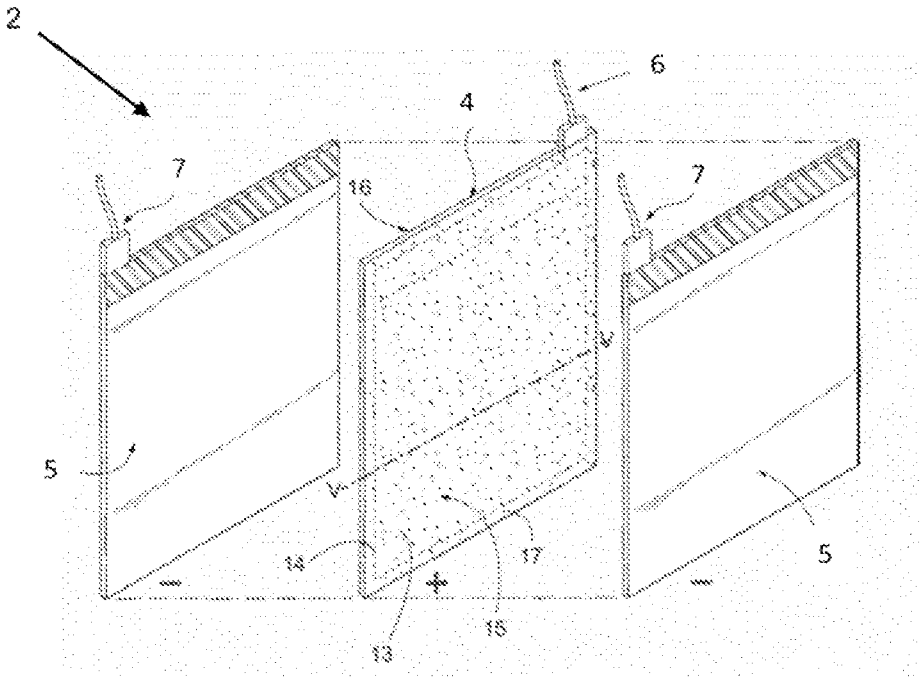


Fig. 5

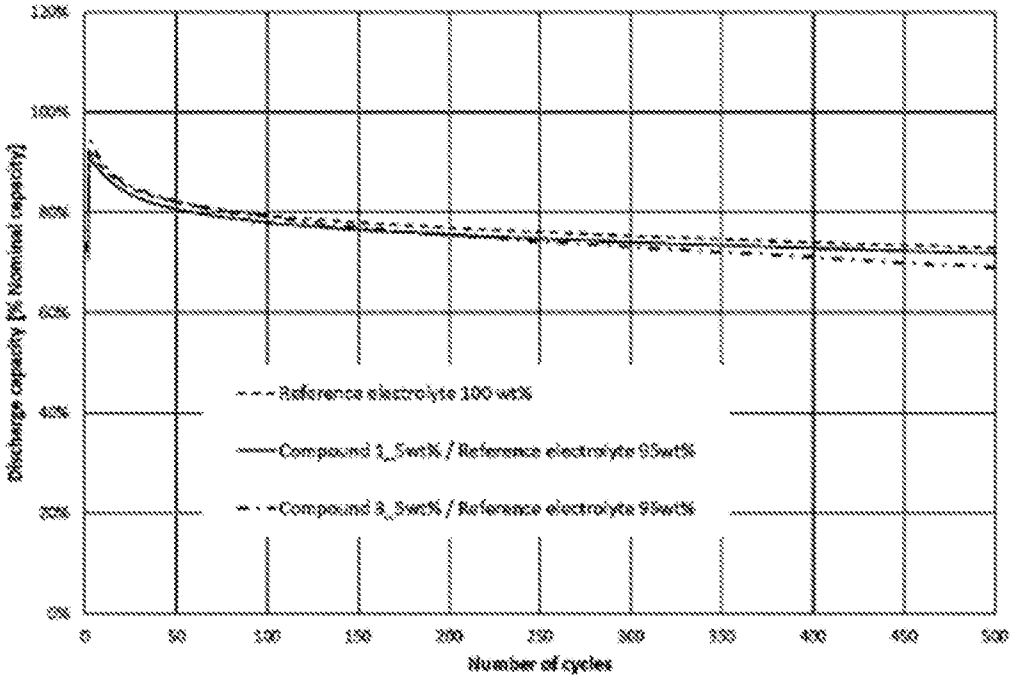

Discharge capacity [% Nominal capacity]
Number of cycles
Reference electrolyte 100 wt%
Compound 1_5wt% / Reference electrolyte 95wt%
