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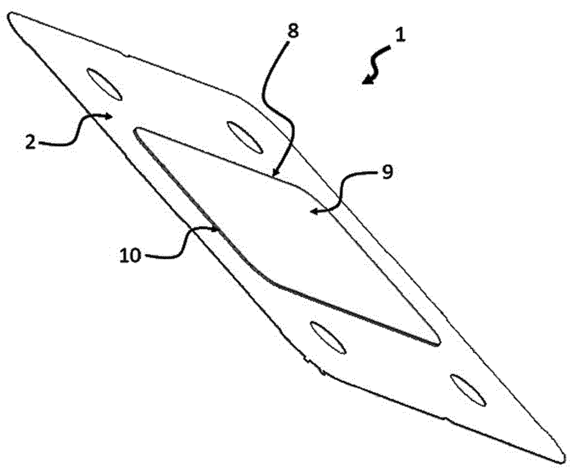
(54) **ELECTROLYTIC CELL COMPONENT**

(57) The present invention relates to an electrolysis cell component (1) comprising at least an electrically conductive sheet (2), intended to be placed between an anodic compartment (3) and a cathodic compartment (4) of two adjacent electrolysis cells, the anodic compartment (3) and the cathodic compartment (4) each comprising an active area (12) for electrolysis, the electrically conductive sheet (2) separating the anodic compartment (3) and the cathodic compartment (4) pressed against each other, characterized in that the electrolysis cell component (1) comprises at least one flowfield (5, 8) disposed each on a side of the electrically conductive sheet (2), the at least one flowfield (5, 8) comprising a cell spacer (7, 10), and in that the electrically conductive sheet (2) and the at least one flowfield (5, 8) are made of a continuity of material.

The invention also claims an electrolysis module comprising a plurality of anodic and cathodic compartments (3, 4), a plurality of such electrolysis cell components (1) between the compartments being stacked against each other.

FIGURE 2



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Description

Technical field

[0001] The present invention pertains to water electrolysis and more particularly to an electrolysis cell component that is used in water electrolysis cells.

Technological background

[0002] The electrolysis of water is an endergonic operation that consists of dissociating water molecules (either in the liquid or vapor state) into gaseous dioxygen and dihydrogen molecules by the action of electricity. The water electrolysis reaction takes place in an electrolysis reactor consisting of a set of water electrolysis cells electrically stacked in series against each other, with fluid (electrolyte) distribution in parallel. The stack of cells thus obtained forms the electrochemical electrolysis reactor which, by misnomer, is also called a stack. The hydrogen (H_2) and oxygen (O_2) production capacity of a given stack is proportional to the total electrochemical surface area of the reactor or stack (which is the product of the electrochemical surface area of an individual cell by the number of cells in the stack), and to the current density of operation. This production capacity or H_2/O_2 flow rate is generally expressed in unit of mass of hydrogen or oxygen per unit of time (e.g. kg/hour) or in unit of volume of hydrogen or oxygen per unit of time (e.g. Nm^3/hour, where the term Nm^3 designates 'normal cubic meters of gas', i.e. a volume of gas measured under normal conditions of temperature and pressure).

[0003] Usually, most water electrolysis cells are planar in shape, with either circular or rectangular geometry. This means that their surface, where electrochemical reactions take place, is much larger than their thickness. Looking at the cross-section of a conventional unit electrolysis cell, such unit cell is delimited by two parallel metal plates called bipolar plates. They are electrically conductive but impermeable to reaction fluids. Due to the series stacking of the cells, each bipolar plate belongs half to two adjacent cells of the stack. The distance between the middle of each of these two plates defines the thickness of the individual unit cell. This thickness is generally of the order of a few millimeters up to a few centimeters. The two bipolar plates of a unit electrolysis cell are kept parallel to each other, at a constant distance from each other, by inserting an electrically insulating component between them. It is generally a thermoplastic frame, that is to say a plate hollowed out in its centre and whose rigid peripheral edge maintains the distance between the bipolar plates. The frame is used as an insulating spacer to avoid electrical short - circuits by direct contact of bipolar plates. It is also used for the management of fluids : diametrically opposed holes machined into the peripheral edge allow fluid supply (reactant) and collection (reaction products). Elastomeric seals placed either at the periphery of the bipolar plates, or on the peripheral edges of the frames, serve to seal the cells. The cavity at the centre of the frame is the place where electrochemical reactions take place. This cell cavity is separated into two cell sub-cavities called anode compartment and cathode compartment, using a thin cell separator placed at the middle of the cell. This is usually a sub-millimeter thick cell component made of an ion-conducting material which is used to conduct electricity across the cell while at the same time acting as a separator of gases (H_2/O_2) formed in each cell compartment. In the void space or cavities formed in each cell, are placed a plurality of cell components, mechanically pressed against each other or stacked, usually between three and eight components per cell. Close to the central cell separator are placed two electrodes, an anode and a cathode. These electrodes are either pressed against or directly deposited onto the thin layer of ion-conducting cell separator. An internal seal called an inter-compartment seal is placed on an internal edge of the frame provided for this purpose. The periphery of the cell separator is pressed against this inter-compartment seal and ensures sealing between the two cell compartments. The two cell compartments (anodic and cathodic) are filled by a plurality of functional layers, whose role is double : (i) to let current flow transversally (along the cell thickness) from one bipolar plate to the next one, but also to allow (ii) the circulation of liquid water and (iii) the collection of gases formed during electrolysis. They are placed between the metallic bipolar plates and the electrodes or between the metallic bipolar plates and the cell separator.

