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(54) A TECHNIQUE FOR ACTIVATING SULFUR-BASED ELECTRODE FOR AN ELECTROLYSER

VERFAHREN ZUR AKTIVIERUNG EINER SCHWEFELBASIERTEN ELEKTRODE FÜR EINEN ELEKTROLYSATOR

TECHNIQUE D'ACTIVATION D'ÉLECTRODE À BASE DE SOUFRE POUR UN ÉLECTROLYSEUR

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Description

[0001] The present invention relates to techniques for activating Sulfur-based electrode i.e. electrode comprising sulfur and an electrically conducting non-Sulfur material.

[0002] In modern times, electrolysis is used for various purposes, for example in Hydrogen and/or Oxygen generation which are achieved by hydrogen evolution reaction (HER) and Oxygen evolution reaction (OER) in an electrolyser by electrolysis of electrolyte i.e. generally water. Usually, alkaline or acidic water is used as the electrolyte. The electrolyser includes electrodes that conduct electrical energy to the electrolyte and thus decomposes the electrolyte.

[0003] Various types of electrodes are used in electrolysers. A commonly used electrode in electrolysers is Sulfur-based electrode for example a metal-sulfur electrode such as a Nickel-Sulfur electrode which is primarily employed as cathode in the electrolyser. The metal-sulfur electrodes are produced by various methods such as electrodeposition. One such method for preparing metal-sulfur electrode is described in United States Patent no. 4,171,247 titled 'Method for preparing active cathodes for electrochemical processes' which describes preparation of electrodes of the nickel-sulfur type using an electrodeposition bath.

[0004] Generally, such electrodeposition baths, including the bath described in United States Patent no. 4,171,247, are typically composed of a nickel salt and a sulfur releasing compound. The sulfur releasing compound is typically selected among Thiourea, Potassium thiocyanate, Sodium thiocyanate, and Sodium hydrosulfite.

[0005] During the electrodeposition procedure an electro-catalytic coating is formed on surface of the electrode, usually the electrode to be used as the cathode in the electrolyser. The coating is usually formed on top of a metallic substrate and it is characterized by its amorphous or nanocrystalline structure. Such coatings have beneficial properties for the HER and/or the OER especially in alkaline electrolysis and in the chloralkali process.

[0006] The formed amorphous alloy formed by the electro-catalytic coating generally includes one or more elements but the main constituent is usually Nickel. Additionally, the electro-catalytic coating includes sulfur. The amount of incorporated sulfur usually varies between 10 and 30 wt%. Other elements can be Cobalt, Molybdenum and Iron. The sulfur containing electro-catalytic coating along with the underlying metallic substrate together forms the electrode.

[0007] When such a Sulfur-based electrode, i.e. the electrode comprising sulfur and an electrically conducting non-sulfur material such as Nickel, is used in the electrolyser for electrolysis reaction it has been observed that during electrolysis in the electrolyser the sulfur from the electro-catalytic coating formed as surface of the electrode is slowly and continuously removed from the electrode into the electrolyser leaving thereby a nickel coating with high catalytic activity compared to non-catalysed Nickel.

[0008] The removal of the sulfur from the Sulfur-based electrode is typically a slow process and usually takes several days going up to months. The sulfur that is slowly released by the Sulfur-based electrode accumulates in the electrolyser and the electrolyser components introducing a contamination and corrosion risk and further increases risk of stress corrosion cracking of pressurized parts of the electrolyser, if any, thereby decreasing lifetime of the electrolyser.

[0009] Thus the object of the present disclosure is to provide a technique by which release and accumulation of sulfur within the electrolyser is at least partially obviated when using in the electrolyser an electrode that has sulfur and an electrically conducting non-sulfur material. Furthermore, it is desirable that the electrolyte in which the sulfur is released is rendered at least partially free from the released sulfur and may be reused in the electrolysis reaction in the electrolyser.

[0010] The above object is achieved by a method for activating a Sulfur-based electrode according to claim 1. Advantageous embodiments of the present technique are provided in dependent claims.

[0011] According to an aspect of the present technique a method for activating a Sulfur-based electrode for an electrolyser is provided. The Sulfur-based electrode is formed of sulfur and an electrically conductive non-sulfur material. In the method, an electrolyte and a complexing agent are provided to a container, either simultaneously or successively. The electrolyte and the complexing agent are provided either separately or as a mixed with each other. The Sulfur-based electrode is positioned in the container. The electrolyte and the complexing agent are contacted with at least a part of a surface of the Sulfur-based electrode. The electrolyte reacts with the Sulfur-based electrode to release at least a part of the sulfur from the Sulfur-based electrode. The complexing agent reacts with the released sulfur to form a coordination complex with the released sulfur. Finally in the method, the coordination complex is removed from the container.

