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(54) **Method for joining an electrode tab to a current collector using ultrasonic welding, an electrode assembly for a battery, and use of the assembly**

(57) The present application discloses an electrode assembly, compositions and batteries comprising the electrode assembly, uses of the electrode assembly and a method for producing the electrode assembly comprising the steps of:

- providing at least a first composite electrode material comprising at least one silicon layer on a current collector material; and
- providing an electrode tab material in contact with the current collector material, to form an aligned electrode assembly stack;
- optionally, providing a composite electrode material comprising at least one silicon layer on a current collector material in contact with the current collector material of another composite electrode, to form an aligned electrode assembly stack;
- optionally, repeating step c at least one time; and
- applying ultrasonic energy to a portion of the aligned electrode assembly stack to form:
 - a weld material;
 - a penetration weld through the electrode tab and optionally through the composite material; and/or
 - at least an attachment weld between the weld material and the composite material;
 thereby forming the electrode assembly.

Method for joining an electrode tab to a current collector using ultrasonic welding, an electrode assembly for a battery, and use of the assembly

Field of the invention

The present invention relates to a negative electrode assembly for a battery and its manufacture, in particular to an improved joining between an electrode tab and an electrode comprising a silicon active material and a current collector using ultrasonic welding techniques.

Background of the invention

A battery is a device consisting of one or more electrochemical cells with external connections that convert stored chemical energy into electrical energy. A cell has a positive electrode and a negative electrode, also termed respectively a cathode and an anode. When a battery is connected to an external circuit electrons flow from the anode to the cathode through the external circuit thereby delivering electrical energy to the circuit and any devices connected to the circuit.

Primary batteries such as alkaline batteries are one-time-use batteries as the electrode material changes permanently during discharge. Secondary batteries such as lithium-ion batteries can be charged and discharged multiple times as the original composition of the electrode material can be restored by applying a reverse current.

A cell is made up of two half-cells connected in series by a conductive electrolyte material. One of the cells contains the cathode, while the other cell contains the anode with the electrolyte present in both cells. A separator may be present between both cells, which prevents mixing of electrolytes when two different types of electrolytes in each of the cells are used, while still allowing ions to flow between both cells.

An electrode comprises an active material layer, for example consisting mostly of silicon, formed on a current collector, for example a copper sheet, and to which a lead or tab, for example a nickel plate, is connected. The tab is typically connected by welding to an exposed part of the current collector, i.e. upon which no active material is formed or where active material is removed.

However, removing the active material from the current collector or masking the current collector during forming of the active material on the current collector is a difficult and complicated process, which may also put the integrity of the electrode at risk. For example, a high degree of precision is required to produce a suitable exposed area of current collector material during for example slurry coating or vapor deposition methods such as plasma-enhanced chemical vapor deposition (PECVD).

The aforementioned drawback of having to manufacture an electrode with exposed areas of current collector material, can be circumvented by for example indirectly welding the tab to the active material of the electrode. US patent US9979009B2 discloses an energy storage device

comprising an electrode tab, a silicon electrode comprising a metal layer that is thinner than the electrode tab and a laser weld coupling the electrode tab to the silicon electrode, wherein a joint of the laser weld comprises a melted material of the electrode tab and in electrical contact with a melted material of the metal layer.

5 International patent application WO2013080459A1 discloses a tab connected to a negative electrode comprising an active material and a current collector via a melting part that is continuously formed across an end surface of the tab and an end surface of the electrode by arc welding, but not by resistance welding or ultrasonic welding.

Alternatively, the drawback could be avoided by supplying an electrode which has active
10 material on only one of two sides, while the other side is bare, exposed current collector material. It is known from patent application GB2458942A that copper can be ultrasonically welded to nickel. However, silicon layers formed on current collectors as electrodes usually have a rigid proto-crystalline composition and are therefore brittle. It is therefore expected that exposing the silicon layer material to the thermal stress of welding, and in particular to the additional severe
15 mechanical stress of ultrasonic welding, will cause the silicon layer to be damaged or even destroyed before an effective weld can be established. In addition, indirectly welding an electrode tab to a current collector material which has a silicon layer attached to the current collector on the opposite side of the intended tab to current collector attachment is also expected to cause the silicon layer on the opposite side to be damaged or even destroyed before an effective weld can
20 be established. In this situation the established attachment between the current collector material and the silicon active material prior to welding will thus be negatively affected by the stresses of (ultrasonic) welding.

A goal of the invention of the present application is to provide an improved method of
25 producing an electrode assembly by welding a tab to an electrode using ultrasonic welding, an electrode assembly comprising an ultrasonic weld attaching a tab to the electrode in an improved fashion, and compositions and batteries comprising assemblies according to the invention. Another goal is to provide electrode assemblies comprising multiple electrodes welded to one tab via one weld and methods for manufacturing the assemblies.

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Summary of the invention

In view of the above discussion, the object of the present invention is therefore to provide a method for producing an electrode assembly comprising the steps of:

- a. providing at least a first composite electrode material comprising at least one
35 silicon layer on a current collector material; and
- b. providing an electrode tab material in contact with the current collector material, to form an aligned electrode assembly stack;

- c. optionally, providing a composite electrode material comprising at least one silicon layer on a current collector material in contact with the current collector material of another composite electrode, to form an aligned electrode assembly stack;
- d. optionally, repeating step c at least one time; and
- 5 e. applying ultrasonic energy to a portion of the aligned electrode assembly stack to form:
 - i. a weld material;
 - ii. a penetration weld through the electrode tab and optionally through the composite material; and/or
 - 10 iii. at least an attachment weld between the weld material and the composite material;

thereby forming the electrode assembly.

It is a further object to provide an electrode assembly obtainable by the method according to the invention.

15 In a further aspect, the subject of the invention is to provide an electrode assembly comprising:

- i) an electrode tab comprising a weld material, wherein at least part of the weld material and the tab material form a first weld interface material;
- ii) a silicon electrode composite material comprising the weld material and a silicon active material layer on a current collector material layer, wherein at least part of the weld material and the current collector material, form a second weld interface material; and
- 20 iii) the weld material adjoining the electrode tab and the current collector material, such that tab, composite and weld material are joined in electrical communication with each other.

25 It is a further object of the invention to provide a battery, comprising an electrolyte, a cathode, a separator and the assembly according to the invention or the composition according to the invention.

30 It is yet a further object of the invention to provide a use of the assembly, the composition or the battery according to the invention as an energy storage and/or release device.

Applicants have found that with the methods, assemblies, compositions and batteries according to the invention the goal has been achieved.

Short Description of the Figures

Figure 1 shows a schematic representation of an electrode assembly stack according to the invention in contact with the horn and anvil of an ultrasonic welding apparatus.

Figure 2 shows a schematic representation of an electrode assembly stack according to the invention in contact with the horn and anvil of an ultrasonic welding apparatus with an optional welding material placed on top of the anvil.

Figure 3 shows a schematic representation of an electrode assembly stack according to the invention, comprising multiple composite electrodes, in contact with the horn and anvil of an ultrasonic welding apparatus with an optional welding material placed on top of the anvil.

Figure 4 shows a schematic representation of an electrode assembly stack according to the invention, comprising multiple composite electrodes, in contact with the horn and anvil of an ultrasonic welding apparatus with an optional welding material placed on top of the anvil and in between the composite electrodes.

Figure 5 shows a schematic representation of an electrode assembly stack, comprising multiple composite electrodes, not according to the invention, in contact with the horn and anvil of an ultrasonic welding apparatus with an optional welding material placed on top of the anvil.

Figure 6 shows a schematic representation of an electrode assembly stack according to the invention, comprising multiple composite electrodes, in contact with the horn and anvil of an ultrasonic welding apparatus with an optional welding material placed on top of the anvil and a mandatory welding material in between the composite electrodes.

Figure 7 shows a schematic representation of an electrode assembly according to the invention attached to a circuit for four-point contact resistance measurement.

Detailed Description of the Invention

The inventors have surprisingly found that an electrode tab can be welded to the current collector material of a composite electrode comprising silicon active material via ultrasonic welding.

Accordingly, the present invention is directed to a method for producing an electrode assembly comprising the steps of:

- a. providing at least a first composite electrode material comprising at least one silicon layer on a current collector material; and
- b. providing an electrode tab material in contact with the current collector material, to form an aligned electrode assembly stack;
- c. optionally, providing a composite electrode material comprising at least one silicon layer on a current collector material in contact with the current collector material of another composite electrode, to form an aligned electrode assembly stack;
- d. optionally, repeating step c at least one time; and

e. applying ultrasonic energy to a portion of the aligned electrode assembly stack to form:

- i. a weld material;
- ii. a penetration weld through the electrode tab and optionally through the composite material; and/or
- iii. at least an attachment weld between the weld material and the composite material;

thereby forming the electrode assembly.

The present invention is also directed to an electrode assembly comprising:

- i) an electrode tab comprising a weld material, wherein at least part of the weld material and the tab material form a first weld interface material;
- ii) a silicon electrode composite material comprising the weld material and a silicon active material layer on a current collector material layer, wherein at least part of the weld material and the current collector material, form a second weld interface material; and
- iii) the weld material adjoining the electrode tab and the current collector material, such that tab, composite and weld material are joined in electrical communication with each other.

Another aspect of the invention is an electrode assembly obtainable by the method according to the invention.

Ultrasonic welding is a welding technique wherein high-frequency ultrasonic acoustic vibrations are locally applied to elements that are held together under pressure in order to create a solid-state weld. When ultrasonic welding is used to join metals the temperature of the metals typically stays below their melting points thereby preventing unwanted properties that can occur due to high temperature exposure, such as damage to the composite electrode material. Moreover, undesirable intermetallic compounds and metallurgical defects such as brittle phases or porosities in the fused zone, that may result from most fusion welding processes, are prevented.

Ultrasonic welding offers advantages over other welding techniques used in the prior art such as laser welding, arc welding or resistance welding. These advantages are reduced energy requirements, increased speed and safety, in addition to the ability to effectively weld thin layers more precisely.

However, an electrode tab cannot be effectively welded directly to a silicon layer of a composite electrode. Silicon layers formed on current collectors as electrodes usually have a rigid proto-crystalline composition and are therefore brittle. It is therefore expected that exposing the

silicon layer material to the thermal stress of welding, and in particular to the additional severe mechanical stress of ultrasonic welding, will cause the silicon layer to be damaged or even destroyed before an effective weld can be established. In addition, indirectly welding an electrode tab to a current collector material which has a silicon layer attached to the current collector on the opposite side of the intended tab to current collector attachment is also expected to cause the silicon layer on the opposite side to be damaged or even destroyed before an effective weld can be established. In this situation the established attachment between the current collector material and the silicon active material prior to welding will thus be negatively affected by the stresses of (ultrasonic) welding.

However, contrary to previous expectations, applicant has now found that an electrode tab can be ultrasonically welded to the current collector layer of a composite electrode material comprising a silicon layer on a current collector material. By applying ultrasonic welding to an assembly stack comprising an electrode tab in connection with the current collector material of composite electrode comprising a current collector material and a silicon active material, a weld material is formed and a penetration weld is formed through the electrode tab and optionally the composite material and a stable mechanical and electrically conductive connection is formed between all of the involved components. In addition, at least part of the weld material and the tab material form a first weld interface material and at least part of the weld material and the composite material form a second weld interface material.

A novel industrial method for manufacturing an anode for use in a secondary battery comprises depositing silicon and/or carbon as the active electrode material on a sheet of a current collector material using chemical vapor deposition (CVD). In order to obtain an exposed section of current collector material to which an electrode tab can be connected, the active material is not deposited on certain defined, masked, parts of the current collector. Tabs are later welded onto these exposed parts of the current collector. Alternatively, the active electrode material may be etched off or removed by techniques such as laser ablation or mechanical grinding after deposition in order to expose the current collector material.