[0004] The present invention relates to water electrolysis cells in which the ion-conducting separator or membrane placed between the electrodes (anode and cathode) is an ion-conducting polymer called an ionomer. This is either a proton-conducting ionomer, also known as cationic membrane, or a hydroxyl ions conducting ionomer, also known as anionic membrane, which conduct electricity by the displacement of ions (migration in response to the electrical field imposed by the external DC power source connected to the reactor). Proton conductors are used in Proton Exchange Membrane (PEM) water electrolysis cells. Hydroxyl ions conductors are used in Anion Exchange Membrane (AEM) water electrolysis cells. The electrodes can be deposited directly onto the surface of polymer membrane. In such cases, electrodes are called (electro) catalyst layers. Polymer membranes are coated on each side with an anodic and a cathodic catalyst layer. The component made of the polymer membrane and the two catalyst layers is called a catalystcoated membrane, which can be shortened to CCM.

[0005] In general, the total number of cell components stacked in each water electrolysis cell can vary between four and ten. The membrane and its catalyst layers (CCM) placed in the middle of the cell is an ion-conducting material. Other cell components are electronic conductors. During electrolysis, electrons are transferred from the bipolar plates to the catalyst layers (electrodes) where half-cell reactions leading to the formation of oxygen (anode) and hydrogen (cathode) take place. Ions (protons in PEM cells and hydroxyl ions in AEM cells) convey electricity across the polymer membrane. Besides electronic transport, cell components also have other functions. Some are designed to allow the circulation of water pumped through the cells in order to feed the water electrolysis reaction and to ensure the cooling of the electrolysis cell during operation. This is because the circulation of electrical current across the cells produces heat by dissipation and this heat need to be extracted from the cells. Some are designed to facilitate the transport of water to the anodic catalyst layers and to facilitate the transport of produced gases (H_2 and O_2) away from the catalyst layers.

[0006] Therefore, several adjacent functional layers are placed in each cell compartment, between the bipolar plate and the CCM. In the simplest case, the same functional layers are placed in both the anodic and cathodic cell compartments. The first functional layer is the bipolar plate itself which is there to separate the cells from each and avoid the mixing of reaction products. The role of the second functional layer which is called a "cell spacer" which is pressed against the bipolar plate is to allow the in-plane circulation of the liquid electrolyte across each cell compartments using an external pump, and the transversal (along the cell thickness) circulation of electricity. This second functional layer can be of different types. For example, this can be expanded metallic meshes through which the electrolyte is pumped. The mesh pattern used sets the hydraulic resistance of the layer and after optimization, ensures a homogeneous distribution of the fluid over the entire surface of the cell and transport electricity. Alternatively, fluid circulation channels can be integrated directly onto the bipolar plates. This is achieved by stamping or hydroforming flat bipolar plates. The reactive fluid (monophasic electrolyte) entering the cells can be an ultra-pure fluid, e.g. strongly deionized water (as a non-limitative example, one can mention milliQ® water, which is a strongly deionized water obtained using a Millipore Corporation MilliQ lab water system), or an alkaline electrolyte (diluted or concentrated) made of an aqueous solution of potassium hydroxide. During electrolysis, gases (H_2 and O_2) form in each cell compartment. The gas bubbles (which can coalesce with each other to form gas pockets of variable size depending on the current and the operating pressure of the cell) are driven out by the flow of electrolyte which circulates in each compartment. Thus, biphasic liquid-gas mixtures form inside the cells. In the anodic compartment, this is a mixture of deionized water and gaseous oxygen (in the case of PEM water electrolysis) or a mixture of aqueous potassium hydroxide and gaseous oxygen (in the case of AEM water electrolysis). In the cathodic compartment, this is a mixture of deionized water and gaseous hydrogen or a mixture of aqueous potassium hydroxide and gaseous hydrogen. Such biphasic mixtures are conveyed to at the exhaust of the cells/stacks to external liquid-gas separators by the electrolyte in motion. The role of the third functional layer is to allow the transport of liquid and gases between the second function layer (the cell spacer) and the electrodes (or CCM). Such layer which is called a "porous transport layer" or PTL can be of different types. For example, this can be a millimeter-thick sheet sintered metallic particles or fibers.