[0012] The coordination complex formed by the chemical reaction between the released sulfur and the complexing agent is in solid state, for example an amorphous state and thus can be removed with ease from the electrolyte which is in liquid state. The removal of the coordination complex may be performed for example by filtration. Thus by using the method for activation of the Sulfur-based electrode according to the present technique, either the sulfur content of the Sulfur-based electrode is already decreased before electrolysis is performed in the electrolyser using the activated electrode or at least a part of the sulfur released from the Sulfur-based electrode is filtered out from the electrolyser and thus not deposited in the electrolyser.

[0013] In an embodiment of the method, the electrolyte is alkaline water. Thus the method is applicable to alkaline water electrolysis technique.

[0014] According to the invention, the complexing agent comprises one of Barium hydroxide, Barium chloride, Barium

nitrate, Strontium hydroxide, Strontium chloride, Strontium nitrate, Calcium hydroxide, Calcium chloride, Calcium nitrate, and a combination thereof. The aforementioned chemicals are readily available or can be easily made and thus provide a simple way of implementing the method of the present technique. When performing the method of the present technique on a Sulfur-based electrode that is already positioned in the electrolyser for alkaline water electrolysis, using hydroxides of Barium, Strontium and/or Calcium in activating the Sulfur-based electrode is specially beneficial because after the removal of the coordination complex, only hydroxide ions from the complexing agent are left in the electrolyte thereby maintaining the chemical integrity of the electrolyte. To explain further, the Barium, Strontium and/or Calcium from the hydroxides of Barium, Strontium and/or Calcium used as the complexing agent is removed as part of the coordination complex, leaving only the hydroxide ion in the electrolyte, and thus does not interfere with the chemistry of the electrolyte.

[0015] In another embodiment of the method, the container is a part of the electrolyser in which the Sulfur-based electrode is positioned for carrying out electrolysis of the electrolyte. In a related embodiment of the method, the method is performed simultaneously with the electrolysis of the electrolyte. Thus in situ activation of the Sulfur-based electrode is performed i.e. the Sulfur-based electrode is activated while positioned in the electrolyser. When the method is performed simultaneously with the electrolysis of the electrolyte, the electrical energy applied to the Sulfur-based electrode for the electrolysis of the electrolyte further increases the rate of the release of the sulfur from the Sulfur-based electrode and thus increasing the rate at which the method for activation of the Sulfur-based electrode according to the present technique is performed.

[0016] In another embodiment of the method, the container is distinct from the electrolyser i.e. the container is not a part of the electrolyser and the method is performed prior to electrolysis of the electrolyte. Subsequently, the electrolysis of the electrolyte may be performed using the activated electrode in the electrolyser. In a related embodiment of the method, an electrical voltage is applied to the Sulfur-based electrode while the electrolyte and the complexing agent are contacted with the Sulfur-based electrode. Thus the Sulfur-based electrode is activated prior to being integrated into the electrolyser. This obviates requirement of modifying the electrolyser to integrate a mechanism for removal of the coordination complex. Furthermore, after the coordination complex has been removed from the electrolyte, the electrolyte subsequently may be used in the electrolyser for electrolysis reaction or may be used back in the container for subsequently performing the method for activating the Sulfur-based electrode.

[0017] In another embodiment of the method, the coordination complex is removed by filtration. This provides a simple and cost effective way of removing the coordination complex from the electrolyte.

[0018] According to another aspect of the present technique, an arrangement for activating a Sulfur-based electrode is provided. The Sulfur-based electrode is for an electrolyser and comprises sulfur and an electrically conductive non-sulfur material. The arrangement includes a container, an electrolyte feed and a filtration unit. The container receives the Sulfur-based electrode. At least a part of the Sulfur-based electrode is positioned within the container such that electrolysis of an electrolyte may be carried out using the Sulfur-based electrode positioned within the container. The electrolyte feed provides the electrolyte and a complexing agent to the container and the container receives the electrolyte and the complexing agent. The electrolyte and the complexing agent so received are contacted with at least a part of a surface of the Sulfur-based electrode within the container. At least a part of the sulfur is released from the Sulfur-based electrode by a chemical action of the electrolyte and the part of the sulfur so released forms a coordination complex by a chemical action with the complexing agent. The filtration unit is in fluid communication with the container. The filtration unit receives the electrolyte from the container after the electrolyte and the complexing agent are contacted with the part of the Sulfur-based electrode within the container. The filtration unit then removes, by filtration, at least a part of the coordination complex from the electrolyte so received. Finally the filtration unit provides the electrolyte so filtered to the container. The coordination complex formed by the chemical reaction between the released sulfur and the complexing agent is in solid state, for example an amorphous state and thus can be removed by the filtration unit with ease from the electrolyte which is in liquid state. Thus with the arrangement for activating the Sulfur-based electrode according to the present technique, at least a part of the sulfur released from the Sulfur-based electrode is filtered out from the electrolyser and thus not deposited in the electrolyser.