Compound 3_5wt% / Reference electrolyte 95wt%

Fig. 6

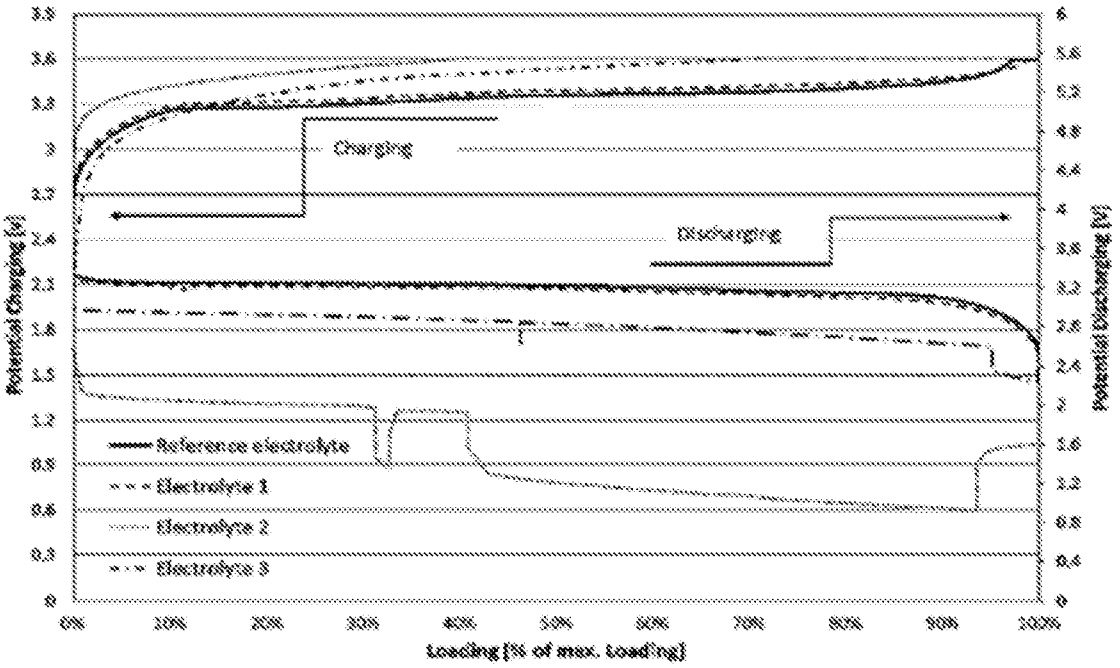

Potential Charging [V]
Potential Discharging [V]
Charging
Discharging
Reference electrolyte
Electrolyte 1
Electrolyte 2
Electrolyte 3
Loading [% of max. Loading]

