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(54) **Rechargeable non-aqueous cell with a chalcogenide-containing electrode, a method for preparing the chalcogenide compound and a method for the preparation of the cell.**

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Rechargeable non-aqueous cell with a chalcogenide-containing electrode, a method for preparing the chalcogenide compound and a method for the preparation of the cell

Background of the Invention

1. Field of the Invention

The invention relates to a nonaqueous secondary cell comprising a negative electrode made with lithium and/or sodium, an electrolyte, and a positive electrode made with a layered chalcogenide as the active material. Further, the invention relates to a method for preparing said cell, as well as to a method for producing the chalcogenide composition itself.

2. Description of the Prior Art

There has been considerable interest in recent years in nonaqueous cells because of their potentially high energy densities. Particularly attractive are nonaqueous cells using negative electrodes made with Group I elements such as lithium or sodium, because the high standard potential and low weight density of these elements afford exceptional possibilities for high cell voltage and high energy capacity per unit weight and per unit volume. Cells having these properties would be useful in any situation in which cell weight and/or volume are critical factors. The positive electrode material should be electrically conductive, because at high discharge rates the energy density depends on the conductivity of the positive electrode material, and also should have properties that enable it to react readily and reversibly with the negative electrode material to enhance secondary battery characteristics. To retain the weight advantages afforded by the negative electrode material, the positive electrode materials should also be light.

Positive electrode materials presently contemplated by persons investigating nonaqueous cells include the layered dichalcogenides of the transition metals of Groups IVB and VB of the periodic table. These materials have attracted much interest because of their ability to intercalate a number of species, including lithium, between the layers. The term intercalate is used to mean movement both into and out of the layered structure.

One such layered chalcogenide that appears promising and has been the object of several studies is TiS_2. The TiS_2 structure consists of a sandwich formed by a layer of Ti atoms surrounded on either side by a layer of chalcogens. The negative electrode is made from a species, e.g., lithium, which intercalates between the TiS_2 layers as the cell charges and discharges. Studies performed with techniques such as nuclear magnetic resonance and x-ray diffraction indicate that Li_yTiS_2, for all values of y between the 0 and 1, i.e., as the cell goes through a complete charge or discharge cycle, forms a single non-stoichiometric phase. Li_yTiS_2 cells have a middischarge, i.e., $y = 0.5$, voltage of 2.2 volts and an energy density of 480 watt-hour/kg and are easily reversible for a large number of cycles.

Theoretically, the use of some layered chalcogenides, such as VS_2, in a cell using a lithium negative electrode should, be more attractive than of TiS_2, because the values for both the voltage and energy density should exceed the values for TiS_2. The BE-A 849 473 discloses the use in a hi-cell of VS_2 as produced by a precipitation reaction from a nonaqueous solution in the form of a lithium addition product using n-butyllithium to obtain $Li_y VS_2$ ($0 < y < 1.5$). However, and fundamentally, as has been found from the present study, $LiVS_2$ cells have limited reversibility, approximately 50 percent of the theoretical capacity based on one lithium atom per vanadium atom, at room temperature when put through complete charge-discharge cycles. Although the reason for this limited reversibility at room temperature could not yet be clarified with certainty, it is believed due to phase changes in the $LiVS_2$ system as lithium intercalates during a charge and discharge cycle. Li_yVS_2 for $y = 0$ and for $y > .6$ has a regular hexagonal structure. The system has slightly distorted monoclinic structures for $0.2 < y < .33$ and $0.5 < y < 0.6$. For $0.33 < y < 0.5$ and $0.0 < y < 0.2$, the system consists of two phases.

The presence, at room temperatures, of the additional phases decreases cell capacity to approximately 50 percent of the theoretical value when the cell is cycled at moderate current densities because the intercalation process is not readily reversed, as it is for TiS_2, due to slow attainment of equilibrium conditions. The reason for slow attainment of equilibrium is not known with certainty but appears related to either reduced lithium mobility or a slow rate of phase nucleation. Similar considerations have limited both use and investigation of $LiCrS_2$ cells. Therefore the problem to be solved by the invention is, to improve the cell reversibility by providing a new class of layer chalcogenides for the active positive electrode material, and to provide a new method for producing the latter.

Summary of the Invention

According to the present invention, the solution of this problem is characterized, for a cell of the initially indicated type, in that said chalcogenide has the nominal atom composition $M_xN_{1-x}S_2$, in which M is Mn, Fe, Ni and/or Co and N is V and/or Cr and in which x is greater than zero but less than or equal to a maximum value of 0.5 when N is V and M is Fe, less than or equal to a maximum value of 0.33 when N is V and M is Ni, Co or Mn, and less than a maximum value of 0.33 when N is Cr, and, when N is V and M is Fe and at least one of Ni, Co and Mn, said maximum value of x scales linearly from 0.33 to 0.50 with the Fe atom percent of M.