[0019] In an embodiment of the arrangement, the electrolyte feed comprises a mixer. The mixer mixes the electrolyte and the complexing agent, for example the mixer by physical action dissolves the complexing agent into the electrolyte, before the electrolyte and the complexing agent are provided to the container.

[0020] The present technique is further described hereinafter with reference to illustrated embodiments shown in the accompanying drawing, in which:

FIG 1 schematically illustrates an exemplary embodiment of an arrangement of the present technique; and

FIG 2 depicts a flow chart showing an exemplary embodiment of a method of the present technique.

[0021] Hereinafter, above-mentioned and other features of the present technique are described in details. Various embodiments are described with reference to the drawing, wherein like reference numerals are used to refer to like

elements throughout. In the following description, for purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more embodiments. It may be noted that the illustrated embodiments are intended to explain, and not to limit the invention. It may be evident that such embodiments may be practiced without these specific details.

[0022] The basic idea of the present technique is to provide a complexing agent along with an electrolyte to a Sulfur-based electrode, i.e. an electrode comprising sulfur and at least one electrically conducting non-Sulfur material such as Nickel, such that the sulfur released into the electrolyte from the Sulfur-based electrode chemically reacts with the complexing agent to form a coordination complex having a solid state. The coordination complex is then filtered out from the electrolyte and rendering the electrolyte, and thus the electrolyser when the electrolyte is in the electrolyser, at least partially free from the sulfur released from the Sulfur-based electrode.

[0023] The Sulfur-based electrode (hereinafter also referred to as, the electrode) may have sulfur limited to a coating formed on top of a substrate or may have sulfur present in the entire electrode material and not only limited to the coating, if present. The at least one electrically conducting non-Sulfur material may be, but not limited to, a metal such as Nickel, Cobalt, Iron, Chromium, Aluminium, Molybdenum, and a combination thereof. In the present application, hereinafter, Nickel (Ni) has been used as an example for the electrically conducting non-Sulfur material; however, it is noteworthy that the scope of the present technique is not limited to only Ni.

[0024] For the purpose of explanation, and without limiting the scope of the present technique, in the present disclosure, the Sulfur-based electrode may be understood as an electrode having sulfur and Ni in a coating on a surface of an electrically conducting substrate material such as, but not limited to, a metallic substrate for example stainless steel, different steel grades, and other electrically conducting metal alloys.

[0025] FIG 1 schematically illustrates an exemplary embodiment of an arrangement 1 for activating a Sulfur-based electrode 10 of the present technique. The electrode 10 has a surface coating of Ni and Sulfur and may be used or intended to be used as a cathode in an electrolyser (not shown). FIG 2 depicts a flow chart showing an exemplary embodiment of a method 100 for activating the electrode 10 of the present technique. Hereinafter, the method 100 of FIG 2 has been explained with help of arrangement 1 of FIG 1.

[0026] The arrangement 1 includes a container 20, an electrolyte feed 30 and a filtration unit 40. The container 20 receives the electrode 10. At least a part (not shown) of the electrode 10 is positioned within the container 20.

[0027] In the method 100, in a step 110 an electrolyte 22 is provided to the container 20 and in a step 120 a complexing agent (not shown) is provided to the container 20. In an exemplary embodiment of the method 100, the step 110 and the step 120 are performed simultaneously. The electrolyte 22 is a liquid for example alkaline water. The alkaline water may be formed for example by adding Sodium or Potassium hydroxide to water for example by adding between 30 and 50 wt% of Sodium or Potassium hydroxide. In general complexing agent is a chemical entity that is capable of forming a coordination complex with Sulfur. The coordination complex formed with Sulfur is essentially solid for example amorphous residue. The complexing agent may include, but not limited to, one or more of Barium hydroxide, Barium chloride, Barium nitrate, Strontium hydroxide, Strontium chloride, Strontium nitrate, Calcium hydroxide, Calcium chloride, and Calcium nitrate. Generally the amount of complexing agent when provided to the electrolyte 22 in the container 20 is substantially equal to or less than 1 M (molar) concentration. For purpose of explanation and not limitation, Barium hydroxide i.e. $Ba(OH)_2$, has been used in the present disclosure hereinafter as the complexing agent with concentration between 10 and 200 gram per liter of the electrolyte 22, and more particularly approximately 171 gram per liter of the electrolyte 22.

[0028] When performing the steps 110 and 120 simultaneously, the electrolyte 22 i.e. the alkaline water 22, and the complexing agent i.e. $Ba(OH)_2$ may be provided separately to the container 20 from the electrolyte feed 30. The complexing agent may be provided as a solid to the container 20 where the complexing agent gets dissolved in the electrolyte 22 or the complexing agent is dissolved in a medium such as water to form complexing agent solution and then provided to the container 20 wherein the complexing agent solution mixes with the electrolyte 22. Alternatively, the complexing agent may be mixed or dissolved in the electrolyte 22 before the complexing agent and the electrolyte 22 are provided to the container 20. The mixing of the complexing agent and the electrolyte 22 may be performed by a mixer 35 of the electrolyte feed 30.