According to the invention an electrode tab can now be connected to the current collector material of an electrode wherein the silicon active material has been attached to the current collector directly opposite of where the tab will be attached. This situation can occur when composite electrode materials are provided wherein only one side of the current collector (sheet) has a layer of silicon active material attached. Moreover, the aforementioned advantages of ultrasonic welding can now be employed.

One or more additional tabs can be ultrasonically welded to the assembly according to the invention to improve the weld. In this way the assembly consists of at least two tabs on opposite ends comprising weld material, composite material and optionally welding material sandwiched and welded in between the at least two tabs.

According to the method of invention providing an electrode tab material in contact with the current collector material may further comprise providing an additional electrode tab material in contact with the current collector material of the composite material, to form an aligned electrode assembly stack.

A second electrode assembly comprising one or more additional electrode tabs may be produced by a method comprising the steps of:

- a. providing a first assembly according to the invention;
- b. optionally providing a welding material in contact with the first assembly, preferably with a silicon layer of the first assembly, preferably wherein the welding material is not in contact with a layer that adjoins the tab material of the first assembly; and
- c. providing a second electrode tab material in contact with the current collector material of the composite material of the first assembly or the optional welding material, preferably the optional welding material, to form an aligned electrode assembly stack;
- d. applying ultrasonic energy to a portion of the aligned electrode assembly stack to form:
 - i. a weld material;
 - ii. a penetration weld through the second electrode tab and the optional welding material and optionally through the composite material; and/or
 - iii. at least an attachment weld between the weld material and the composite material;

preferably wherein at least part of the weld material and the second tab material form a first weld interface material and at least part of the weld material and the composite material form a second weld interface material, thereby forming the second electrode assembly.

Accordingly, the assembly according to the invention may comprise a second tab comprising a weld material adjoining the second electrode tab and the composite such that tab, composite and weld material are joined in electrical communication with each other, and preferably wherein at least part of the weld material and the tab material form a first weld interface material.

Preferably, according to the method of the invention, the method further comprises providing a welding material in contact with the aligned electrode assembly stack and with the anvil of an ultrasonic welding apparatus prior to applying ultrasonic energy. This can result in a further improved weld according to the invention and can also facilitate the incorporation of even more units of composite material layers into the electrode assembly according to the invention.

Preferably, according to the method of the invention, providing a composite electrode material comprising at least one silicon layer on a current collector material in contact with the current collector material of another composite electrode, to form an aligned electrode assembly stack comprises providing the at least one silicon layer or the current collector material in contact

with the current collector material of another composite electrode, more preferably the at least one silicon layer.

Preferably, repeating step c at least one time, comprises repeating step c one time, two times, three times, four times, five times, six times, seven times, eight times or nine times.

5 Preferably, according to the invention, the penetration weld is formed through the current collector material of the composite material.

Preferably, according to the invention, the attachment weld is formed between the weld material and current collector material of the composite material.

10 According to the method of the invention, the method preferably comprises an additional step, before the step of applying ultrasonic energy, of providing a welding material in between two composite electrode materials, optionally repeating the additional step. Preferably, providing a welding material in contact with the composite material or in between two composite electrode materials according to the invention comprises providing a welding material in contact with the current collector material or with the at least one silicon layer of the composite material, more
15 preferably providing a welding material in contact with the at least one silicon layer of the composite material.

Preferably, the composite material according to the invention comprises at least one layer of silicon on each of two sides of the current collector material.

20 Advantageously, according to the invention, the materials are essentially flat, sheet-like materials, and the materials are aligned and fixed prior to, and during the welding process. Electrode materials are commonly produced in an industrial process wherein the electrode active material is deposited as a layer on a sheet of current collector foil, for example by physical vapor deposition (PVD), chemical vapor deposition (CVD) or plasma-enhanced chemical vapor deposition (PECVD). Electrode tabs are commonly also attached to the electrodes in the form of
25 essentially flat, sheet-like materials. A stack of materials that are essentially flat and sheet-like in structure enables an easy alignment and fixing prior to and during welding. Herein, the silicon layer according to the invention is an active material layer. Silicon layer and silicon active material layer are used interchangeably.

Preferably, the assembly according to the invention comprises a welding material.

30 Preferably, the welding material according to the invention comprises aluminium, gold, copper, iron, lithium, manganese, palladium, platinum, thulium, titanium, tungsten, silver, beryllium, magnesium, nickel, silicon or zirconium, more preferably aluminium, gold or copper, even more preferably copper.

35 Preferably, the welding material or the current collector material according to the invention each have a thickness of from 1 to 100 μm , preferably of from 5 or 10 to 50 μm , more preferably of from 10 to 15 μm or about 10 or 12 μm .

Advantageously, the current collector material according to the invention comprises copper, tin, chromium, nickel, titanium, stainless steel, or silver, or alloys thereof, more preferably copper or nickel, or alloys thereof, most preferably copper.

5 The current collector material includes sheet-like materials produced by either cold rolling or electroplating, and can also comprise alloys of copper or titanium with elements such as magnesium, zinc, tin, phosphor and/or silver. It can be smooth, rough, or textured, with a tensile strength preferably ranging from 150 to 600 MPa, and might comprise a passivation layer deposited on the copper foil to protect the copper foil from oxidation in air. The sheet-like materials produced by cold rolling or electroplating can have certain defects such as rolling lines, potential
10 strains, impurities, and native oxide, which can impact the quality of the active material layer. Thus, the current collector material may be subjected to surface treatment. For example, the roughness of the foil can be increased to varying degrees by attaching nodules of current collector material or other metals at the surface of the current collector material, by for example electroplating. Other surface treatment techniques known in the art include annealing, knurling,
15 etching, liquefying, physical polishing and electro-polishing, and are used to improve the morphology of the current collector material prior to deposition of active material.

Preferably, the current collector material according to the invention comprises a metal, metal alloy and/or metal salts and/or oxide.

The metal, metal alloy and/or metal salts and/or oxide according to the invention are
20 advantageously selected from aluminium, copper, nickel, tin, indium and zinc, preferably nickel, ZnO or SnO₂, most preferably ZnO; preferably, wherein the current collector comprises a copper or nickel core layer, more preferably a core layer doped with oxides or fluorides of zinc, aluminium, tin or indium. Preferably, the metal, metal alloy and/or metal salts and/or oxide or the core layer are in a layer at a thickness of from 0.1 to 5 nm, more preferably of from 1 to 2 nm.
25 Preferably, a current collector according to the invention comprising copper or nickel comprises nickel, ZnO or SnO₂.

The term "doping" is herein understood to mean introducing a trace of an element into a material to alter the original electrical properties of the material or to improve the crystal structure of the silicon material.

30 In the pending international patent application WO2021029769 of current applicant, applicant has found that an adhesion layer comprising a metal, metal alloy and/or metal salts and/or oxide attached to the current collector material, increases adhesion of the silicon material to the current collector material of the composite electrode. According to the present invention, the current collector material comprising a metal, metal alloy and/or metal salts and/or oxide
35 adhesion layer preferably comprises an adhesion layer. This adhesion layer increases the adhesion between silicon material and the current collector material as different complexes of silicon are being formed on the interface between the current collector material and the silicon.

Such an adhesion layer preferably comprises nickel, zinc or tin, such as ZnO or SnO₂. The adhesion layer can be formed by coating or depositing the metal, metal alloy and/or metal salts and/or oxide on the current collector material. Preferably, the adhesion layer is in a layer at a thickness of from 0.1 to 5 nm, more preferably of from 1 to 2 nm.

5 Preferably, according to the invention the at least one silicon layer has a thickness of from 0.1 to 500 μm , preferably of from 1 to 100 or 200 μm , more preferably of from 1 to 30 or 50 μm , most preferably of from 3 or 5 to 15 or 20 μm or about 10 μm . Alternatively, according to the invention, the at least one silicon layer preferably has a mass loading of from 0.1 to 4.0 mg/cm^2 , more preferably of from 0.5 or 0.8 to 2.0 or 2.5 mg/cm^2 , or of from 2.5 to 3.5 or 4.0 mg/cm^2 , most
10 preferably of from 1.0 to 2.0 mg/cm^2 . The mass loading pertains to mass loading of one silicon layer that is present on one side of a current collector layer.

Advantageously, the at least one silicon layer according to the invention has a porosity of from 5% or 10% to 50%. Preferably, the average pore size of the silicon layer is in the range of from 0.5 to 40 nm, preferably of from 1 to 20 nm. Porosity and (average) pore size according to
15 the invention are preferably determined according to the method specified by the ISO (International Organization for Standardization) standard: ISO 15901-2:2006 "Pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption — Part 2: Analysis of mesopores and macropores by gas adsorption" using nitrogen gas. Briefly, a N₂ adsorption-isotherm is measured at about -196 °C (liquid nitrogen temperature). According to the
20 calculation method of Barrett-Joyner-Halenda (Barrett, E. P.; Joyner, L.G.; Halenda, P. P. (1951), "The Determination of Pore Volume and Area Distributions in Porous Substances. I. Computations from Nitrogen Isotherms", Journal of the American Chemical Society, 73 (1): 373–380) the pore size and pore volume can be determined. Specific surface area can be determined from the same isotherm according to the calculation method of Brunauer-Emmett-Teller
25 (Brunauer, S.; Emmett, P. H.; Teller, E. (1938), "Adsorption of Gases in Multimolecular Layers", Journal of the American Chemical Society, 60 (2): 309–319). Both calculation methods are well-known in the art. A brief experimental test method to determine the isotherm can be described as follows: a test sample is dried at a high temperature and under an inert atmosphere. The sample is then dried and placed in the measuring apparatus. Next, the sample is brought under vacuum
30 and cooled using liquid nitrogen. The sample is held at liquid nitrogen temperature during recording of the isotherm.

The silicon layer according to the invention is preferably attached to the current collector layer or the adhesion layer as a layer comprising a plurality of adjacent columns and aggregated particles with a diameter of at least 5 nm, up to 50 nm, more preferably in the range of from 10
35 up to 20 nm, the columns extending in a perpendicular direction from the copper foil surface, wherein the adjacent columns are separated by column boundaries extending in the perpendicular direction.

The silicon layer according to the invention has preferably an amorphous structure in which nano-crystalline regions exist. More preferably, the silicon layer or the columns comprise up to 30% of nano-crystalline silicon. According to an embodiment, the silicon layer advantageously comprises n-type or p-type dopants to obtain a silicon layer of respectively n-type conductivity or p-type conductivity.

Advantageously, the silicon columns further comprise a silicon alloy, wherein the silicon alloy is preferably selected from the group comprising Si-C and/or Si-N. Preferably, the composite material according to the invention comprises carbon or an alloy comprising carbon or silicon. The silicon alloy may be either an addition or an alternative to the amorphous silicon. Thus, according to an aspect of the invention, the material of the columns comprises at least one material selected from amorphous silicon and amorphous silicon alloy.

According to a further aspect, the material of the columns comprises amorphous silicon and nano-crystalline silicon alloy. In some embodiments, the silicon alloy may be present in the electrode layer as a nano-crystalline phase. Also, the anode layer may comprise a mixture of an amorphous material and nano-crystalline phase. For example, a mixture of amorphous silicon and nanocrystalline silicon, or a mixture of amorphous silicon with nano-crystalline silicon alloy, or a mixture of silicon and silicon-based alloy predominantly in an amorphous state comprising a fraction (up to about 30%) of the mixture in a nano-crystalline state. According to the present invention, the amorphous silicon columns are preferably extending in a perpendicular direction from the anode surface, i.e. the interface between the anode layer and the electrolyte layer, in which the plurality of silicon columns are arranged adjacent to each other while separated by interfaces extending perpendicularly to the anode surface.

The silicon layer according to the invention may comprise silicon oxide.