The method of preparing the compound having the aforesaid nominal atom composition $M_xN_{1-x}S_2$ is characterized according to the invention, in that an oxidizing agent having an oxidizing potential of at least 2.8 volts is added to $Li_yM_xN_{1-x}S_2$, where y is less than or equal to one, said $Li_yM_x\ N_{1-x}\ S_2$ being prepared by reacting stoichiometric quantities of the alkali metal carbonate, an oxide of M and N with sulfur, said chalcogenide preparations being carried out in the absence of air and/or moisture.

As has been found, the addition of Mn, Fe, Ni or Co makes the intercalation of lithium or sodium with $M_xN_{1-x}S_2$ readily reversible and permits the cells to be cycled numerous times. In a preferred embodiment M is Fe, N is V, and *x* is greater than 0.20 and less than or equal to 0.33.

Brief Description of the Drawing

FIG. 1 shows a side view of a cell employing a conventional negative electrode and a positive electrode having a layered chalcogenide as the active substance.

FIG. 2 shows cell voltage in volts, on the ordinate for $Li_y\ TiS_2$ and $Li_y\ VS_2$ cells as a function of lithium content, as represented by y, on the abscissa, for cells using TiS_2 (solid line) and VS_2 as the positive electrode material, and

FIG. 3 shows cell voltage in volts, on the ordinate, as a function of percent charge and discharge at a constant charge and discharge current, on the abscissa, for a cell using $Fe_{.25}V_{.75}S_2$ as the active cathode material and having a lithium anode.

Detailed Description

FIG. 1 shows a side view of a cross-section of a cell structure 10 with a negative electrode 11, a separator 12 impregnated with an electrolyte and a postive electrode 13 containing the layered chalcogenide as the active electrode material. Also shown are current collectors 14, on both sides of the electrodes, and the surrounding structure 15 which is usually made of an inert, non-conducting material. Other cell structures such as one having thin film electrodes may also be constructed. A cell with thin film electrodes may be assembled in several ways including putting the various sheets forming the electrodes and separator together to form a rectangular battery or rolling in the form of a cylinder.

FIG. 2 relates for a Li_yTiS_2 cell, solid line, and a Li_yVS_2 cell, dashed line, cell voltage in volts, on the ordinate and lithium content, represented by *y*, on the abscissa. The circles on the dashed line represent the open circuit values for Li_yVS_2 compounds prepared as later described and with no current flowing.

The dichalcogenides having the nominal atom composition $M_xN_{1-x}S_2$, where M is Mn, Fe, Co, or Ni or mixtures thereof, and N is V or Cr, form two dimensional layered structures structurally similar to TiS_2 and VS_2 and also possessing the ability to intercalate, with relative ease, small atomic species, such as lithium, between layers of the structure. Although the composition of the active cathode material is described in terms of a stoichiometric composition, this composition is only the nominal atom composition and the actual compositions used may deviate from the nominal composition by as much as plus or minus five percent from stoichiometry. Greater deviations from stoichiometry are undesirable as the intercalation process may be significantly slowed. The chalcogenide is described in terms of N being V or Cr or mixtures thereof, and the Mn, Fe, Co or Ni atoms randomly substitute in the lattice for V or Cr atoms without significantly changing the voltages shown in FIG. 2. The substituents apparently reduce order in the structure and the reduced order probably results in only a single phase being present during the intercalation process and certainly results in weakening and broadening phase transitions to allow easy formation of these phases at room temperature as atomic species intercalate. Minimization of the problem of slow intercalation due to, e.g., phase transitions, by the addition of order reducing substituents results in cells having $M_xN_{1-x}S_2$ as the active positive electrode material and easy reversibility. Easy intercalation of lithium and other atoms, such as sodium, in the $M_xN_{1-x}S_2$ structure makes the compounds useful as the active material in cathodes of nonaqueous cells operating at room temperature and having high cell voltage and high energy density.

I. Preparation of the Active Cathode Material

The active material, $M_xN_{1-x}S_2$, may be prepared in a variety of ways. The preparatory operations are carried out in the absence of air since the chalcogenides in the discharged state may be highly reactive toward moisture. The following methods have been found to yield good results.