Fig. 7

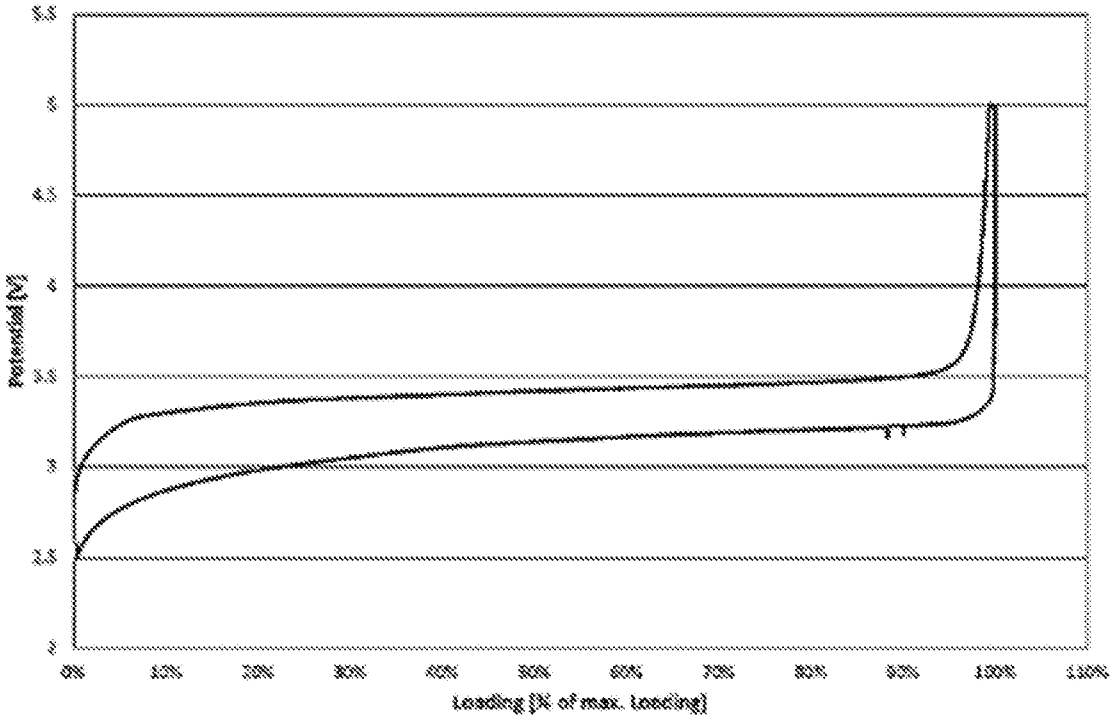

Potential [V]
Loading [% of max. Loading]