The term "amorphous silicon" herein is understood to mean as comprising protocrystalline silicon, which is a definition for amorphous silicon comprising a fraction of nanocrystalline silicon. This fraction may be up to about 30% of the silicon layer. For ease of reference the term amorphous silicon will be used herein to indicate that the silicon layer comprises amorphous silicon, in which nano-crystalline regions of the silicon layer may be present with a fraction of nanocrystalline silicon up to about 30%.

The silicon layer according to the invention may be on the current collector layer in a variety of configurations. The silicon may be on nanowire templates that are attached to a substrate such as the current collector layer or the adhesion layer. The term "nanowire" herein is understood to mean a branched or non-branched wire-like structure with at least one dimension with a length of up to about 1 μm . The nanowire is an electrically conductive material comprising for example carbon, a metal or a metal silicide such as nickel silicide, copper silicide, silver silicide, chromium silicide, cobalt silicide, aluminium silicide, zinc silicide, titanium silicide or iron silicide, preferably comprising at least one nickel silicide phase comprising Ni_2Si , NiSi or NiSi_2 . The

nanowire may be the same material as the current collector such as nickel, copper or titanium. Alternatively, the nanowire may be a separate material and layer from the current collector material such as a copper current collector coated with a nickel layer. One or more layers of active material such as silicon may be deposited on nanowires via for example PVD, CVD or PECVD.

5 The silicon layer may comprise carbon, copper, a sulfide, a metal oxide, a fluorine containing compound, a polymer or a lithium phosphorous oxynitride. The silicon layer may be coated with a layer comprising carbon, copper, a sulfide, a metal oxide, a fluorine containing compound, a polymer or a lithium phosphorous oxynitride, preferably a carbon layer with a thickness of from 1 nm to 5 μm , preferably of from 10 nm to 1 μm .

10 Advantageously, according to the invention, the tab material preferably has a thickness of from 1 μm to 1 mm, more preferably of from 10 to 500 μm , of from 20 to 200 μm , from 50 to 150 μm or about 100 μm .

According to the invention, the tab is preferably a sheet-like material comprising a metal with a thickness of from 1 μm to 1 mm, more preferably of from 10 to 500 μm , of from 20 to 200 μm , from 50 to 150 μm or about 100 μm .

15 According to the invention the tab material preferably comprises nickel or copper or an alloy comprising nickel, copper, tin, silicon, copper and nickel, copper and tin or copper and silicon. More preferably the tab material comprises nickel.

Preferably, according to the invention if the tab material comprises nickel, the current collector material or the welding material is selected from materials comprising aluminium, gold, copper, iron, lithium, manganese, palladium, platinum, thulium, titanium, tungsten or combinations thereof, more preferably aluminium, gold, copper, lithium or manganese, even more preferably copper; and if the tab material comprises copper but not nickel, the current collector material or the welding material is selected from materials comprising silver, aluminium, gold, beryllium, copper, iron, magnesium, manganese, nickel, palladium, platinum, silicon, thulium, titanium, tungsten, zirconium or combinations thereof, more preferably silver, aluminium, gold, copper or magnesium.

Preferably, the tab material according to the invention has a higher melting temperature point than the melting temperature point of the current collector material.

30 Without wishing to be bound to the following theory, it can be speculated that a higher melting temperature of the tab material compared to a lower melting temperature of the current collector material enables a penetration weld to be formed in the tab material, wherein the current collector material penetrates into the tab material, thereby forming a weld material with a first weld interface. Thus, any current collector material having a lower melting temperature point than the melting temperature point of the tab material could be most suitable according to the invention.

35 In addition, the porous structure of the silicon material may facilitate the potential formation of a penetration weld in the composite electrode material. Alternatively, an attachment weld

comprising tab material and/or composite material may be formed having a small or even a minimal penetration into the composite material, which is sufficient for a secure weld and effective electrical communication between the composite material and the tab. Thus, both the penetration weld and the attachment weld can form a weld material with a second weld interface. Penetration

5 of the weld material in the composite material may enable the welding and electrical communication of a plurality of independent layers of composite material to each other and thereby also to the tab material. In this situation, the weld material may comprise or consist of silicon material, welding material and/or current collector material. Preferably, the weld material comprises silicon. Alternatively, an attachment weld having a small or even a minimal penetration

10 into the composite material, the weld comprising tab material, welding material and/or composite material, preferably welding material, current collector material and/or silicon material, may be formed between the independent layers of composite material, which is sufficient for a secure weld and effective electrical communication between the independent layers. Insertion of additional welding material layers in between one or more of the independent layers of composite

15 material could facilitate the subsequent welding of the one or more of the independent layers, but is only necessary when layers of silicon active material of each independent layer of composite material are facing each other, and is not necessary when a layer of current collector material of one layer of composite material is facing a layer of silicon active material of a subsequent layer of current collector material. Thus, a plurality of layers of composite material can be welded and

20 in electrical communication with the tab material. Different configurations prior to welding can be foreseen such as for example a stack consisting of subsequently a tab material, four layers of composite material, wherein the composite material layers are in contact via a current collector material layer of one composite layer facing a silicon layer of a subsequent composite layer, two layers of welding material, two layers of composite material, , wherein the composite material

25 layers are in contact via a current collector material layer of one composite layer facing a silicon layer of a subsequent composite layer, one layer of welding material, five layers of composite material, wherein the composite material layers are in contact via a current collector material layer of one composite layer facing a silicon layer of a subsequent composite layer, and one layer of welding material, wherein the welding material is in contact with the at least one silicon layer of

30 the composite material. A welding layer, which is not in contact with the tab material may also be in contact with the current collector material of the composite material. Therefore, according to the method of the invention, step d preferably comprises repeating step c at least once, for example 2 to 100 times, 3 to 50 times, 4 to 30 times, 10 to 20 times or 4 to 9 times. For example, a composition according to the invention to be used in a large pouch cell has step c repeated

35 about 50 times.

Without wishing to be bound to the following theory it can be speculated that the current collector material according to the invention enables a dissipation of energy (e.g. thermal and/or

vibration) generated by the ultrasonic welding apparatus during ultrasonic welding. This dissipation of energy prevents damage to or destruction of the more rigid silicon active material of the composite electrode material by the ultrasonic welding and thus enables the manufacture of an electrode assembly according to the invention, optionally having multiple units of composite electrode material incorporated therein.

According to the method of the invention, the method preferably comprises a step of, before the step of applying ultrasonic energy, holding in place the assembly stack in a layered manner by applying pressure, preferably with a pressure of from 50 kPa or 200 kPa to 700 kPa or 1500 kPa, more preferably of from 250 kPa to 550 kPa, or of from 300 kPa to 500 kPa, or about 415 kPa.

According to the method of the invention, applying the energy preferably comprises applying the energy via ultrasonic acoustic vibrations. The term "ultrasound" herein is understood to mean sound waves with a frequency of from 10 kHz and higher.

According to the method of the invention, applying the energy preferably comprises applying the energy at a frequency of from 10 to 200 kHz, more preferably of from 20 to 100 kHz, of from 20 or 40 to 80 kHz, most preferably of from 20 to 60 kHz, of from 30 to 50 kHz, of from 20 to 40 kHz, of from 40 to 60 kHz, of from 35 to 45 kHz, or about 40 kHz.

According to the method of the invention, applying the energy preferably comprises applying the energy with a duration of from 0.01 to 100 s, more preferably of from 0.01 to 50 s, of from 1 to 30 s, of from 2 to 20 s, of from 3 to 10 s or of from 4 to 8 s. Preferably, according to the method of the invention, applying the energy comprises applying the energy with a duration of from 0.01 to 100 s for each separate composite electrode material, more preferably of from 0.01 to 50 s, of from 1 to 30 s, of from 2 to 20 s, of from 3 to 10 s, of from 4 to 8 s, even more preferably of from 0.05 to 5 s, of from 0.1 to 3 s, of from 0.5 to 2 s, of from 0.8 s to 1.6 s. For example, when 10 composite electrode material layers are contacted with each other prior to welding, the duration of applying the energy has a total duration of from 10×0.01 to 100 s, which is equal to from 0.1 to 1000 s.

According to the method of the invention, applying the energy preferably comprises applying the energy with a power of from 200 W to 10 kW, more preferably of from 500 W to 5 or 6 kW, from 800 W to 3 or 4 kW or from 1 kW to 2 kW. The energy can be applied to a surface area of for example about 9 mm^2 . A such, according to the method of the invention, applying the energy preferably comprises applying the energy with a power of from 22 W/mm^2 to 1100 W/mm^2 , more preferably of from 55 W/mm^2 to 555 W/mm^2 or 666 W/mm^2 , from 90 W/mm^2 to 333 W/mm^2 or 444 W/mm^2 or from 111 W/mm^2 to 222 W/mm^2 .

According to the method of the invention applying the energy preferably comprises applying the energy via oscillating a sonotrode, preferably with an amplitude of from 1 to $130 \text{ }\mu\text{m}$, more preferably of from 5 to $50 \text{ }\mu\text{m}$ or from 10 to $30 \text{ }\mu\text{m}$.

The person skilled in the art understands that by adjusting the vibration frequency, the vibration amplitude and the power of the ultrasonic welding device, adjusting the duration and adjusting the holding in place the assembly stack in a layered manner by applying pressure, a multitude of different combinations of parameters is possible that could, according to the method
5 of the invention, enable a portion of the aligned electrode assembly stack to form a weld material; a penetration weld through the electrode tab and the composite material; and/or at least an attachment weld between the weld material and the composite material, wherein preferably at least part of the weld material and the tab material form a first weld interface material and at least part of the weld material and the composite material form a second weld interface material,
10 thereby forming the electrode assembly. For example, a higher frequency with a lower duration may produce the same results as a lower frequency with a longer duration. However, a successful weld according to the invention depends not only on the combination of welding parameters, but also on the (combination of the) materials to be welded.

The first weld interface material according to the invention preferably comprises the tab
15 material or an alloy thereof, or the tab material and the composite material, preferably silicon or the current collector material, or an alloy thereof.

The second weld interface material according to the invention preferably comprises the welding material and the composite material, preferably silicon or the current collector material, or an alloy thereof, or the tab material and the composite material, preferably silicon or the current
20 collector material, or an alloy thereof.

The term "weld interface" herein is understood to mean a new hybrid area that is formed in a first material after ultrasonic welding of the first material and at least one second material, the hybrid area comprising at least the first material and the at least one second material in a mixed configuration. When additional materials are subjected to the ultrasonic welding the weld interface
25 may comprise one or more of these additional materials. The mixed configuration may be an ordered or disordered alloy, an intermetallic alloy or a homogeneous mixture, wherein the composition and properties are uniform throughout the mixture, and/or a heterogeneous mixture, wherein the composition and properties are not uniform throughout the mixture, or combinations thereof. Preferably, the first weld interface material is an alloy. Preferably, the second weld
30 interface material is a heterogeneous mixture.

Preferably, according to the invention the weld material comprises silicon and extends into, is extended into or penetrates the current collector material, the welding material and/or the tab material.

Preferably, according to the invention the weld material comprises the current collector
35 material and extends into, is extended into or penetrates the composite material, the current collector material, the silicon layer and/or the tab material. More preferably, the weld material comprises the current collector material and extends into, is extended into or penetrates the tab

material. Preferably, the weld material comprises the current collector material and forms an attachment with the composite material, preferably the current collector material or the silicon, more preferably the current collector material.

5 Preferably, according to the invention the weld material comprises the tab material and extends into, is extended into or penetrates the composite material, the current collector material, the welding material and/or the silicon layer. Preferably, the weld material comprises the tab material and extends into, is extended into or penetrates the current collector material.

10 Preferably, according to the invention the weld material comprises the current collector material and extends into, is extended into or penetrates the silicon layer, the welding material and/or the tab material. More preferably, the weld material comprises the current collector material and extends into, is extended into or penetrates the tab material.