To prepare the active material in the discharged state, i.e., with sodium or lithium, stoichiometric quantities of the alkali metal carbonate and the oxide of M, and an oxide of N, e.g., V_2O_5 or Cr_2O_3, are placed in an inert container, such as a graphite boat, within a quartz tube. The temperature is raised to a value that is typically within the range extending from 300 degrees C to 800 degrees C and a flow of sulfur or a sulfur containing compound such as CS_2 or H_2S introduced. The reaction is allowed to proceed until evolution of water or CO_2, depending upon the sulfur compound used, ceases. Lower temperatures require a longer time and above 800 degrees C, if H_2S is used, water is evolved too vigorously to permit easy preparation of the material. The quartz tube is then sealed under an inert atmosphere, e.g., argon, and placed in a dry box. To insure complete reaction of all of the initial material, the material is no ground, thoroughly mixed and refined in H_2S at a temperature within the

range from 300 degrees C to 800 degrees C for 16 to 24 hours. This step is desirable as all of the material may not have been exposed to sulfur in the initial step. The quartz tube is sealed under argon and reopened only under argon. $M_xN_{1-x}S_2$, the charged state, may be prepared by adding an oxidizing agent with an oxidizing potential of at least 2.8 volts (measured with respect to a Li/Li^+ electrode) to the material prepared according to the previous paragraph. Suitable oxidizing agents include iodine, chlorine and bromine. The oxidizing agent is conveniently added in a solvent which is inert to the oxidizing agent and in which the lithium or sodium containing product is soluble. A suitable solvent is acetonitrile. The mixture is stirred until the oxidizing agent is consumed. The mixture is then filtered, washed with a solvent such as acetonitrile and vacuum dried. If $x = 0$, the method permits preparation of VS_2. Pure CrS_2 cannot be prepared in this manner but $M_xCr_{1-x}S_2$, with x having values less than 0.33 may be prepared. $Cr_zV_{1-z}S_2$, with z less than or equal to 0.75 may also be prepared in this manner.

The chemistry of the described processes is summarized by an example showing the preparation of $LiFe_xV_{1-x}S_2$:

$$Li_2CO_3 + (1\text{-}x)\,V_2O_5 + xFe_2O_3 \xrightarrow[700\text{ degrees C}]{H_2S} 2LiFe_xV_{1-x}S_2 \qquad (1)$$

$$LiFe_xV_{1-x}S_2 \xrightarrow[CH_3OH]{I_2} Fe_xV_{1-x}S_2 \qquad (2)$$

If desired, intermediate compounds, i.e., compounds with y less than one, with the formula $Li_yFe_xV_{1-x}S_2$ may also be prepared:

$$LiFe_xV_{1-x}S_2 + \left(\frac{1-y}{2}\right) I_2 \longrightarrow Li_yFe_xV_{1-x}S_2 + (1\text{-}y)\,LiI \qquad (3)$$

Similar equations describe the processes for the other cathode materials, i.e. for the cases where M is Mn, Ni or Co; N is Cr, or where Na is used as the anode material. If M is Fe and N is V, the value of x is ≤ 0.5 as Fe compounds other than $Fe_xN_{1-x}S_2$ may be present if this value is exceeded. It has been found that the best cell properties are obtained if x is greater than 0.20 and less than 0.33. For Mn, Ni and Co, where N is V the value of x is less than or equal to 0.33 to prevent formation of unwanted compounds. If N is Cr, x is less than or equal to 0.33, to insure that unwanted compounds are not present. If mixtures are present, the maximum value of x scales linearly with the atom percent of each element. For example, if N is V and M is 50 percent Fe and 50 percent Mn by atom percent, the maximum value of x is 0.42.

II. Cell Construction

In general, cell fabrication may be carried out to yield the cell in either the charged or discharged state. One typical construction method will be briefly outlined. A mixture of $LiM_xN_{1-x}S_2$ and a material, such as polyethylene, that acts as a binder is thoroughly mixed as by rolling on a jar mill. Other materials that are also nonreactive with the compound and do not alloy with lithium may also be used. The mixture is pressed into a nonreactive metal gride such as one made of Ni, Fe, Co or Ti. The pressing should result in mechanical integrity and good electrical contacts as well as good electrical conductivity. It has been found that pressing at 130 degrees C with a pressure of approximately 2,000 pounds per square inch (13,789,600 newtons per square meter) yields good results. It is also desirable that air be excluded during these operations to prevent undesired chemical reactions between the chalcogenide or anode material, such as lithium, and water and accordingly the operations are conveniently carried out in a dry box. The pressed material forms the cathode and is sandwiched between two plates forming a conventional anode made from, e.g., lithium or sodium. Alternatively, the structure of FIG. 1 may be made in which case only one lithium or sodium plate is necessary to form the anode. The electrolyte used in the cell is conventional and a variety of electrolytes which do not react chemically with either the anode or cathode materials and which are electrically conductive to permit ready migration of ions during the intercalation process may be used. Typical electrolytes include $LiPF_6$, $LiClO_4$, etc. The electrolyte may be present either in the pure state or dissolved in a suitable solvent such as propylene carbonate, ethylene carbonate, etc. Solid electrolytes such as LiI may also be used. The cell is sealed to insure isolation of the material from air after its removal from the dry box and provided with suitable electrical contacts.