Fig. 8

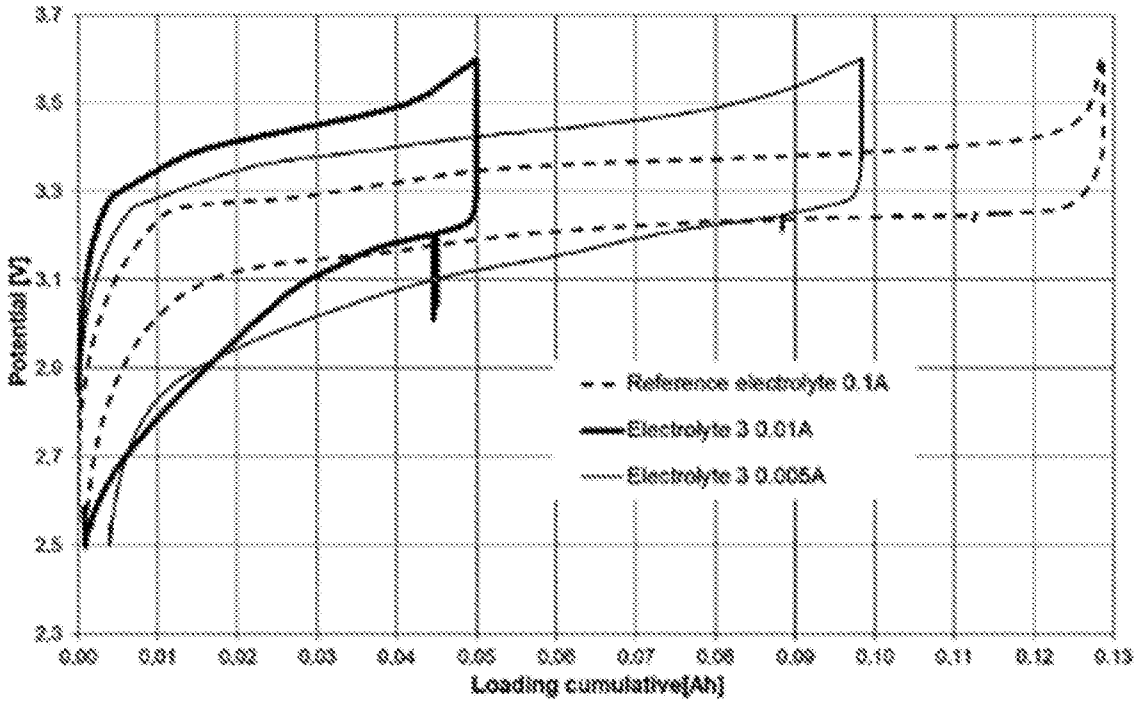

Potential [V]
Loading cumulative[Ah]
Reference electrolyte 0.1A
Electrolyte 3 0.01A
Electrolyte 3 0.005A

Fig. 9

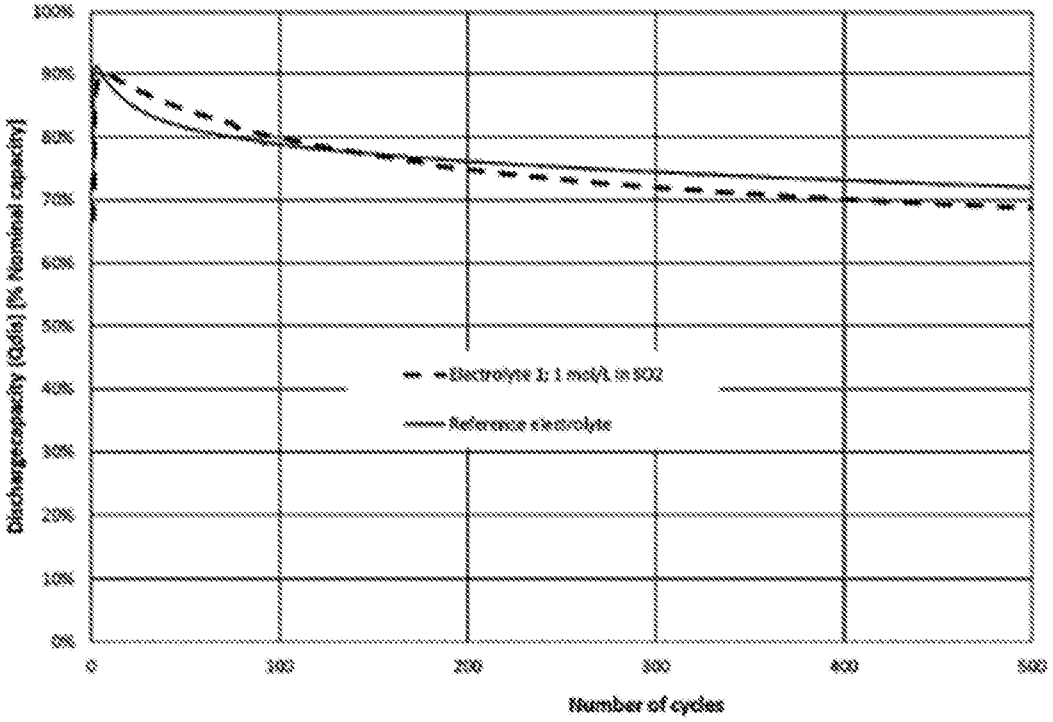

Discharge capacity (Qdis) [% Nominal capacity]
Number of cycles
Electrolyte 1; 1 mol/L in SO2
Reference electrolyte