[0029] When performing the steps 110 and 120 successively, the electrolyte 22 i.e. the alkaline water 22, and the complexing agent i.e. $Ba(OH)_2$ are provided separately to the container 20 from the electrolyte feed 30, preferably the step 120 is performed after the step 110. The complexing agent may be provided as a solid to the container 20 to the electrolyte 22 already provided to the container 20 where the complexing agent gets dissolved in the electrolyte 22 in the container 20 or the complexing agent is dissolved in a medium such as water to form complexing agent solution and then provided to the container 20 wherein the complexing agent solution mixes with the electrolyte 22.

[0030] In the method 100, in a step 130 performed subsequent to steps 110 and 120, the electrolyte 22 and the complexing agent are contacted with at least a part of a surface of the electrode 10. The electrolyte 22 reacts with the electrode 10 to release at least a part of the sulfur from the electrode 10. In an exemplary embodiment of the method 100, when performing the step 130, no electrical energy is provided to the electrode 10. In an alternate exemplary

embodiment of the method 100, when performing the step 130, electrical energy is provided to the electrode 10 in form of electrical current and in this embodiment the electrode 10 is positioned to act as a cathode for the electrolyte 22 and an additional electrode (not shown) acting as anode is positioned in the arrangement 1 to complete current flow path through the electrolyte 22.

[0031] In the embodiment of the method 100 of open potential i.e. when no electrical current is passed through the electrode 10, the Sulfur-based electrode is not chemically stable in the alkaline environment formed by the alkaline electrolyte and Sulfur from the electrode is leached into the electrolyte 22 as schematically depicted in the following equation (i):

$$NiS + 2e^- \rightarrow Ni + S^{2-} \quad \ldots \quad \text{(i)}$$

[0032] In equation (i) the Sulfur-based electrode is depicted by chemical formulation NiS representing Nickel (Ni) and Sulfur (S) in the electrode 10. The alkalinity of the electrolyte 22 is raised by presence of strong bases such as Potassium or Sodium hydroxide used to prepare the alkaline water used as the electrolyte 22. Thus Sulfur is released in the electrolyte 22 in the container 20 in form of sulfide ion.

[0033] In the embodiment of the method 100 where electric current is passed through the electrolyte 22 in the container 20 and where the additional electrode (not shown) is positioned as anode to complete the current flow path through the electrolyte 22 in the container 20, the Sulfur from the electrode 10 leaches out of the electrode 10 as schematically depicted in the following equations (ii), (iii) and (iv):

$$2\,H^+ + S + 2e^- \rightarrow H_2S\,(g) \quad \ldots \quad \text{(ii)}$$

$$H_2(g) + S \rightarrow H_2S\,(g) \quad \ldots \quad \text{(iii)}$$

$$H_2S\,(g) + 4\,OH^- \rightarrow 3\,H_2(g) + 2e^- + SO_4^{2-} \quad \ldots \quad \text{(iv)}$$

[0034] The electrical current ranging approximately between 0.1 and 10 Ampere per square centimeter of the surface of the electrode 10 may be used, and more particularly for the aforementioned reactions depicted by equations (ii), (iii) and (iv) the electrical current with current densities of 0.2 - 1 Ampere per square centimeter of the surface of the electrode 10 was used. It may be noted that with an increase in current density passing through the electrode 10 a rate of leaching of sulfur from the electrode 10 is generally increased, however the allowable current density is dependent on structural and compositional parameters of the electrode 10 for example the allowable current density is dependent on quality the deposited NiS layer in the electrode 10.

[0035] As a result of application of electrical current or external electrical voltage, water in the electrolyte 22 is dissociated into hydrogen ion (H^+) and hydroxide ion (OH^-). At the electrode 10 acting as the cathode, water in the electrolyte 22 is reduced to form H_2 gas and possibly H^+ as an intermediate step during the formation of H_2 gas. Sulfur from the electrode 10 or the coating of the electrode 10, represented by NiS or Ni-S, reacts with either H^+ or H_2(g) to form Hydrogen sulfide gas i.e. H_2S (g) by chemical reactions depicted hereinabove represented by equations (ii) and (iii) respectively. Subsequently, H_2S (g) is reduced to H_2 gas and sulfate ion i.e. SO_4^{2-} by chemical reactions with hydroxide ion i.e. OH^- as depicted hereinabove represented by equation (iv). Thus Sulfur is released in the electrolyte 22 in the container 20 in form of sulfate ion.