III. Examples

1. Preparation of $LiFe_{0.25}V_{0.75}S_2$. A mixture of 4.329 grams of Li_2CO_3, 2.339 grams of Fe_2O_3 and 7.992 grams of V_2O_5 was placed in a graphite boat, within a quartz tube, and maintained for two hours

at a temperature of 500 degrees C in a flow of H_2S. The temperature was raised to 700 degrees C for 18 hours. The quartz tube was sealed under argon and placed in a dry box. The material was ground, mixed and refired in H_2S for 18 hours at 700 degrees C. The tube was then sealed and subsequently opened only when under argon.

2. Preparation of $Fe_{0.25}V_{0.75}S_2$. To 1.450 grams of $LiFe_{0.25}V_{0.75}S_2$, 50 ml of a 0.236 N iodine solution in 200 ml of acetonitrile were added under argon. The reaction mixture was stirred for 18 hours, filtered, washed with acetonitrile and vacuum dried.

3. Preparation of $LiCr_{0.33}V_{0.33}Fe_{0.33}S_2$. A mixture of 5.031 grams of Li_2CO_3, 3.45035 grams of Cr_2O_3, 3.6237 grams of Fe_2O_3, and 4.1275 grams of V_2O_5 was placed in a graphite boat and prepared as was the material in Example 1.

4. Preparation of $LiV_{0.67}Mn_{0.33}S_2$. A mixture of 4.9566 grams of Li_2CO_3, 8.1339 grams of V_2O_5 and 3.8874 grams of MnO_2 was placed in a graphite boat and prepared as was the material in Example 1.

5. Preparation of a $LiFe_{0.5}V_{0.5}S_2$ (discharged) cell. A mixture of $LiFe_{0.5}V_{0.5}S_2$ (77.1%), graphite (15.4%) and polyethylene powder (7.5%) was thoroughly mixed by rolling on a jar mill. 1.005 grams of the mixture were pressed into an expanded nickel grid having dimensions of 2.2 cm x 2.5 cm at 130 degrees C with a pressure of approximately 2000 p.s.i. (13,789,600 newtons per square meter) The rolling and pressing operations were carried out with air excluded. This electrode, forming the cathode, was sandwiched between two conventional lithium anodes. Adjacent electrodes were separated by glass filter paper. A 1*M* solution of $LiClO_4$ in propylene carbonate was added as the electrolyte. The entire cell was sealed to exclude air and electrical contacts were provided.

6. Preparation of a $LiFe_{0.25}V_{0.75}S_2$ (discharged) cell with lithium. The cell was constructed, as in FIG. 1, with a sheet of lithium as the anode approximately 15 mils (38×10^{-3}cm.) thick and having a surface area of about 1 cm^2, a porous glass separator, 27.7 mg of loose $LiFe_{0.25}V_{0.75}S_2$ powder prepared as in Example 1, and several drops of 1*M* $LiClO_4$ in propylene carbonate as the electrolyte. The nickel-plated current collectors were tightened to make electrical contact.

7. Preparation of a $Fe_{0.25}V_{0.75}S_2$ (charged) cell with lithium. The cell was constructed with a lithium sheet approximately 15 mils (38×10^{-3}cm.) thick and a surface area of about 1 cm^2, a porous glass separator, 14 mg of loose $Fe_{0.25}V_{0.75}S_2$ powder prepared as in Example 2, and several drops of 1*M* $LiClO_4$ in propylene carbonate. The nickel plated current collectors were tightened to make electrical contacts.

8. Preparation of a $LiCr_{0.33}V_{0.33}Fe_{0.33}S_2$ (discharged) cell. The cell was prepared as in Example 6 using material prepared as in Example 3.

9. Preparation of a $LiV_{0.67}Mn_{0.33}S_2$ (discharged) cell. The cell was prepared as in Example 6 using material prepared as in Example 4.

10. Preparation of VS_2. $LiVS_2$ was prepared as in Example 1 using stoichiometric quantities of Li_2CO_3 and V_2O_5. 200 ml of a 0.192 N iodine solution in acetonitrile were added to 4.670 grams of $LiVS_2$. The reaction mixture was stirred until the iodine color faded, filtered, washed with acetonitrile and vacuum dried.

Similar methods may be used for other values of *x* within the ranges previously given and for materials and cells using Ni, Mn or Co rather than Fe.