15 According to the invention, the weld material preferably extends into, is extended into or penetrates the composite material throughout at least 0.01 to 0.1% or at least 0.1 to 1% of a dimension of the composite material, at least 10 to 20% of a dimension of the composite material, throughout at least 20 to 50% of a dimension of the composite material, throughout at least 50 to 90% of a dimension of the composite material, or throughout at least 0.01%, 0.1%, 1%, 5%, 10%, 20%, 50%, 90%, 95%, 99% or 100% of a dimension of the composite material.

20 According to the invention, the weld material preferably extends into, is extended into or penetrates the tab material throughout at least 5 or 10 to 20% of a dimension of the tab material, more preferably throughout at least 20 to 50% of a dimension of the tab material, even more preferably throughout at least 50 to 90% of a dimension of the tab material, or throughout at least 5%, 10%, 20%, 50%, 90%, 95%, 99% or 100% of a dimension of the tab material.

25 During welding, the weld material is formed in a direction mostly determined by the direction of the ultrasonic acoustic vibrations that originate from the sonotrode, which are typically mostly directed in an axial direction towards the anvil. During welding, the weld material thus extends into or penetrates the tab material and optionally the composite material preferably along a dimensional direction mostly determined by the direction of the ultrasonic acoustic vibrations.

30 Advantageously, according to the invention the weld material preferably comprises silicon and extends into, is extended into or penetrates the current collector material or the welding material.

35 Preferably, the assembly according to the invention comprises one or more, preferably 4 to 9, additional composites in electrical communication with each other and with the first composite. Without being bound by the following theory, it is speculated that the weld material may extend into or penetrate into a subsequent connecting composite material whereby prior to welding no welding material or current collector material was in contact with the subsequent composite material. The above effect may therefore help to enable multiple composite materials to be connected to each other and the tab material via one weld generated by one welding action.

According to the invention, the weld material, the welding material, the current collector material or the weld interface material preferably comprises aluminium, gold, copper, iron, lithium, manganese, palladium, platinum, thulium, titanium, tungsten, silver, beryllium, magnesium, nickel, silicon or zirconium. Preferably, the weld material, the current collector material or the welding material comprises copper and nickel.

The assembly according to the invention preferably has a resistance of equal to or less than 20 mΩ, preferably less than 10 mΩ, between the distal end of the tab and the proximal end of composite, wherein the weld material adjoins the electrode tab and the composite with a surface area of about 9 mm², as determined by a volt-ohm-milliammeter using a four-point measurement structure.

The tab material and the current collector material of the composite of the assembly according to the invention preferably have a connection with an adhesive strength of at least 0.5 or 1 N/mm, preferably of at least 5 or 8 N/mm, more preferably of at least 10, 11, 12, 13 or 14 N/mm. The tab material and the current collector material of the composite of the assembly according to the invention preferably have a connection with an adhesive strength of from 0.5 or 1 to 100 N/mm, preferably of from 5 or 8 to 100 N/mm, more preferably of from 10 to 12 to 15, 20 or 100 N/mm or about 14 N/mm.

The weld material according to the invention is preferably an ultrasonic weld material. The term "ultrasonic weld material" herein is understood to mean a weld material formed by ultrasonic welding. An ultrasonic weld or weld material can be identified by a combination of characteristics that are specific to the result of ultrasonic welding. These characteristics can for example be assessed via optical or (scanning) electron microscopy. Examples of these characteristics are indentations of the sonotrode and/or anvil on the surface of the contacted materials, micro-bonds (metallurgical adhesion), interfacial waves (mechanical interlocking), and deformed material overflowing into a space that is not into contact with the sonotrode, as for instance disclosed in "Characterization of Joint Quality in Ultrasonic Welding of Battery Tabs", S. Shawn Lee , Tae Hyung Kim , S. Jack Hu , Wayne W. Cai , Jeffrey A. Abell , Jingjing Li., J. Manuf. Sci. Eng., Apr. 2013, 135(2): 021004 (13 pages).

Another aspect of the invention is a method for producing a composition comprising the steps of:

- a. providing a first assembly according to the invention;
- b. providing a second assembly according to the invention;
- c. contacting an electrode tab of the first assembly with an electrode tab of the second assembly; and
- d. welding the tabs, thereby adjoining the tab of the first assembly with the tab of the second assembly such that they are joined in electrical communication with each other.

Another aspect of the invention is a composition comprising at least two assemblies according to the invention, comprising a weld adjoining the tab of a first assembly with the tab of a second assembly.

Another aspect of the invention is a method for producing a composition comprising the steps of:

- a. providing a first assembly according to the invention;
- b. providing a second assembly according to the invention;
- c. providing an electrode tab material;
- d. optionally providing a welding material in contact with the first and second assembly;
- e. contacting in order to form a composition stack:
 - i. at least the current collector material of at least one assembly with the other assembly; or
 - ii. the welding material with each assembly;
 - iii. the tab material with the current collector material or the welding material;

applying ultrasonic energy to a portion of the composition stack to form a weld material; a penetration weld through the tab material and the welding material or the current collector material, wherein preferably at least part of the weld material and the tab material form a first weld interface material; and/or a penetration or attachment weld through the first and second assembly, wherein preferably at least part of the weld material and the composite material form a second weld interface material, thereby forming the composition.

Another aspect of the invention is a composition comprising at least two assemblies according to the invention, comprising a weld comprising weld material adjoining, preferably penetrating, the composite of a first assembly and the composite of a second assembly, wherein at least part of the weld material and the composite material, preferably silicon or current collector material, form a second weld interface material.

A further aspect of the invention is a battery, comprising an electrolyte, a cathode, a separator and the assembly or the composition according to the invention.

The battery according to the invention preferably comprises an electrolyte comprising a medium and a lithium salt compound arranged between the cathode and the assembly.

The medium may be liquid or solid. An electrolyte comprising a liquid medium and a lithium salt may for example consist of any of LiPF_6 , LiBF_4 or LiClO_4 in an organic solvent such as ethylene carbonate, dimethyl carbonate, propylene carbonate, ethyl methyl carbonate, diethyl carbonate, or mixtures of any combination thereof, or other lithium salts and solvents known in the art such as room-temperature ionic liquids. The electrolyte may be solid such as a ceramic electrolyte. The lithium salt in a solid ceramic electrolyte is usually present as a lithium metal

oxide. Examples of solid ceramic electrolytes are lithium super ion conductors and perovskites optionally arranged as an amorphous structure.

The battery according to the invention preferably comprises a single assembly or composition or a multitude of assemblies or compositions. The single assembly or composition or a multitude of assemblies or compositions according to the invention may be folded or rolled to obtain a suitable configuration for use in a battery.

Advantageously, the battery according to the invention preferably has the electrolyte, cathode, separator and assembly or composition in a rolled or folded configuration or contained within a non-metallic pouch.

Examples of such cells are cylindrical, prismatic, pouch and coin cells. Several configurations of cells can also be combined. For example, a coin cell can have an internal cylindrical configuration (as disclosed in international patent application WO2015188959A1) or a pouch cell can have an internal prismatic configuration.

Preferably, the battery according to the invention comprises a single anode electrode tab. Preferably, such a battery comprises a prismatic cell or a cylindrical cell.

An additional aspect of the invention is the use of the assembly, the composition or the battery according to the invention as an energy storage and/or release device.

The term "energy storage and/or release device" herein is understood to mean a secondary battery, including an electrode assembly of a cathode/separator/anode structure mounted in a suitable battery case. Such batteries include lithium ion secondary batteries, which are excelling in providing high energy density, and a high capacity; and their use in secondary battery modules comprising a plurality of secondary batteries, which are typically connected in series with each other to form a battery pack that can be incorporated into a casing to form the module.

Detailed Description of the Figures

The invention will now be discussed with reference to the figures, which show preferred exemplary embodiments of the subject invention.

Figure 1 shows a schematic representation of an electrode assembly stack (100) according to the invention, prior to or during ultrasonic welding, in contact with the horn (101) and anvil (102) of an ultrasonic welding apparatus. The horn (101) is shown pressing down on top of the stack. The stack comprises in sequence the electrode tab (103), a current collector layer (106) and a silicon material layer (105). The anvil (102) is shown holding in place the bottom of the stack. A composite electrode material (109) comprises one silicon material layer (105) and the current collector layer (106).

Figure 2 shows a schematic representation of an electrode assembly stack (100) according to the invention, prior to or during ultrasonic welding, in contact with the horn (101) and

anvil (102) of an ultrasonic welding apparatus. The horn (101) is shown pressing down on top of the stack. The stack comprises in sequence the electrode tab (103), a current collector layer (106), one silicon material layer (105), and an optional welding material layer (108). The anvil (102) is shown holding in place the bottom of the stack. A composite electrode material (109) comprises one current collector layer (106) and one silicon material layer (105).

Figure 3 shows a schematic representation of an electrode assembly stack (100) according to the invention, prior to or during ultrasonic welding, in contact with the horn (101) and anvil (102) of an ultrasonic welding apparatus. The horn (101) is shown pressing down on top of the stack. The stack comprises in sequence the electrode tab (103), a current collector layer (106), one silicon material layer (105), a second current collector layer (106), a second silicon material layer (105), and an optional welding material layer (108). The anvil (102) is shown holding in place the bottom of the stack. A first composite electrode material (109) comprises one current collector layer (106) and one silicon material layer (105). A second composite electrode material (110) comprises one current collector layer (106) and one silicon material layer (105).

Figure 4 shows a schematic representation of an electrode assembly stack (100) according to the invention, prior to or during ultrasonic welding, in contact with the horn (101) and anvil (102) of an ultrasonic welding apparatus. The horn (101) is shown pressing down on top of the stack. The stack comprises in sequence the electrode tab (103), a current collector layer (106), one silicon material layer (105), an optional welding material layer (108), a second current collector layer (106), a second silicon material layer (105), and a second optional welding material layer (108). The anvil (102) is shown holding in place the bottom of the stack. A first composite electrode material (109) comprises one current collector layer (106) and one silicon material layer (105). A second composite electrode material (110) comprises one current collector layer (106) and one silicon material layer (105).

Figure 5 shows a schematic representation of an electrode assembly stack (100) not according to the invention, prior to or during ultrasonic welding, in contact with the horn (101) and anvil (102) of an ultrasonic welding apparatus. The horn (101) is shown pressing down on top of the stack. The stack comprises in sequence the electrode tab (103), a current collector layer (106), one silicon material layer (105), a second silicon material layer (105), a second current collector layer (106), and an optional welding material layer (108). The anvil (102) is shown holding in place the bottom of the stack. A first composite electrode material (109) comprises one current collector layer (106) and one silicon material layer (105). A second composite electrode material (110) comprises one current collector layer (106) and one silicon material layer (105). Because the separate composite electrodes are in contact with each other via their silicon layers no or an improper weld is formed and as such this assembly does not result in an assembly with a sufficient adhesive strength and electrical communication necessary for commercial operability

of the electrode assembly. A minor pulling force applied on either end of the assembly separates one or more of the layers from the other layers of the assembly.

Figure 6 shows a schematic representation of an electrode assembly stack (100) according to the invention, prior to or during ultrasonic welding, in contact with the horn (101) and anvil (102) of an ultrasonic welding apparatus. The horn (101) is shown pressing down on top of the stack. The stack comprises in sequence the electrode tab (103), a current collector layer (106), one silicon material layer (105), a mandatory welding material layer (104), a second current collector layer (106), a second silicon material layer (105), and an optional welding material layer (108). The anvil (102) is shown holding in place the bottom of the stack. A first composite electrode material (109) comprises one current collector layer (106) and one silicon material layer (105). A second composite electrode material (110) comprises one current collector layer (106) and one silicon material layer (105)..

The electrode assembly stacks presented in figures 1 to 4 and 6 can be welded according to the invention and result in electrode assemblies according to the invention wherein each component is in electrical communication with each other component and wherein all components are held together with a more than sufficient adhesive strength necessary for commercial operability of the electrode assembly.