[0036] In one embodiment of the method 100, the step 130 is performed at a temperature ranging between 20 degree Centigrade and 200 degree Centigrade i.e. temperature within the container 20. Furthermore, pressure ranging between 1 bar and 100 bar is maintained in the container 20 while performing the step 130.

[0037] In the method 100, the complexing agent reacts with the released sulfur to form a coordination complex with the released sulfur for example as schematically depicted in the following equations (v):

$$SO_4^{2-} + Ba(OH)_2 \rightarrow BaSO_4\,(s) + 2\,OH^- \quad \ldots \quad \text{(v)}$$

[0038] Thus, as shown in equation (v) above, the released sulfur for example the sulfate ion in equation (v) chemically reacts with the complexing agent for example Barium hydroxide in equation (v) to form coordination complex for example in equation (v) Barium sulfate in solid state i.e. $BaSO_4$ (s) in the electrolyte 22 in the container 20.

[0039] Finally in the method 100, in a step 140 subsequent to step 130, the coordination complex i.e. $BaSO_4$ (s) in

equation (v) is removed from the container 20. In arrangement 1, the step 140 is performed by a filtration unit 40. The filtration unit 40 is in fluid communication with the container 20. The filtration unit 40 receives the electrolyte 22 from the container 20 after the step 130 has been performed and thus the electrolyte 22 that is received by the filtration unit 40 includes the coordination complex. The filtration unit 40 then removes for example by mechanical or physical filtration at least a part of the coordination complex i.e. $BaSO_4$ (s) in equation (v) from the electrolyte 22 so received. The electrolyte 22 that is rendered at least partially free of some of the coordination complex is provided back by the filtration unit 40 back to the container 20.

[0040] It may be noted that use of hydroxide as complexing agent for example Barium hydroxide, Strontium hydroxide and/or Calcium hydroxide is specially advantageous because after removal of the coordination complex from the electrolyte 22 using the filtration unit 40, the part of the complexing agent left behind in the electrolyte 22 by the complexing agent is hydroxide ion i.e. OH^- as depicted in equation (v) that shows that hydroxide ions i.e. OH^- are generated in equation (v) along with the coordination complex i.e. $BaSO_4$ (s) in equation (v), and thus when the coordination complex i.e. $BaSO_4$ (s) in equation (v) is removed in the step 140 only hydroxide ions i.e. OH^- is left behind in the electrolyte 22 and thus the chemical integrity of the electrolyte 22, specially when alkaline water is used as the electrolyte 22, is not compromised or altered. Thus the electrolyte 22 that is provided back by the filtration unit 40 to the container 20 may be used for continuation of the method 100, or for subsequent repetition of method 100 using another sulfur-based electrode 10, or for use as electrolyte in an electrolytic reaction in an electrolyser.

[0041] The step 140 may be performed by a filter element for example a filter paper, a fibrous filter such as a Nickel-fibrous filter, and so on and so forth. For filtration of coordination complex in form of $BaSO_4$ (s) in equation (v) a filter paper having a particle retention of approximately 1 μm was used. In arrangement 1, the filtration unit 40 includes the filter element (not shown). The filter may be replaceable or regenerative.

[0042] The method 100 may be performed either prior to carrying out the electrolysis of the electrolyte 22 in the electrolyser or simultaneously along with the electrolysis of the electrolyte 22 in the electrolyser. It may be noted that in an exemplary embodiment, where the method 100 is performed prior to carrying out the electrolysis of the electrolyte 22 in the electrolyser the container 20 is a distinct from the electrolyser i.e. the container 20 is not part of the electrolyser. In this embodiment of the method 100, the electrode 10 is activated i.e. at least a part of the sulfur from the electrode 10 is removed by the method 100, and then the electrode 10 in its activated form is placed in an electrolyser and the electrolyte 22 or some other electrolyte is provided in the electrolyser and thereby electrolysis of the electrolyte 22 or of the some other electrolyte in the electrolyser is performed. The activation of the electrode 10 may be performed with or without use of electrical energy.

[0043] However, in the embodiment where the method 100 is performed simultaneously along with the electrolysis of the electrolyte 22 in the electrolyser, the container 20 is part of the electrolyser i.e. the container 20 is the site or seat of electrolysis of the electrolyte 22.

[0044] While the present technique has been described in detail with reference to certain embodiments, it should be appreciated that the present technique is not limited to those precise embodiments. Rather, in view of the present disclosure which describes exemplary modes for practicing the invention, many modifications and variations would present themselves, to those skilled in the part.

[0045] The scope of the invention is, therefore, indicated by the following claims rather than by the foregoing description.