IV. Cell Characteristics

The cell prepared as in Example 5 was cycled at room temperature with an average capacity over seven cycles of 22 ma hours with a middischarge voltage of 2.0 volts. The temperature was raised to 63 degrees C and the average capacity for the net five cycles was 70 ma hours. The discharge current was then raised from 5 ma to 10 ma and the average capacity was 35 ma hours for the next six cycles.

A cell prepared according to the process described in Example III.6 was cycled with charge and discharge currents of 0.25 ma. The average discharge was 80 percent to 90 percent of one lithium atom per $Fe_{0.25}V_{0.75}S_2$ unit with middischarge potentials being approximately 2.2 volts. Curves showing the cell voltage, on the ordinate, plotted against the percent theoretical cell charge or discharge capacity on the abscissa, are shown in FIG. 3. The figure on the left is for charging and the figure on the right is for discharging. The solid lines represent the first charge and discharge cycle and the dashed lines represent the fifth charge and discharge cycle.

The cell prepared as in Example 7 was cycled at 0.5 ma. The initial capacity was 100 percent of the theoretical limit with a middischarge potential of 2.2 volts. The capacity on the fifteenth cycle was 90 percent of the theoretical limit.

The cell prepared as in Example 8 was cycled at 0.25 ma. The initial capacity was 75 percent of the theoretical limit with a middischarge potential of 2.45 volts. The capacity on the fourth cycle was 55 percent of the theoretical limit.

The cell prepared as in Example 9 was cycled at 0.25 ma. The initial capacity was approximately 50 percent of the theoretical limit with a middischarge potential of 2.25 volts. The capacity on the eighth cycle was 45 percent of the theoretical limit and the middischarge potential was 2.25 volts.

The easy reversibility of cells using layered chalcogenides having the nominal atom composition $M_xN_{1-x}S_2$ as the active cathode material, compared to cells using $LiVS_2$ or LiCrS, is believed at least partially due to $LiM_xN_{1-x}S_2$ forming, as indicated by x-ray diffraction differential scanning calorimetry

and magnetic susceptibility, weaker and broader distorted intermediate phases as the lithium or sodium concentration varies from zero to its stoichiometric value.

Claims

1. A nonaqueous secondary cell, comprising
— a negative electrode made with lithium and/or sodium,
— an electrolyte, and
— a positive electrode made with a layered chalcogenide as the active material,
characterized in that
— said chalcogenide has the nominal atom composition $M_xN_{1-x}S_2$,
in which
— M is Mn, Fe, Ni and/or Co and
— N is V and/or Cr,
— x is greater than zero but
— less than or equal to a maximum value of 0.5 when N is V and M is Fe,
— less than or equal to a maximum value of 0.33 when N is V and M is Ni, Co or Mn, and
— less than a maximum value of 0.33 when N is Cr, and
— when N is V and M is Fe and at least one of Ni, Co and Mn, said maximum value of x scales linearly from 0.33 to 0.50 with the Fe atom percent of M.

2. A cell according to claim 1, characterized in that M is Fe and N is V.

3. A cell according to claim 2, characterized in that x is less than 0.33 and greater than 0.20.

4. A cell according to claim 1, characterized in that N has a nominal atom composition Cr_zV_{1-z}, wherein z is less than or equal to 0.75.

5. A cell according to any one of claims 1, 2, 3 or 4, characterized in that the cathode is made with lithium.

6. A cell according to any one of claims 1, 2, 3, 4 or 5, characterized in that said electrolyte is composed of $LiClO_4$ dissolved in propylene carbonate.

7. A method of preparing the nonaqueous secondary cell according to any one of the preceding claims by assembling into a cell said negative electrode, at least one electrolyte-containing spacer, and said positive electrode made with said layered chalcogenide, characterized by preparing the said chalcogenide in the desired nominal atom composition by adding an oxidizing agent having an oxidizing potential of at least 2.8 volts to $Li_yM_xN_{1-x}S_2$, where y is less than or equal to one, said $Li_yM_xN_{1-x}S_2$ being prepared by reacting stoichiometric quantities of the alkali metal carbonate, and oxide of M and an oxide of N with sulfur, said preparation being carried out in the absence of air and/or moisture.