Figure 7 shows a schematic representation of an electrode assembly (100) according to the invention attached to a circuit for four-point contact resistance measurement. The tab material (103) is welded to the electrode assembly (100) via a weld (200) comprising weld material generated by ultrasonic welding. A battery (201) providing a current is attached with a first terminal (202) to a proximal point on the electrode tab and with the second terminal (203) to a proximal point on the electrode assembly. A volt-ohm-milliammeter (204) is attached at a proximal point (205) on the electrode tab and on a distal point (206) on the electrode assembly. The volt-ohm-milliammeter (204) can be used to determine the resistance between the two contact points (205, 206) of the volt-ohm-milliammeter (204), thereby verifying the electrical communication of the circuit comprising the ultrasonically welded tab material, weld material, composite material, and optionally the welding material.

The following, non-limiting examples illustrate the process and materials according to the invention.

Example 1

A nickel tab with a thickness of 100 μm was ultrasonically welded onto the exposed copper surface side of a silicon-coated copper foil (10 μm thick foil coated on one side with a 10 μm thick

layer of porous silicon active material; i.e. composite electrode material according to the invention).

The nickel tab was placed on the copper foil of the silicon-coated copper foil, thereby forming an aligned electrode assembly stack. The stack was placed between the horn and anvil of a GN-800 ultrasonic welding apparatus (manufactured by GELON) similar to the orientation as presented in figure 1. The ultrasonic weld was subsequently made using the ultrasonic welding apparatus set at a power of 800 W, for 3 s, with a pressure of 414 kPa, across a sonotrode to nickel tab contact surface area of about 3 by 3 mm, thereby producing an effective electrode assembly according to the invention.

The contact resistance of the electrode assemblies as a result of the two different welding methods was compared using four-point probe measurements according to figure 7.

The four-point probe contact resistance measurement resulted in values of less than 10 m Ω .

CONCLUSIES

1. Werkwijze voor het produceren van een elektrodegeheel, de stappen omvattende met:

- 5 a. het voorzien van ten minste een eerste composiet-elektrodemateriaal, met ten minste één siliciumlaag op een stroomcollectormateriaal; en
- b. het voorzien van een elektrode-kussenmateriaal dat in contact staat met het stroomcollectormateriaal, teneinde een uitgelijnde elektrodegeheelstapel te vormen;
- 10 c. optioneel, het voorzien van een composiet elektrodemateriaal dat ten minste één siliciumlaag omvat op een stroomcollectormateriaal dat in contact staat met het stroomcollectormateriaal van een andere composietelektrode, teneinde een uitgelijnde elektrodegeheelstapel te vormen;
- 15 d. optioneel, het ten minste één maal herhalen van stap (c); en
- e. het aanbrengen van ultrasone energie op een deel van de uitgelijnde elektrodegeheelstapel, teneinde te vormen:
 - i. een gelast materiaal;
 - 20 ii. een doorgaande las door het elektrodekussen en optioneel door het composietmateriaal; en/of
 - iii. ten minste een verbindingslas tussen het gelaste materiaal en het composietmateriaal;
 waardoor het elektrodegeheel gevormd wordt.

25 2. Werkwijze volgens conclusie 1, waarbij ten minste een deel van het gelaste materiaal en van het kussenmateriaal een eerste lasinterfacemateriaal vormt, en waarbij ten minste een deel van het gelaste materiaal en van het composietmateriaal, bij voorkeur het stroomcollectormateriaal, een tweede lasinterfacemateriaal vormt.

30 3. Werkwijze volgens conclusie 1 of conclusie 2, voorafgaand aan de stap met het aanbrengen van ultrasone energie, de bijkomende stap omvattende met het voorzien van een lasmateriaal tussen twee composiet-elektrodematerialen, en optioneel het herhalen van de bijkomende stap.

4. Werkwijze volgens een der conclusies 1 tot en met 3, waarbij het composietmateriaal ten minste één laag silicium omvat op elke van twee zijden van het stroomcollectormateriaal.
5. Werkwijze volgens een der conclusies 1 tot en met 4, waarbij de materialen in hoofdzaak platte velvormige materialen zijn, en waarbij de materialen zijn uitgelijnd en gefixeerd, voorafgaand aan en tijdens het lasproces.
- 10 6. Werkwijze volgens een der conclusies 1 tot en met 5, waarbij het lasmateriaal aluminium, goud, koper, ijzer, lithium, mangaan, palladium, platina, thulium, titanium, wolfram, zilver, beryllium, magnesium, nikkel, silicium, en/of zirkonium omvat, en bij voorkeur koper.
- 15 7. Werkwijze volgens een der conclusies 1 tot en met 6, waarbij het kussenmateriaal nikkel of koper, dan wel een legering die nikkel, koper, tin, silicium, koper en nikkel, koper en tin, of koper en silicium omvat.
- 20 8. Werkwijze volgens een der conclusies 1 tot en met 7, waarbij de eerste en tweede lasinterfacematerialen het kussenmateriaal en het composietmateriaal of een legering daarvan omvatten.
- 25 9. Werkwijze volgens een der conclusies 1 tot en met 8, waarbij het stroomcollectormateriaal koper, tin, chroom, nikkel, titanium, roestvrij staal of zilver, of een legering die koper, tin, chroom, nikkel, titanium, roestvrij staal of zilver omvat, omvat.
- 30 10. Werkwijze volgens een der conclusies 1 tot en met 9, waarbij de siliciumlaag een amorfe structuur heeft waarin nanokristallijne gebieden aanwezig zijn, bij voorkeur waarbij de siliciumlaag tot 30% nanokristallijn silicium omvat.
11. Elektrodegeheel, omvattende:

- a. een elektrodekussen dat een gelaste materiaal omvat, waarbij ten minste een deel van het gelaste materiaal en van het kussenmateriaal een eerste lasinterfacemateriaal vormt;
 - b. een silicium elektrode-composietmateriaal, omvattende het gelaste materiaal en een actieve siliciummateriaallaag op een stroomcollectormateriaallaag, waarbij ten minste een deel van het gelaste materiaal en van het stroomcollectormateriaal een tweede lasinterfacemateriaal vormt; en
 - c. het gelaste materiaal dat in de buurt is gelegen van het elektrodekussen en van het stroomcollectormateriaal, op een zodanige wijze dat het kussenmateriaal, het composietmateriaal, en het gelaste materiaal elektrisch met elkaar verbonden zijn.
12. Geheel volgens conclusie 11, waarbij het gelaste materiaal een ultrasoon gelast materiaal is.
13. Geheel volgens conclusie 11 of 12, waarbij het kussenmateriaal nikkel of koper of een legering die nikkel, koper, tin, silicium, koper en tin, of koper en silicium omvat, omvat, en waarbij het stroomcollectormateriaal, het gelaste materiaal, het lasmateriaal, of het lasinterfacemateriaal aluminium, goud, koper, ijzer, lithium, mangaan, palladium, platina, thulium, titanium, wolfraam, zilver, beryllium, magnesium, nikkel, silicium, of zirkonium omvatten.
14. Geheel volgens een der conclusies 11 tot en met 13, waarbij de eerste en tweede lasinterfacematerialen het kussenmateriaal en het composietmateriaal of een legering daarvan omvatten.
15. Batterij, omvattende een elektrolyt, een kathode, een scheider, en een geheel dat te verkrijgen is aan de hand van een werkwijze volgens een der conclusies 1 tot en met 10, of een geheel volgens een der conclusies 11 tot en met 14.