Fig. 10

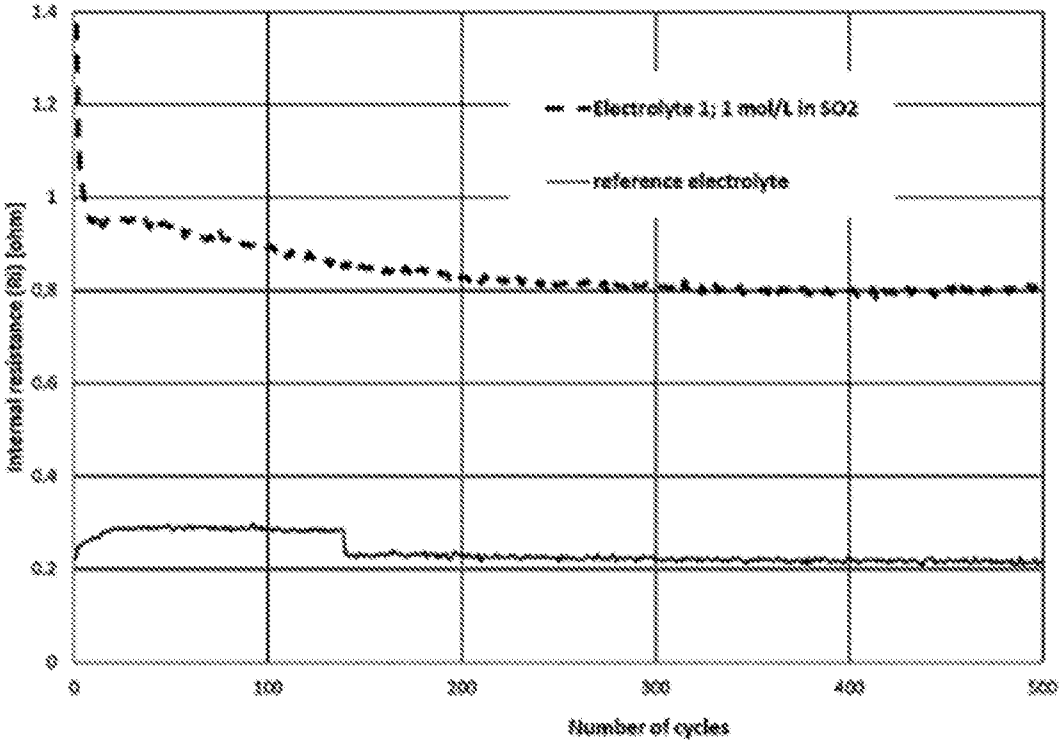

Internal resistance (Rb) [ohm]
Number of cycles
Electrolyte 1; 1 mol/L in SO2
reference electrolyte