8. A method according to claim 7, characterized in that iodine, chlorine and/or bromine is used as said oxidizing agent.

9. A method according to claim 7 or 8, characterized by dissolving said oxidizing agent in a solvent.

10. A method according to claim 9, characterized by using acetonitrile as the said solvent.

11. A method of preparing a layered chalcogenide compound, characterized in that the layered chalcogenide compound has the nominal atom composition $M_xN_{1-x}S_2$, where
— M is Mn, Fe, Ni and/or Co,
— N is V and/or Cr,
— x is greater than zero, but
— less than or equal to a maximum value of 0.5 when N is V and M is Fe,
— less than or equal to a maximum value of 0.33 when N is V and M is Ni, Co or Mn, and
— less than a maximum value of 0.33 when N is Cr, and
— when N is V and M is Fe and at least one of Ni, Co and Mn said maximum value of x scales linearly from 0.33 to 0.50 with the Fe atom percent of M, the preparation comprising adding an oxidizing agent having an oxidizing potential of at least 2.8 volts to $Li_yM_xN_{1-x}S_2$, where y is less than or equal to one,
— said $Li_yM_xN_{1-x}S_2$ being prepared by reacting stoichiometric quantities of the alkali metal carbonate, an oxide of M and an oxide of N with sulfur,
— said chalcogenide preparation being carried out in the absence of air and/or moisture.

12. A method according to claim 11, characterized in that iodine, chlorine and bromine are used as said oxidizing agent.

13. A method according to claims 11 or 12, characterized by dissolving said oxidizing agent in a solvent.

14. A method according to claim 13, characterized by using acetonitrile as the said solvent.

15. A method according to claim 11, 12, 13 or 14, characterized by selecting the composition such that N is V and M is Fe.

16. A method according to claim 11, 12, 13 or 14, characterized in that the composition is selected such than N has the nominal atom composition Cr_zV_{1-z} in which z is less than or equal to 0.75.

Patentansprüche

1. Nichtwässrige Sekundärzelle mit
— einer negativen Elektrode mit Lithium und/oder Natrium,
— einer Elektrolyten und
— einer positiven Elektrode mit einem geschichteten Chalkogenid als das aktive Material, dadurch gekennzeichnet, daß
— das Chalkogenid die nominelle Atomzusammensetzung $M_xN_{1-x}S_2$ hat, mit
— M gleich Mn, Fe, Ni und/oder Co und
— N gleich V und/oder Cr,
— x größer als Null aber
— kleiner oder gleich einem Maximalwert von 0,5, wenn N gleich V und M gleich Fe sind,
— kleiner oder gleich einem Maximalwert von 0,33, wenn N gleich V und M gleich Ni, Co oder Mn sind, und
— kleiner als ein Maximalwert von 0,33, wenn N gleich Cr ist, und,
— wenn N gleich V ist und M gleich Fe und wenigstens eines der Elemente Ni, Co und Mn ist, sich der Maximalwert von x linear von 0,33 auf 0,50 mit dem Fe-Gehalt in Atomprozent von M ändert.

2. Zelle nach Anspruch 1, dadurch gekennzeichnet, daß M gleich Fe ist und N gleich V ist.

3. Zelle nach Anspruch 2, dadurch gekennzeichnet, daß x kleiner als 0,33 und größer als 0,20 ist.

4. Zelle nach Anspruch 1, dadurch gekennzeichnet, daß N eine nominelle Atomzusammensetzung von Cr_zV_{1-z} hat, worin z kleiner oder gleich 0,75 ist.

5. Zelle nach einem der Ansprüche 1, 2, 3 oder 4, dadurch gekennzeichnet, daß die Kathode mit Lithium hergestellt ist.

6. Zelle nach einem der Ansprüche 1, 2, 3, 4 oder 5, dadurch gekennzeichnet, daß sich der Elektrolyt zusammensetzt aus $LiClO_4$, das in Propylenkarbonat aufgelöst ist.

7. Verfahren zur Herstellung der nichtwässrigen Sekundärzelle nach einem der vorstehenden Ansprüche durch Zusammenbauen der negativen Elektrode, wenigstens einem elektrolythaltigen Abstandsglied und der positiven, mit dem geschichteten Chalkogenid hergestellten Elektrode in eine Zelle, dadurch gekennzeichnet, daß das Chalkogenid in der gewünschten nominellen Atomzusammensetzung hergestellt wird durch Hinzufügen eines Oxidationsmittels, das ein Oxidationspotential von wenigstens 2,8 Volt besitzt, zu $Li_yM_xN_{1-x}S_2$, mit y kleiner oder gleich 1, wobei $Li_yM_xN_{1-x}S_2$ hergestellt wird durch Reagierenlassen stöchiometrischer Anteile des Alkalimetallkarbonates und Oxides von M und eines Oxides von N mit Schwefel, wobei die Herstellung bei Fehlen von Luft und/oder Feuchtigkeit ausgeführt wird.

8. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß Jod, Chlor und/oder Brom als das Oxidationsmittel verwendet wird.