1/4

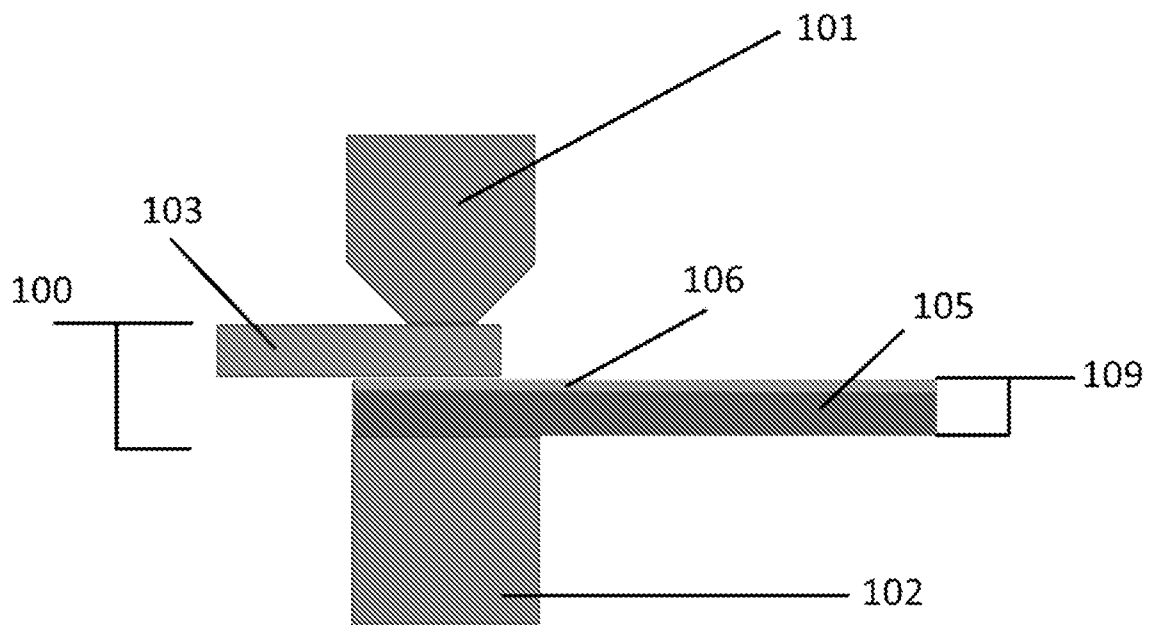


Figure 1

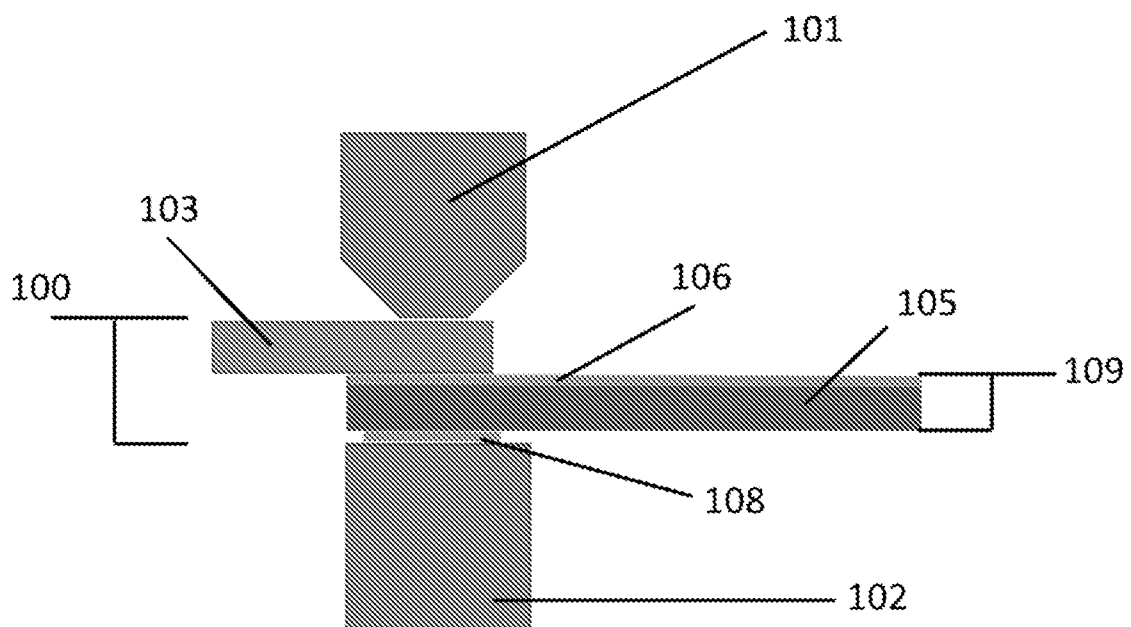


Figure 2

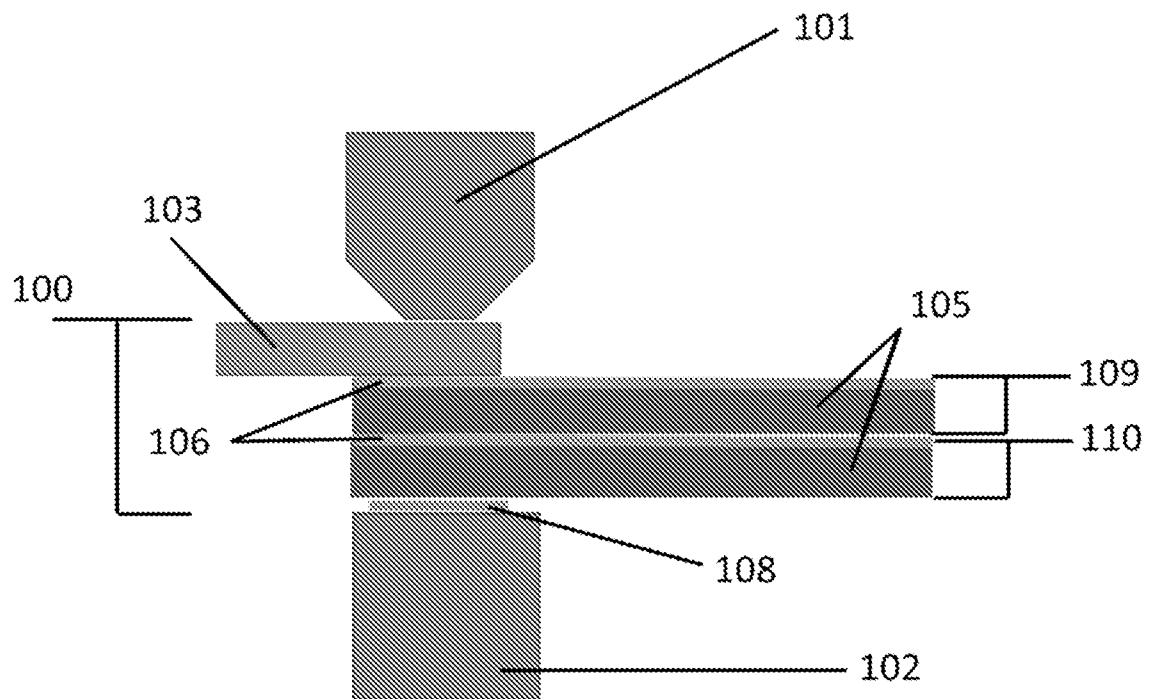


Figure 3

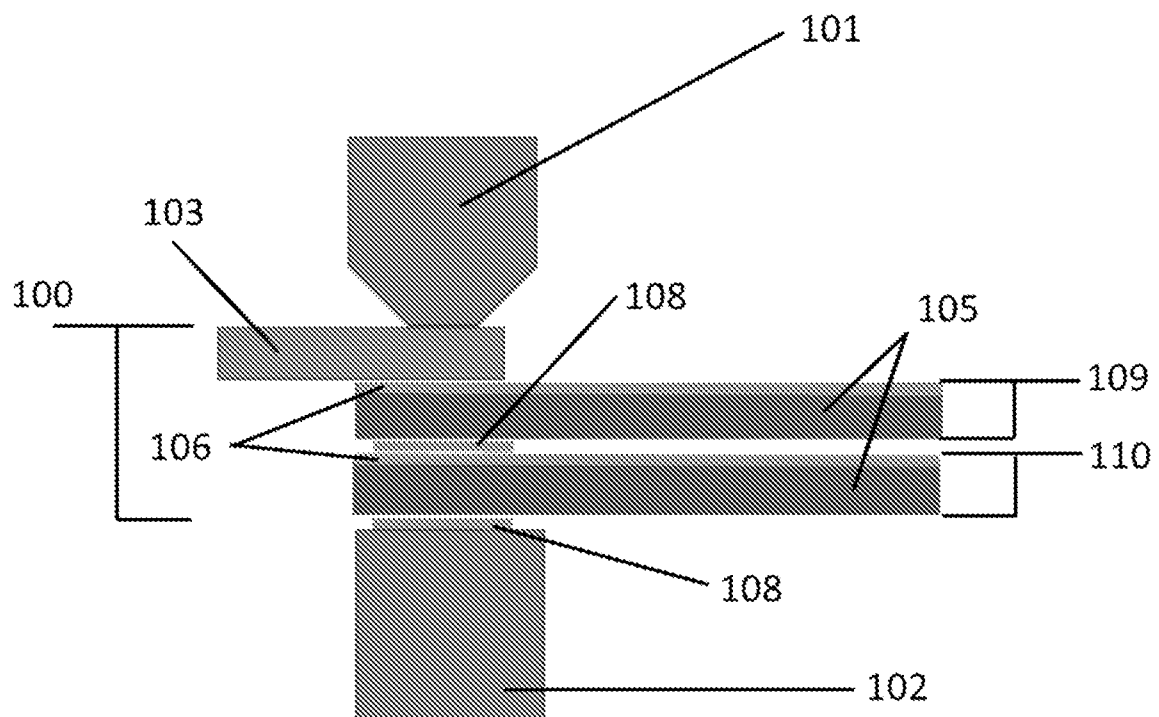


Figure 4

3/4

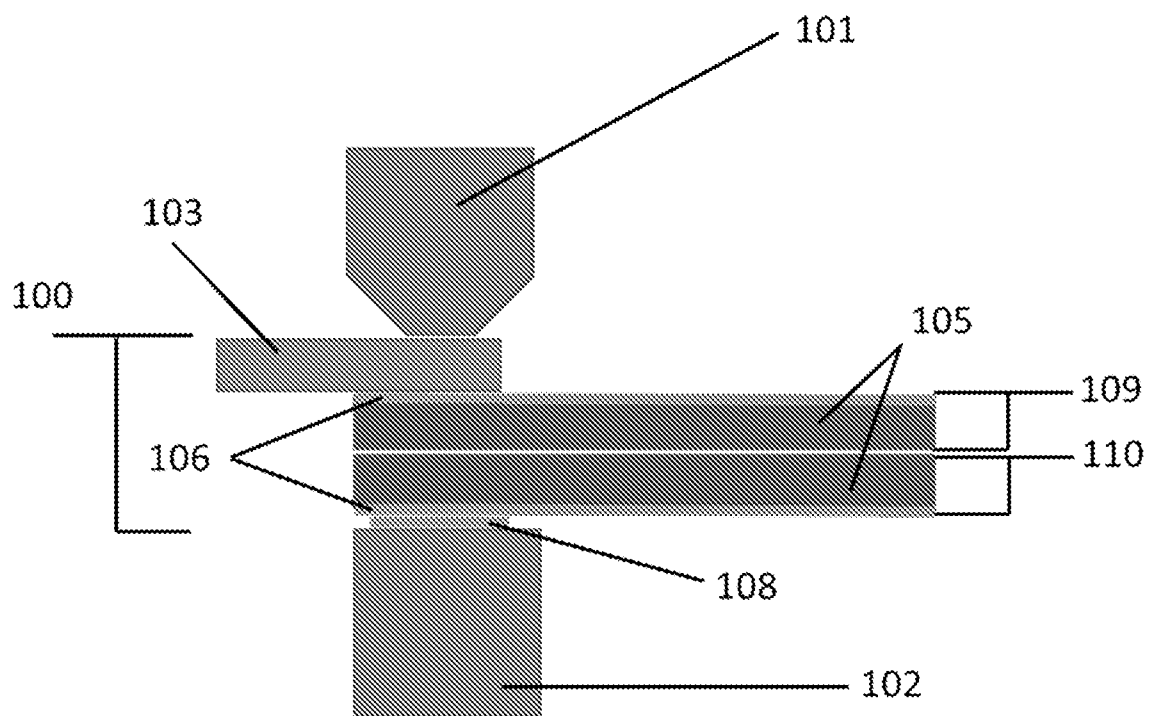


Figure 5

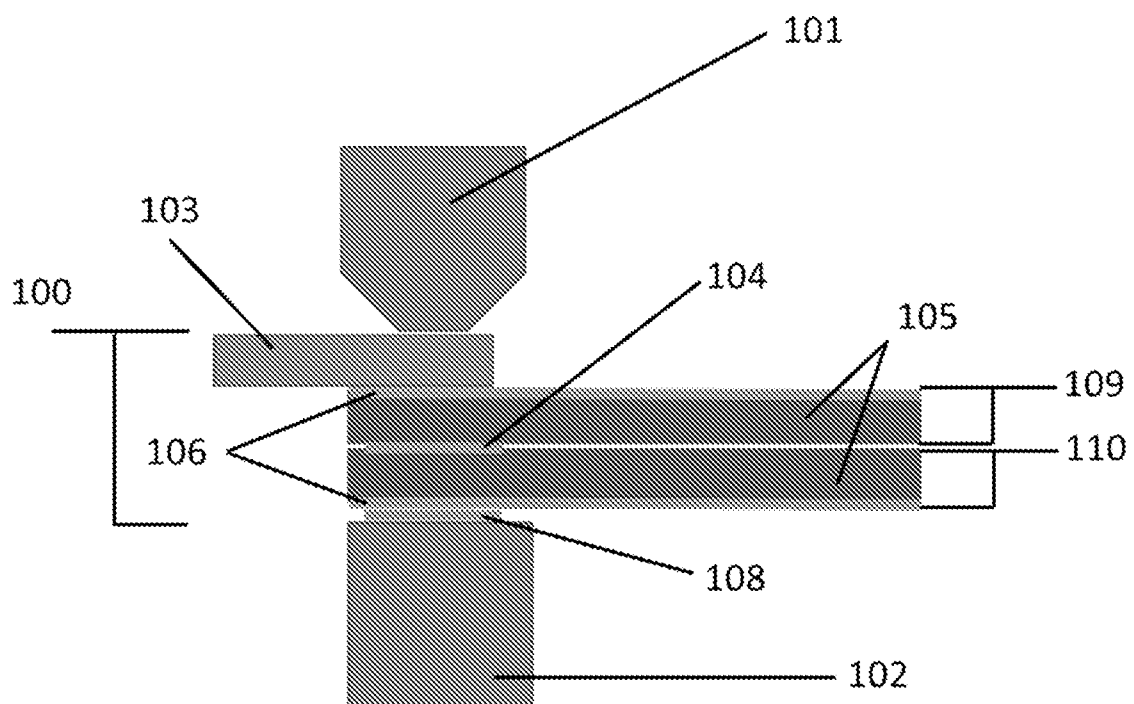


Figure 6

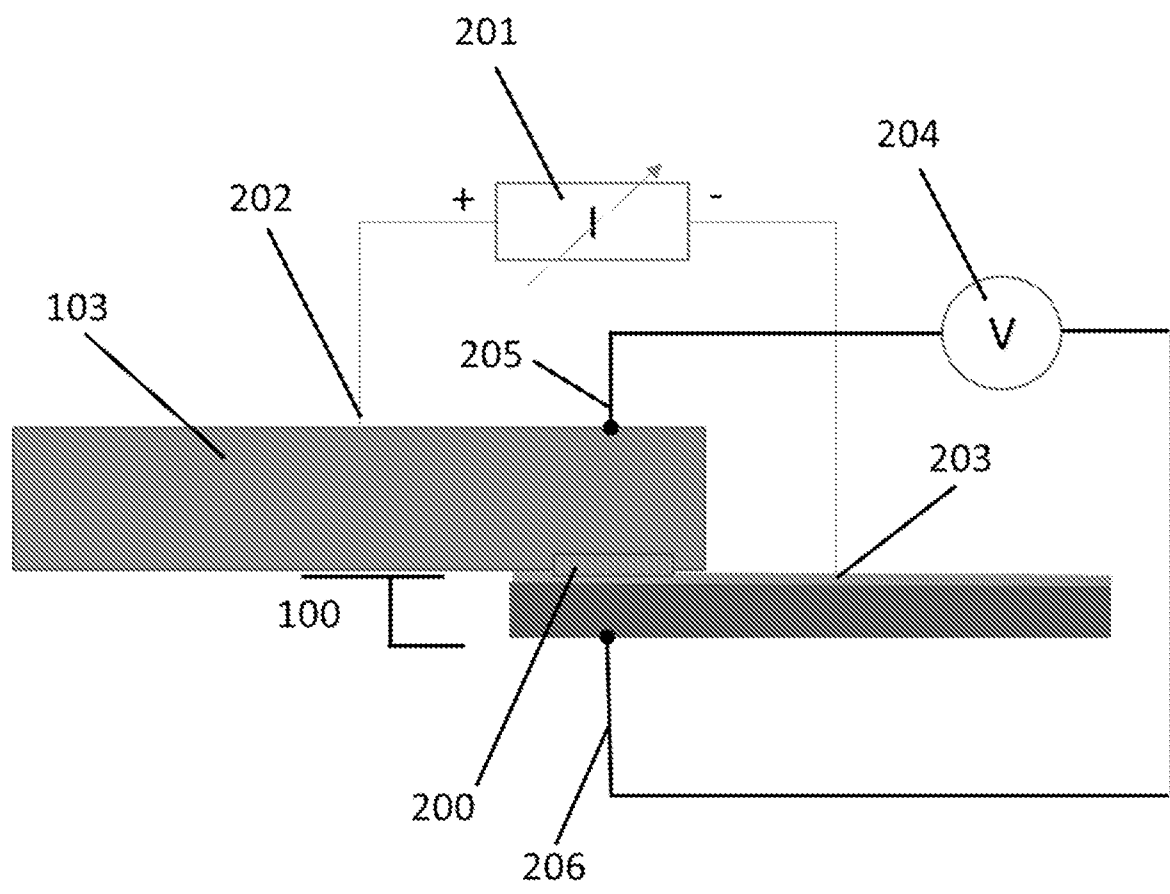


Figure 7



ONDERZOEKSRAPPORT

BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK

RELEVANTE LITERATUUR			
Categorie ¹	Literatuur met, voor zover nodig, aanduiding van speciaal van belang zijnde tekstgedeelten of figuren.	Van belang voor conclusie(s) nr:	Classificatie(IPC)
X	US 2020/373584 A1 (MORIN BRIAN G [US] ET AL) 26 november 2020 (2020-11-26)	1, 2, 4-7, 9-13, 15	INV.
A	* alinea [0002] * * alinea [0014] - alinea [0015] * * alinea [0046] - alinea [0050] * * alinea [0061] - alinea [0063] * * alinea [0074] * * conclusies 1-12 * * figuren 4, 5B, 9A-9C * -----	3, 8, 14	H01M4/134 H01M4/1395 H01M4/38 H01M4/66 H01M10/48 H01M50/536 H01M50/566 B23K26/211 H01M10/058
A	EP 3 738 704 A1 (LG CHEMICAL LTD [KR]) 18 november 2020 (2020-11-18) * alinea [0036] - alinea [0048] * * alinea [0070] * * figuren 1, 2, 6 * -----	1-15	ADD. H01M4/04 H01M4/02
A	EP 2 605 313 A1 (OXIS ENERGY LTD [GB]) 19 juni 2013 (2013-06-19) * conclusies 1-16 *	1-15	
A	US 9 300 007 B1 (DAI XIANGYANG [US] ET AL) 29 maart 2016 (2016-03-29) * conclusies 1-16 *	1-15	Onderzochte gebieden van de techniek
X, D	US 9 979 009 B2 (INTEL CORP [US]) 22 mei 2018 (2018-05-22)	11-13, 15	H01M H01G B23K
A	* kolom 1, regel 66 - kolom 2, regel 35; conclusies 1-16 * * kolom 3, regel 35 - regel 57 * * kolom 7, regel 1 - regel 17 * * conclusies 1-16 * * figuren 1, 3 * -----	1-10, 14	
Indien gewijzigde conclusies zijn ingediend, heeft dit rapport betrekking op de conclusies ingediend op:			
Plaats van onderzoek: München		Datum waarop het onderzoek werd voltooid: 9 januari 2022	Bevoegd ambtenaar: Kuhn, Tanja

¹ NDERLINCATEGORIE VAN DE VERMELDE LITERATUUR

X: de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur
Y: de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht
A: niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft
O: niet-schriftelijke stand van de techniek
P: tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

T: na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvraag, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding
E: eerdere octrooi(aanvraag), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven
D: in de octrooiaanvraag vermeld
L: om andere redenen vermelde literatuur
&: lid van dezelfde octrooifamilie of overeenkomstige octrooi-publicatie

**AANHANGSEL BEHORENDE BIJ HET RAPPORT BETREFFENDE
HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK,
UITGEVOERD IN DE OCTROOIAANVRAGE NR.**

**NO 141254
NL 2028136**

Het aanhangsel bevat een opgave van elders gepubliceerde octrooiaanvragen of octrooien (zogenaamde leden van dezelfde octrooifamilie), die overeenkomen met octrooischriften genoemd in het rapport.

De opgave is samengesteld aan de hand van gegevens uit het computerbestand van het Europees Octrooibureau per De juistheid en volledigheid van deze opgave wordt noch door het Europees Octrooibureau, noch door het Bureau voor de Industriële eigendom gegarandeerd;; de gegevens worden verstrekt voor informatiedoeleinden.

09-01-2022

In het rapport genoemd octrooigescrift		Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 2020373584	A1	26-11-2020	GEEN	
EP 3738704	A1	18-11-2020	CN 111867775 A	30-10-2020
			EP 3738704 A1	18-11-2020
			JP 2021515957 A	24-06-2021
			KR 20200095683 A	11-08-2020
			US 2021119305 A1	22-04-2021
			WO 2020159116 A1	06-08-2020
EP 2605313	A1	19-06-2013	CA 2852246 A1	20-06-2013
			CN 103999261 A	20-08-2014
			CN 110010834 A	12-07-2019
			EP 2605313 A1	19-06-2013
			EP 2791998 A1	22-10-2014
			ES 2613543 T3	24-05-2017
			JP 6285366 B2	28-02-2018
			JP 2015505131 A	16-02-2015
			KR 20140113646 A	24-09-2014
			PL 2791998 T3	30-06-2017
			RU 2014128829 A	10-02-2016
			US 2015056506 A1	26-02-2015
			WO 2013088115 A1	20-06-2013
US 9300007	B1	29-03-2016	GEEN	
US 9979009	B2	22-05-2018	US 2017179466 A1	22-06-2017
			WO 2017105613 A1	22-06-2017

SCHRIFTELIJKE OPINIE

DOSSIER NUMMER NO141254	INDIENINGSDATUM 04.05.2021	VOORRANGSDATUM	AANVRAAGNUMMER NL2028136
CLASSIFICATIE INV. H01M4/134 H01M4/1395 H01M4/38 H01M4/66 H01M10/48 H01M50/536 H01M50/566 B23K26/211 H01M10/058 ADD. H01M4/04 H01M4/02			
AANVRAGER LeydenJar Technologies B.V.			