Claims

1. A method (100) for activating a Sulfur-based electrode (10) for an electrolyser, the Sulfur-based electrode (10) comprising sulfur and an electrically conductive non-sulfur material, the method (100) comprising:

   - providing (110) an electrolyte (22) to a container (20), wherein the electrolyte (22) is adapted to release at least a part of the sulfur from the Sulfur-based electrode (10),
   - providing (120) a complexing agent to the container (20), wherein the complexing agent is adapted to form a coordination complex with the released sulfur and comprises one of Barium hydroxide, Barium chloride, Barium nitrate, Strontium hydroxide, Strontium chloride, Strontium nitrate, Calcium hydroxide, Calcium chloride, Calcium nitrate, and a combination thereof,
   - contacting (130) the electrolyte (22) and the complexing agent with at least a part of a surface of the Sulfur-based electrode (10), wherein the Sulfur-based electrode (10) is positioned in the container (20), and
   - removing the coordination complex from the container (20).

2. The method (100) according to claim 1, wherein the electrically conductive non-sulfur material comprises a metal.

3. The method (100) according to claim 2, wherein the metal is one of Nickel, Cobalt, Iron, Chromium, Aluminium,

Molybdenum, and a combination thereof.

4. The method (100) according to any of claims 1 to 3, wherein the electrolyte (22) is alkaline water.

5. The method (100) according to any of claims 1 to 4, wherein the electrolyte (22) and the complexing agent are mixed prior to contacting (130) with the part of the surface of the Sulfur-based electrode (10).

6. The method (100) according to any of claims 1 to 5, wherein the electrolyte (22) and the complexing agent are contacted (130) with the part of the surface of the Sulfur-based electrode (22) at a temperature ranging between 20 degree centigrade and 200 degree centigrade.

7. The method (100) according to any of claims 1 to 6, wherein the electrolyte (22) and the complexing agent are contacted (130) with the part of the surface of the Sulfur-based electrode (22) at a pressure ranging between 1 bar and 100 bar.

8. The method (100) according to any of claims 1 to 7, wherein the container (20) is a part of the electrolyser in which the Sulfur-based electrode (10) is positioned for carrying out electrolysis of the electrolyte (22).

9. The method (100) according to claim 8, wherein the method (100) is performed simultaneously with the electrolysis of the electrolyte (22).

10. The method (100) according to any of claims 1 to 7, wherein the container (20) is distinct from the electrolyser and wherein the method (100) is performed prior to electrolysis of the electrolyte (22) in the electrolyser.

11. The method (100) according to claim 10, wherein in contacting (130) the electrolyte (22) and the complexing agent with the Sulfur-based electrode (10) an electrical voltage is applied to the Sulfur-based electrode (10).

12. The method (100) according to any of claims 1 to 11, wherein the coordination complex is removed (140) by filtration.

Patentansprüche

1. Verfahren (100) zur Aktivierung einer schwefelbasierten Elektrode (10) für einen Elektrolyseur, wobei die schwefelbasierte Elektrode (10) Schwefel und ein elektrisch leitendes Nicht-Schwefel-Material umfasst, wobei das Verfahren (100) umfasst:

    - Bereitstellen (110) eines Elektrolyten (22) für einen Behälter (20), wobei der Elektrolyt (22) zum Freisetzen wenigstens eines Teils des Schwefels aus der schwefelbasierten Elektrode (10) ausgelegt ist,
    - Bereitstellen (120) eines Komplexbildners für den Behälter (20), wobei der Komplexbildner zum Bilden eines Koordinationskomplexes mit dem freigesetzten Schwefel ausgelegt ist und eines von Bariumhydroxid, Bariumchlorid, Bariumnitrat, Strontiumhydroxid, Strontiumchlorid, Strontiumnitrat, Calciumhydroxid, Calciumchlorid, Calciumnitrat und einer Kombination davon umfasst,
    - In-Kontakt-bringen (130) des Elektrolyten (22) und des Komplexbildners mit mindestens einem Teil einer Oberfläche der schwefelbasierten Elektrode (10), wobei die schwefelbasierte Elektrode (10) im Behälter (20) positioniert ist, und
    - Entfernen des Koordinationskomplexes aus dem Behälter (20) .

2. Verfahren (100) nach Anspruch 1, wobei das elektrisch leitende Nicht-Schwefel-Material ein Metall umfasst.

3. Verfahren (100) nach Anspruch 2, wobei das Metall eines von Nickel, Cobalt, Eisen, Chrom, Aluminium, Molybdän und einer Kombination davon ist.

4. Verfahren (100) nach einem der Ansprüche 1 bis 3, wobei der Elektrolyt (22) alkalisches Wasser ist.

5. Verfahren (100) nach einem der Ansprüche 1 bis 4, wobei der Elektrolyt (22) und der Komplexbildner gemischt werden, bevor sie mit dem Teil der Oberfläche der schwefelbasierten Elektrode (10) in Kontakt gebracht werden (130).