9. Verfahren nach Anspruch 7 oder 8, gekennzeichnet durch Auflösen des Oxidationsmittels in einem Lösungsmittel.

10. Verfahren nach Anspruch 9, gekennzeichnet durch Verwendung von Acetonitril als das Lösungsmittel.

11. Verfahren zur Herstellung einer geschichteten Chalkogenidverbindung, dadurch gekennzeichnet, daß die geschichtete Chalkogenidverbindung die nominelle Atomzusammensetzung $M_xN_{1-x}S_2$ hat mit
— M gleich Mn, Fe, Ni und/oder Co,
— N gleich V und/oder Cr,
— x größer als Null, aber
— kleiner oder gleich einem Maximalwert von 0,5, wenn N gleich V ist und M gleich Fe ist,
— kleiner oder gleich einem Maximalwert von 0,33, wenn N gleich V ist und M gleich Ni, Co oder Mn ist, und
— kleiner als ein Maximalwert von 0,33, wenn N gleich Cr ist und,
— wenn N gleich V ist und M gleich Fe und wenigstens eines der Elemente Ni, Co und Mn ist, der Maximalwert von x sich linear von 0,33 auf 0,50 mit dem Fe-Anteil in Atomprozent von Mn ändert, und
— die Herstellung erfolgt durch Zugabe eines Oxidationsmittels, das ein Oxidationspotential von wenigstens 2,8 Volt besitzt, zu $Li_yM_xN_{1-x}S_2$, mit y kleiner oder gleich 1, wobei
— das $Li_yM_xN_{1-x}S_2$ hergestellt wird durch Reagierenlassen stöchiometrischer Anteile des Alkalimetallkarbonates, eines Oxides von M und eines Oxides von N mit Schwefel und
— die Chalkogenidherstellung bei Abwesenheit von Luft und/oder Feuchtigt durchgeführt wird.

12. Verfahren nach Anspruch 11, dadurch gekennzeichnet, daß Jod, Chlor und Brom als das Oxidationsmittel verwendet werden.

13. Verfahren nach Anspruch 11 oder 12, dadurch gekennzeichnet, daß das Oxidationsmittel in einem Lösungsmittel aufgelöst wird.

14. Verfahren nach Anspruch 13, gekennzeichnet durch die Verwendung von Acetonitril als das Lösungsmittel.

15. Verfahren nach Anspruch 11, 12, 13 oder 14, gekennzeichnet durch Wahl der Zusammensetzung derart, daß N gleich V ist und M gleich Fe ist.

16. Verfahren nach Anspruch 11, 12, 13 oder 14, dadurch gekennzeichnet, daß die Zusammensetzung so gewählt wird, daß N die nominelle Zusammensetzung Cr_zV_{1-z} hat, mit z kleiner oder gleich 0,75.

Revendications

1. Accumulateur non aqueux comprenant:
— une électrode négative en lithium et/ou en sodium,
— un électrolyte, et
— une électrode positive en un chalcogénure couché à titre de matière active,
caractérisé en ce que
— la chalcogénure a la composition atomique nominale $M_xN_{1-x}S_2$, dans laquelle
— M est Mn, Fe, Ni et/ou Co et
— N est V et/ou Cr,
— x est supérieur à zéro mais
— inférieur ou égal à une valeur maximale de 0,5 quand N est V et M est Fe,
— inférieur ou égal à une valeur maximale de 0,33 quand N est V et M est Ni, Co ou Mn, et
— inférieur à une valeur maximale de 0,33 quand N est Cr, et
— quand N est V et M est Fe et au moins l'un de Ni, Co et Mn, la valeur maximale de x varie linéairement de 0,33 à 0,50 en fonction du pourcentage atomique en Fe de M.

2. Accumulateur suivant la revendication 1, caractérisé en ce que M est Fe et N est V.

3. Accumulateur suivant la revendication 2, caractérisé en ce que x est inférieur à 0,33 et supérieur à 0,20.

4. Accumulateur suivant la revendication 1, caractérisé en ce que N a la composition atomique nominale Cr_zV_{1-z}, z étant inférieur ou égal à 0,75.

5. Accumulateur suivant l'une quelconque des revendications 1, 2, 3 ou 4, caractérisé en ce que la cathode est en lithium.

6. Accumulateur suivant l'une quelconque des revendications 1, 2, 3, 4 ou 5, caractérisé en ce que l'électrolyte est composé de $LiClO_4$ dissous dans du carbonate de propylène.

7. Procédé de préparation de l'accumulateur non aqueux suivant l'une quelconque des revendications précédentes en assemblant en un accumulateur l'électrode négative, au moins un intercalaire contenant un électrolyte et l'électrode positive constituée de chalcogénure couché, caractérisé en ce qu'il consiste à préparer le chalcogénure à la composition atomique nominale souhaitée en ajoutant un agent oxydant ayant un potentiel d'oxydation d'au moins 2,8 volts à $Li_yM_xN_{1-x}S_2$; y étant inférieur ou égale à un, le $Li_yM_xN_{1-x}S_2$ étant préparé en faisant réagir des quantités stoechiométriques du carbonate de métal alcalin, d'un oxyde de M et d'un oxyde de N sur du soufre, cette préparation étant effectuée en l'absence d'air et/ou d'humidité.