Deze schriftelijke opinie bevat een toelichting op de volgende onderdelen:

- ☒ Onderdeel I Basis van de schriftelijke opinie
- ☐ Onderdeel II Voorrang
- ☐ Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk
- ☐ Onderdeel IV De aanvraag heeft betrekking op meer dan één uitvinding
- ☒ Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid
- ☐ Onderdeel VI Andere geciteerde documenten
- ☐ Onderdeel VII Overige gebreken
- ☒ Onderdeel VIII Overige opmerkingen

	DE BEVOEGDE AMBTENAAR Kuhn, Tanja
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Onderdeel I Basis van de Schriftelijke Opinie

1. Deze schriftelijke opinie is opgesteld op basis van de meest recente conclusies ingediend voor aanvang van het onderzoek.
2. Met betrekking tot **nucleotide en/of aminozuur sequenties** die genoemd worden in de aanvraag en relevant zijn voor de uitvinding zoals beschreven in de conclusies, is dit onderzoek gedaan op basis van:
 - a. type materiaal:
 - ☐ sequentie opsomming
 - ☐ tabel met betrekking tot de sequentie lijst
 - b. vorm van het materiaal:
 - ☐ op papier
 - ☐ in elektronische vorm
 - c. moment van indiening/aanlevering:
 - ☐ opgenomen in de aanvraag zoals ingediend
 - ☐ samen met de aanvraag elektronisch ingediend
 - ☐ later aangeleverd voor het onderzoek
3. ☐ In geval er meer dan één versie of kopie van een sequentie opsomming of tabel met betrekking op een sequentie is ingediend of aangeleverd, zijn de benodigde verklaringen ingediend dat de informatie in de latere of additionele kopieën identiek is aan de aanvraag zoals ingediend of niet meer informatie bevatten dan de aanvraag zoals oorspronkelijk werd ingediend.
4. Overige opmerkingen:

Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid

1. Verklaring

Nieuwheid	Ja: Conclusies 1-10, 14 Nee: Conclusies 11-13, 15
Inventiviteit	Ja: Conclusies 3, 8, 14 Nee: Conclusies 1, 2, 4-7, 9-13, 15
Industriële toepasbaarheid	Ja: Conclusies 1-15 Nee: Conclusies

2. Citaties en toelichting:

Zie aparte bladzijde

Onderdeel VIII Overige opmerkingen

De volgende opmerkingen met betrekking tot de duidelijkheid van de conclusies, beschrijving, en figuren, of met betrekking tot de vraag of de conclusies nawerkbaar zijn, worden gemaakt:

Zie aparte bladzijde

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following documents:

- D1 US 2020/373584 A1 (MORIN BRIAN G [US] ET AL) 26 november 2020 (2020-11-26)
- D2 EP 3 738 704 A1 (LG CHEMICAL LTD [KR]) 18 november 2020 (2020-11-18)
- D3 US 2010/190055 A1 (KHAKHALEV ALEXANDER D [US]) 29 juli 2010 (2010-07-29)
- D4 US 9 300 007 B1 (DAI XIANGYANG [US] ET AL) 29 maart 2016 (2016-03-29)
- D5 US 9 979 009 B2 (INTEL CORP [US]) 22 mei 2018 (2018-05-22)

2 **Prior art and lack of novelty**

D1 (US2020373584) discloses an energy storage device with anode, a cathode and at least one separator present between them, an electrolyte, at least one metallized thin film current collector in contact with at least one of said anode and said cathode, **and at least one tab attached to said at least one metallized thin film current collector**, wherein said at least one metallized thin film current collector has a polymer substrate layer with a first metallized (eg. aluminium and/or copper) layer is placed on said polymer substrate top layer, see also Fig. 4 and 5B, [0074], and a second metallized layer to said polymer substrate bottom layer, and **wherein said current collector exhibits weld divot therein such that at least a portion of said first and second metallized layer are in contact with one another and at least one electrical connection tab attached through said weld divot to the current collector by ultrasonic welding claims 1, 2, [0002], [0046] - [0050]. The at least one tab is contacted with a base thin film collector through between 2 and 50 welds**, which may be uniformly spaced and sized, leading along the length of said current collector, wherein said at least one tab is laid upon said thin film such that said at least one tab has an exposed top surface or a bottom surface in contact with a covered surface of said thin film current collector, wherein said welds exhibit placement of conductive material passing through said tab from its exposed top surface to said covered surface

of said thin film current collector, [00015]. D1 also discloses silicon as anode active material coated on at least one metallised current collector [0061] - [0063]. Thereby lithium batteries with high safety and power are provided, [0014].