6. Verfahren (100) nach einem der Ansprüche 1 bis 5, wobei der Elektrolyt (22) und der Komplexbildner bei einer im Temperatur im Bereich von 20 Grad Celsius bis 200 Grad Celsius mit dem Teil der Oberfläche der schwefelbasierten Elektrode (22) in Kontakt gebracht werden (130).

7. Verfahren (100) nach einem der Ansprüche 1 bis 6, wobei der Elektrolyt (22) und der Komplexbildner bei einem Druck im Bereich von 1 bar bis 100 bar mit dem Teil der Oberfläche der schwefelbasierten Elektrode (22) in Kontakt gebracht werden (130) .

8. Verfahren (100) nach einem der Ansprüche 1 bis 7, wobei der Behälter (20) ein Teil des Elektrolyseurs, in welchem die schwefelbasierte Elektrode (10) positioniert ist, zum Durchführen von Elektrolyse des Elektrolyten (22) ist.

9. Verfahren (100) nach Anspruch 8, wobei das Verfahren (100) gleichzeitig mit der Elektrolyse des Elektrolyten (22) durchgeführt wird.

10. Verfahren (100) nach einem der Ansprüche 1 bis 7, wobei der Behälter (20) sich vom Elektrolyseur unterscheidet, und wobei das Verfahren (100) vor der Elektrolyse des Elektrolyten (22) im Elektrolyseur durchgeführt wird.

11. Verfahren (100) nach Anspruch 10, wobei beim In-Kontakt-bringen (130) des Elektrolyten (22) und des Komplexbildners mit der schwefelbasierten Elektrode (10) eine elektrische Spannung an die schwefelbasierte Elektrode (10) angelegt wird.

12. Verfahren (100) nach einem der Ansprüche 1 bis 11, wobei der Koordinationskomplex durch Filtration entfernt wird (140).

Revendications

1. Procédé (100) d'activation d'une électrode (10) à base de soufre pour un électrolyseur, l'électrode (10) à base de soufre comprenant du soufre et une matière non soufrée conductrice de l'électricité, le procédé (100) comprenant :

    - on met (110) un électrolyte (22) dans un récipient (20), l'électrolyte (22) étant conçue pour libérer au moins une partie du soufre de l'électrode (10) à base de soufre,
    - on met (120) un agent complexant dans le récipient (20), l'agent complexant étant conçu pour former un complexe de coordination avec le soufre libéré et comprenant l'un de l'hydroxyde de baryum, du chlorure de baryum, du nitrate de baryum, de l'hydroxyde de strontium, du chlorure de strontium, du nitrate de strontium, de l'hydroxyde de calcium, du chlorure de calcium, du nitrate de calcium et de leurs combinaisons,
    - on met (130) l'électrolyte (22) et l'agent complexant en contact avec au moins une partie d'une surface de l'électrode (10) à base de soufre, l'électrode (10) à base de soufre étant mise en position dans le récipient (20), et
    - on retire le complexe de coordination du récipient (20).

2. Procédé (100) suivant la revendication 1, dans lequel la matière non soufrée conductrice de l'électricité comprend un métal.

3. Procédé (100) suivant la revendication 2, dans lequel le métal est l'un du nickel, du cobalt, du fer, du chrome, de l'aluminium, du molybdène et de leurs combinaisons.

4. Procédé (100) suivant l'une quelconque des revendications 1 à 3, dans lequel l'électrolyte (22) est de l'eau alcaline.

5. Procédé (100) suivant l'une quelconque des revendications 1 à 4, dans lequel on mélange l'électrolyte (22) et l'agent complexant avant la mise en contact (130) avec la partie de la surface de l'électrode (10) à base de soufre.

6. Procédé (100) suivant l'une quelconque des revendications 1 à 5, dans lequel on met l'électrolyte (22) et l'agent complexant en contact (130) avec la partie de la surface de l'électrode (22) à base de soufre à une température comprise entre 20 degrés centigrades et 200 degrés centigrades.

7. Procédé (100) suivant l'une quelconque des revendications 1 à 6, dans lequel on met l'électrolyte (22) et l'agent complexant en contact (130) avec la partie de la surface de l'électrode (22) à base de soufre à une pression comprise entre 1 bar et 100 bar.

8. Procédé (100) suivant l'une quelconque des revendications 1 à 7, dans lequel le récipient (20) est une partie de l'électrolyseur, dans laquelle l'électrode (10) à base de soufre est mise en position pour effectuer une électrolyse de l'électrolyte (22).

9. Procédé (100) suivant la revendication 8, dans lequel on effectue le procédé (100) simultanément avec l'électrolyse de l'électrolyte (22).

10. Procédé (100) suivant l'une quelconque des revendications 1 à 7, dans lequel le récipient (20) est distinct de l'électrolyseur et dans lequel on effectue le procédé (100) avant l'électrolyse de l'électrolyte (22) dans l'électrolyseur.