8. Procédé suivant la revendication 7, caractérisé en ce que on utilise de l'iode, du chlore et/ou du brome comme agent oxydant.

9. Procédé suivant la revendication 7 ou 8, caractérisé en ce que il consiste à dissoudre l'agent oxydant dans un solvant.

10. Procédé suivant la revendication 9, caractérisé en ce que il consiste à utiliser de l'acétonitrile comme solvant.

11. Procédé de préparation d'un chalcogénure couché, caractérisé en ce que le chalcogénure couché a la composition atomique nominale $M_xN_{1-x}S_2$, dans laquelle
— M est Mn, Fe, Ni et/ou Co,
— N est V et/ou Cr,
— x est supérieur à zéro, mais
— inférieur ou égal à une valeur maximale de 0,5 quand N est V et M est Fe,
— inférieur ou égal à une valeur maximale de 0,33 quand N est V et M est Ni, Co ou Mn, et
— inférieur à une valeur maximale de 0,33 quand N est Cr, et
— quand N est V et M est Fe et au moins l'un de Ni, Co et Mn, cette valeur maximale de x varie linéairement de 0,33 à 0,50 en fonction du pourcentage atomique en M, la préparation consistant à ajouter un agent oxydant et un potentiel d'oxydation d'au moins 2,8 volts à $Li_yM_xN_{1-x}S_2$ y étant inférieur ou égal à un,
— $Li_yM_xN_{1-x}S_2$ étant préparé en faisant réagir des quantités stoechiométriques du carbonate de métal alcalin, d'un oxyde de M et d'un oxyde de N sur du soufre,
— la préparation du chalcogénure étant effectuée en l'absence d'air et/ou d'humidité.

12. Procédé suivant la revendication 11, caractérisé en ce que on utilise d l'iode, du chlore et du brome comme agent oxydant.

13. Procédé suivant la revendication 11 ou 12, caractérisé en ce que il consiste à dissoudre l'agent oxydant dans un solvant.

14. Procédé suivant la revendication 13, caractérisé en ce que il consiste à utiliser de l'acétonitrile comme solvant.

15. Procédé suivant la revendication 11, 12, 13 ou 14, caractérisé en ce que il consiste à choisir la composition de manière à ce que N soit V et M soit Fe

16. Procédé suivant la revendication 11, 12, 13 ou 14, caractérisé en ce que il consiste à choisir la composition de manière à ce que N ait la composition atomique nominale Cr_zV_{1-z} dans laquelle z est inférieur ou égal à 0,75.

FIG. 1

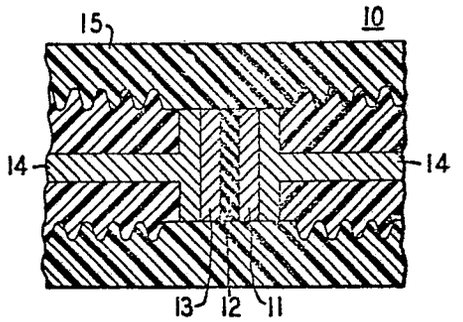

FIG. 2

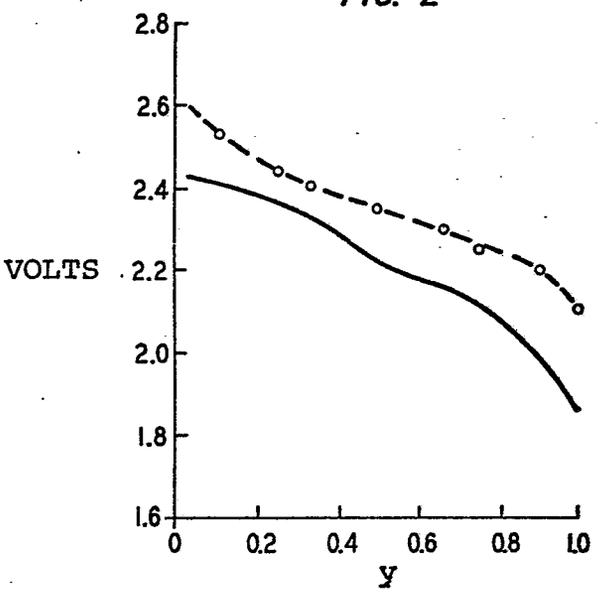

FIG. 3