D1 does not disclose the additional technical feature of claim 1, "het voorzien van ten minste een eerste composiet-elektrodemateriaal dat ten minste één **siliciumlaag op een stroomcollectormateriaal** omvat".

Therefore claims 1 to 10 are novel over D1.

D1 discloses the subject matter of independent claim 11, an "Elektrodegeheel, omvattende: a. een elektrodekussen (**tab**) dat een gelast materiaal omvat, waarbij ten minste een deel van het gelaste materiaal en van het kussenmateriaal een eerste lasinterfacemateriaal vormt; b. een silicium elektrode-composietmateriaal (in D1 the silicium is present as active material in the anode electrode composition (choice from one list)), omvattende het gelaste materiaal (in D1: after the welding) en een actieve siliciummateriaallaag op een stroomcollectormateriaallaag, waarbij ten minste een deel van het gelaste materiaal en van het stroomcollectormateriaal een tweede lasinterfacemateriaal vormt; en c. het gelaste materiaal dat in de buurt is gelegen van het elektrodekussen (in D1: the electrode tab) en van het stroomcollectormateriaal, op een zodanige wijze dat het kussenmateriaal (tab material), het composietmateriaal, en het gelaste materiaal elektrisch met elkaar verbonden zijn (in D1 the composite material is electrically connected with the tab material and welded material interface via the current collector). Thus claim 11 is not novel.

D1 also discloses the additional technical features of claims 12, 13 and 15, which are therefore not novel.

D2 (EP3738704) discloses an electrode assembly with electrode plates 11, positive electrode tabs 12, negative electrode tabs 13, a bundle of positive and negative electrode tabs 14, 15, positive electrode lead 15 and a negative electrode lead 17, see [0036], [0070] and Fig. 1. Electrode tabs are joined by ultrasonic welding, see [0037] - [0044] and Fig 2. In a concrete example, one of the opposite sides of a bundle of electrode tabs formed by welding electrode tabs is coupled to an electrode lead, [0045]-[0048]. FIG. 6 is a perspective view of a horn and an anvil of an ultrasonic welding apparatus according to D2.

D3 (EP2605313) discloses a method of connecting at least one electrode comprising a sheet or foil having a contact area to a contact lead comprising a conductive lead having an end portion, wherein: i) there is an overlap between the end portion and the contact area. Placing the contact area of the contact lead and the at least one electrode, and ii)

connecting the contact area to the contact lead in order to couple the at least one electrode to the contact lead by ultrasonic welding, wherein at least the contact area of the sheet or foil is formed of an alkali metal or an alloy of alkali metals, see claim 1. It also discloses the ultrasonic welding to interconnect several tabs and that the end portion of the contact lead is an integral part of the contact lead, **or the end portion of the contact lead is a separate metallic component coupled to the contact lead**, see claim 15 and 16 and [0026] and [0042]. It also discloses details of ultrasonic welding, [0020] to [0025].

D4(US9300007) discloses an electrode assembly comprising an anode composed of an active anode material, a cathode composed of an active cathode material and a method of joining the surfaces of the current collectors to their associated electrode materials by ultrasonic welding, see claim 1, Fig. 7A and 7B and the passages in the description relating to these Figures. The current collector of the electrode is composed of titanium, stainless steel, copper or nickel, see summary of the invention paragraphs 1 and 2 and claim 13. In D4 an active electrode material such as lithium is directly joined to a current collector composed of titanium, stainless steel, copper or nickel. In D4, the active cathode material 40 may be a sheet or foil and comprise a metal element, a metal oxide, a mixed metal oxide and a metal sulfide, and combinations thereof. The active cathode material 40 is ultrasonically welded to the surface of the cathode current collector 42.

*D2 to D4 do at least not disclose the additional technical feature of independent claim 1, "a het voorzien van ten minste een eerste composiet-elektrodemateriaal dat ten minste één **siliciumlaag op een stroomcollectormateriaal** omvat" and they do at least also not disclose the additional technical feature of independent claim 11 "b. een **silicium elektrode-composietmateriaal**, omvattende het gelaste materiaal en een actieve **siliciummateriaallaag op een stroomcollectormateriaallaag**".*

Therefore claims 1 to 15 are novel over D2 to D4 . It is noted that claim 15 is a product (battery) produced by a method according to claims 1 to 10 or a battery with an electrode assembly according to claims 11 to 14 and is therefore also novel over D2 to D4.

D5 (US9979009) cited in the application discloses a battery as energy storage device comprising, an electrode tab; **a silicon electrode comprising a metal layer that is thinner than the electrode tab**; and **a laser weld coupling the electrode tab to the silicon electrode**, wherein a joint of the laser weld comprises a melted material of the electrode tab and in electrical contact with a melted material of the metal layer. D5 further discloses, see Fig. 3 and the respective passages relating to Fig. 3, a laser-welded configuration 300 of an energy storage device (e.g., 100 of FIG. 1) such as a

lithium-ion battery. A laser weld 302 is formed by *laser* welding an electrode tab 304 to a top layer 310 of the electrode 308. **In some examples, tabs 304 may be attached to lithium ion (Li-ion) battery silicon anodes and silicon cathodes using laser welding.** For an anode electrode 310, the tab 304 may be **copper, titanium or nickel, for instance.** For a cathode electrode 310, **the tab 304 may be aluminum (Al),** nickel or NiP. D5 does not disclose *ultrasonic* welding and claims 1 to 10 are thus novel.

However D5 discloses the product of claims 11 and 15, which are therefore not new. Claim 12 is a product-by-process claim. However the product of D5 is not different from the product of claim 12. If the applicant disagrees with this finding he is kindly requested to give proof e.g. by suitable experimental data that indeed the product of claim 12 differs from the product of D5.

3 **Lack of inventive step**

- D1 can be seen as closest prior art to the subject matter of claims 1, 2, 4 to 7, 9 and 10 as it shares most of its technical features and aims at solving the same problem.

Claim 1 differs from the subject matter disclosed in D1 in that the at least a first composite electrode material comprises at least one silicon layer on a current collector material. However silicon layers as active material on a current collector are general knowledge in the art, see just as an example US99779009. To replace the silicon containing layer by a silicon layer as alternative active material is just an obvious design feature for the person skilled in the art of battery electrodes without an inventive skill. Independent claim 1 thus lacks an inventive step.

D1 also discloses the additional technical feature of claim 2, that at least part of the welded material and of the tab material forms a first weld interface material, and at least part of the welded material and of the composite material, in D1 the current collector material of the electrode composite material of D1, which comprises the active material layer material and the current collector material, forms a second weld interface material. Thus claim 2 is also not inventive.

As to claim 4, the reasoning with respect to claim 1 applies accordingly. To provide active material on both sides of the current collector is also general knowledge in the art and can therefore not establish an inventive step.

Also the the additional technical features of claim 5 are disclosed in D1 and also general knowledge in the art of battery tab ultrasonic welding.

D1 discloses the additional technical feature of claims 6 and 9, that the welding material contains copper or aluminium, in D1 in the form the metal layers of the current collector.

The additional technical feature of claim 7, that tab material material can be e. g. copper is general knowledge in the art and can not establish an inventive step.

As to claim 10: It is not apparent, what could be the surprising technical effect of the "de amorfe structuur met **nanokristallijne gebieden of the silicium layer** met of the active material layer". Therefore an inventive step can not be acknowledged with respect to claim 10. It appears in view of the entire application in claim 10 and in view of the prior art at hand, that essential method steps are missing in claim 10, see the technical features of claim 3, which are not anticipated by the prior art. To choose the silicon layer material as defined in claim 10 appears to be just a design modification for the person skilled in the art of battery electrode materials and an inventive step can not be acknowledged. If the applicant disagrees with this finding, he is kindly requested to substantiate an inventive step with the problem solution approach in case he chooses to enter the examination phase.

The additional technical features of claim 13, that the tab material is e.g. nickel or copper and the power collector material, the welded material, the welding material, or the welding interface material includes e.g. copper is general knowledge in the art of welding battery tabs and batteries and claim 13 can not establish an inventive step.

- Also starting from D5 as closest prior art the subject matter of claim 13 lacks an inventive step, the reasoning with respect to document D1 applies accordingly

4 Inventive step - claims 3, 8 and 14

None of the available prior art documents discloses or hints at the additional technical features of claims 3 and 14 they are also no general knowledge in the art of batteries. However it is noted that the clarity objections, se RE Item VIII, have to be overcome.

Re Item VIII

Certain observations on the application

Lack of clarity

- Claim 1 refers to an "elektrode-kussenmaterial", claims 2, 7, 8, 11, 13 and 14 to a "kussenmaterial" : These terms are contradictory and vague and therefore render these claims unclear for the following reasons: It is clear from the entire description, the Figures of the application and the method example in the application, that the electrode

layer is welded to the **electrode tab**. Therefore terms an "elektrode-kussenmaterial" and "kussenmaterial" in the claims should be each be replaced by the term "een elektrode tab materiaal" to overcome this objection.

- **The term "b. het voorzien van een elektrode-kussenmateriaal dat in contact staat met het stroomcollectormateriaal, teneinde een uitgelijnde elektrodegeheelstapel te vormen"**, used in claim 1 is not clear, as the claim does just defines the result that should be achieved, but does not contain the technical features of how the electrode tab material ("elektrode-kussenmateriaal") and the current collector material are joined and where the electrode tab, the current collector are positioned in the electrode assemblies (have to more than one electrode assembly) with respect to each other to form the electrode assembly stack (desiderata claim). Claim 1 also defines a method for producing an electrode assembly, but refers to another entity, an electrode assembly **stack**, which does not form part of the scope of claim 1, which leads to a lack of clarity of the claim. The electrode assembly stack should thus be part of the scope of claim 1 and be clearly defined.

The same clarity objection is raised against the term "c. ten minste één siliciumlaag omvat op een stroomcollectormateriaal **dat in contact staat met het stroomcollectormateriaal van een andere (how are the silicium layers in contact with each other)**, teneinde een uitgelijnde elektrodegeheelstapel te vormen" used in claim 1

- The term "de bijkomende stap omvattende met het voorzien van een lasmateriaal tussen twee **composiet**-elektrodematerialen", used in claim 3 is also not clear as the claim does not contain the technical feature of where the welding material is situated in between two composite electrode materials.

- In the paragraph "field of the invention" in the application it is set out, that the invention relates to a negative electrode assembly for a battery and its manufacture, in particular to an improved joining between an electrode tab and an electrode comprising a silicon active material and a current collector using ultrasonic welding techniques. Further, the only example according to the invention comprises the method steps of **adding** a copper foil **welding material** with a thickness of 10 µm **between the nickel tab and the silicon** and using ultrasonic welding.

However independent claim 1 is only optionally claiming the silicium material layer and therefore is lacking an essential technical feature of the invention and independent claim 1 does not clearly define the presence of a tab material and a welding material. Thus independent claims 1 does not contain all the technical features essential for and defining the present invention and does thus not comply with Art. 84.

- As the example is very vague **the applicant is herewith kindly requested to send all the details of the example, thus information on where is the silicon of the example is positioned and all the other production details as well as including test results with respect to the technical effect of the invention with respect to the comparative examples of ultrasonically welding nickel tab material directly onto silicon** in case he chooses to enter the examination phase.
- Figure 5, relating to the comparative example is falling under the scope of the claim. It appears from the examples of the invention shown in the F

Further objections

- Claim 12 to 14 refer back to claim 11, which defines an "Electrodengeheel". Thus, for consistency and clarity the term "Geheel" in claims 12 to 14 should be replaced by the term "Electrodengeheel".
- "Example 1" refers both to a method according to the invention and a method not according to the present invention. Suitable amendment is thus necessary, so that it is unambiguously clear, that two examples are disclosed and which of the two method examples forms part of the present invention and which not.
- The features of the claims are not provided **should be provided with reference signs placed in parentheses**.