Fig. 11

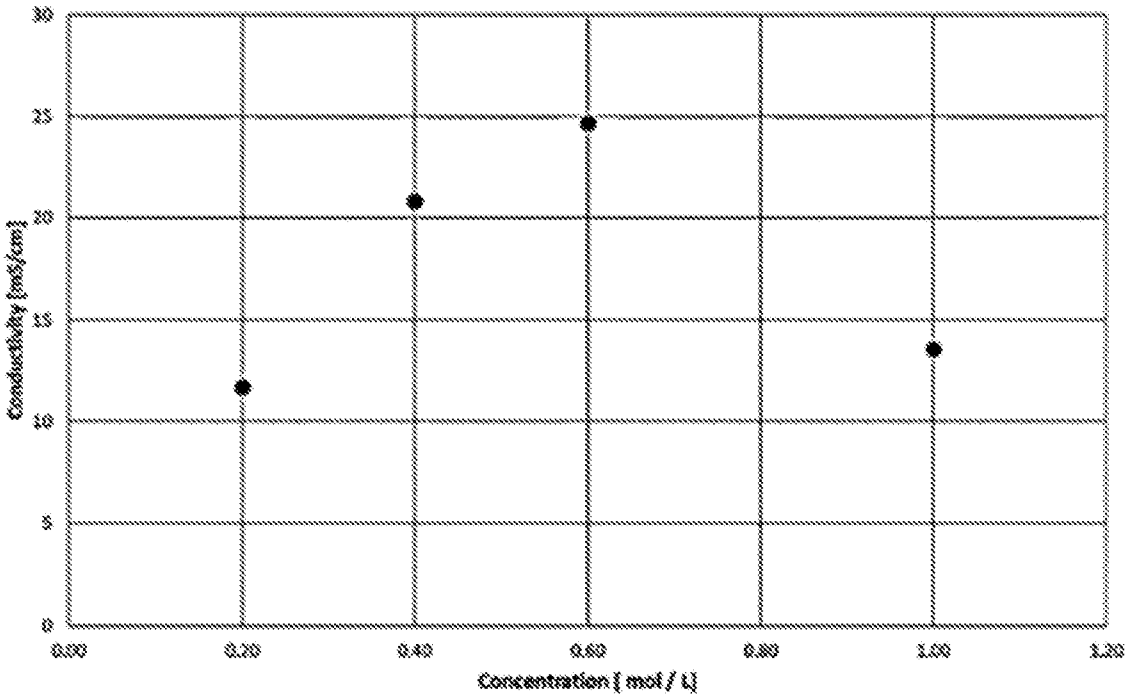

Conductivity [mS/cm]
0
5
10
15
20
25
30
0.00
0.20
0.40
0.60
0.80
1.00
1.20
Concentration (mol / L)

Fig. 12

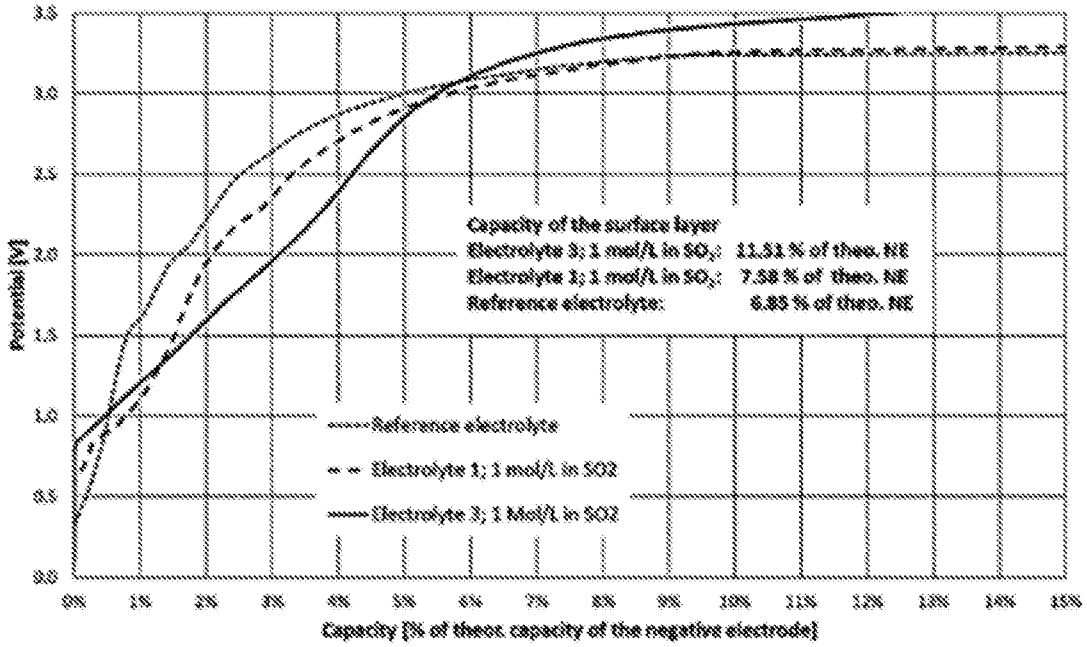

Potential [V]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0%
1%
2%
3%
4%
5%
6%
7%
8%
9%
10%
11%
12%
13%
14%
15%
Capacity [% of theor. capacity of the negative electrode]
Capacity of the surface layer
Electrolyte 3; 1 mol/L in SO2: 11.51 % of theo. NE
Electrolyte 1; 1 mol/L in SO2: 7.58 % of theo. NE
Reference electrolyte: 6.85 % of theo. NE
Reference electrolyte
Electrolyte 1; 1 mol/L in SO2
Electrolyte 3; 1 Mol/L in SO2

Fig. 13