11. Procédé (100) suivant la revendication 10, dans lequel, dans la mise en contact (130) de l'électrolyte (22) et de l'agent complexant en contact avec l'électrode (10) à base de soufre, on applique une tension électrique à l'électrode (10) à base de soufre.

12. Procédé (100) suivant l'une quelconque des revendications 1 à 11, dans lequel on retire (140) le complexe de coordination par filtration.

FIG 1

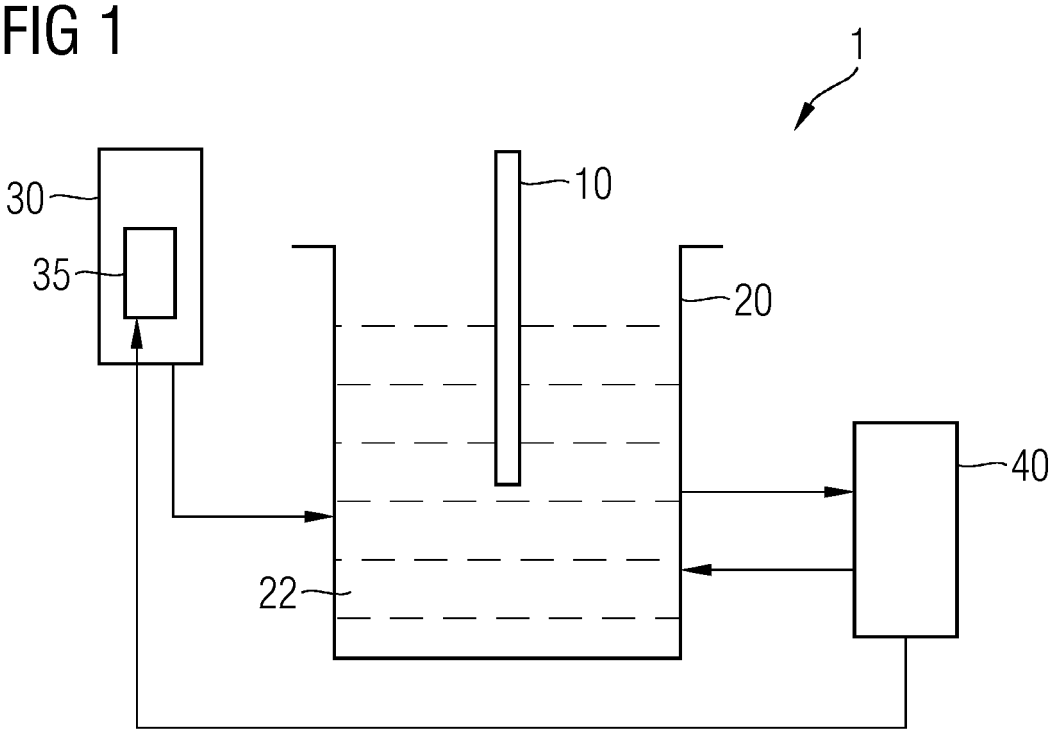
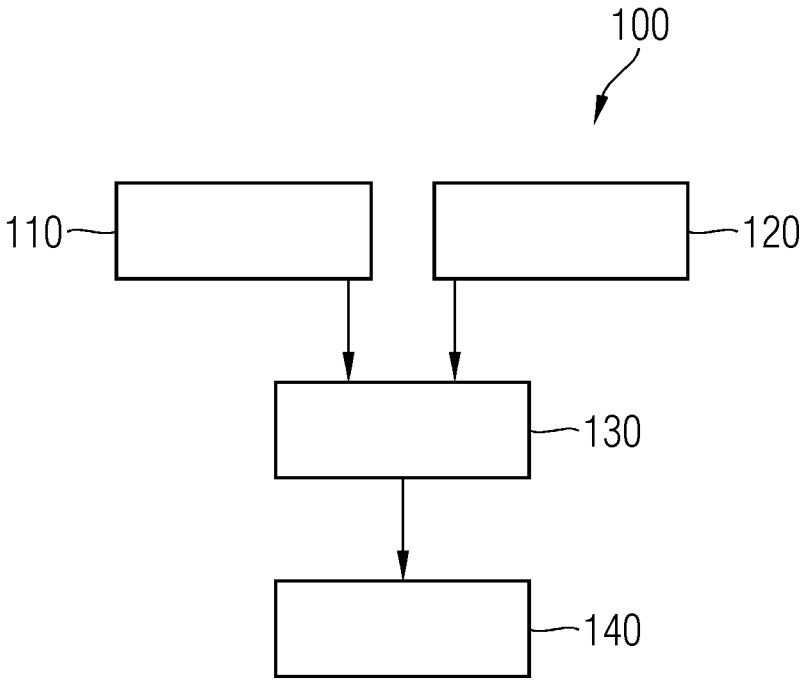


FIG 2



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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