[0007] This type of cell structure which prevails in the state of the art has several disadvantages. First, the different cell components, especially the metallic ones, are prone to ageing and this leads to a reduction of the energy efficiency of the electrolysis reactor or stack over time. Different degradation mechanisms are taking place. In particular, the various interfaces existing between internal metallic components can undergo surface oxidation in the presence of strongly deionized water and oxygen, and/or in the presence of weakly concentrated alkaline electrolytes. This oxidation, which occurs essentially but not exclusively in the anodic compartment, leads to the development of an electrically insulating layer of metal oxide (e.g. titanium dioxide for example when titanium is used as material of cell component). Such layer increases the contact resistance therefore the ohmic resistance of the cell, which inhibits the circulation of the electric current (electrons), increase heat production per dissipative effects thus limiting the efficiency of the electrolysis cell. Mitigation measures such as surface coating of the functional layers are known in the state-of-art but their implementation is expensive and only contributes to reducing the rate of cell aging. Another technical problem resulting from the mechanical stacking of individual cell components is the irregular interlocking of the functional metal layers when clamping the reactor, especially when large surface area cells (> several hundreds or several thousands of cm^2) are used. This leads to cell thickness heterogeneities which lead to the formation of less resistive zones where the current tends to pass preferentially, which induces heterogeneous functioning of the cells and their accelerated aging. Another technical problem resulting from the mechanical stacking of individual cell components is the need to use high tightening torques to ensure good mechanical contact between metal layers. However, the polymer membrane placed in the center of the cell is a mechanically fragile component. Using high clamping force may damage it and reduce cell life. Another technical problem resulting from the mechanical stacking of individual cell components is that thin (sub-millimeter thick) PTLs, which are required when the cells are operated at elevated current densities (i.e. at elevated gas production rates) cannot be used because they are mechanically too weak and cannot sustain the high clamping pressures without detrimental negative effects such as local thickness changes or even rupture. Another technical problem resulting from the mechanical stacking of individual cell components is that the multiplication of the number of components of an electrolysis cell is a major source of misalignment defects, because cell stacking requires a greater number of manipulations, a good control of component alignment, tight dimensional tolerances and a sufficient and homogeneous mechanical contact of the different cell components in order to minimize the cell impedance and guarantee the optimal operation of the stack.

[0008] The present invention takes this particular context into account and proposes a new concept of single and multifunction composite cell component designed in such a way that the technical limitation of the state of the art can be overcome. This water electrolysis component contains three main functional layers :

- a central electrically conductive sheet called a bipolar plate which is used to separate two adjacent water electrolysis cells, which is permeable to electricity and impermeable to fluids (water, oxygen and hydrogen), and at least one of
- an anodic flowfield placed on one side of the bipolar plate which is designed to allow forced water circulation for cell cooling purpose and for oxygen collection and transport out of the cell.
- a cathodic flowfield placed on the other side of the bipolar plate which is designed to allow forced water circulation for cell cooling purpose and for hydrogen collection and transport out of the cell.

[0009] To this end, the invention concerns an electrolysis cell component comprising an electrically conductive sheet or bipolar plate, equipped with flowfields intended to be placed between the anodic compartment and cathodic compartment of two adjacent electrolysis cells. According to the invention, the electrolysis cell component comprises at least one flowfield disposed on one side of the electrically conductive sheet or bipolar plate, the at least one flowfield comprising several functional sub-layers, the said entire cell component being made of a continuity of material. The flowfield is either an anodic flowfield or a cathodic flowfield. The anodic flowfield placed on one side of the electrically conductive sheet or bipolar plate, can be made of several functional sub-layers. The three main functional sub-layers used in flowfields are :

- the first functional sub-layer of a flowfield is placed adjacent to the bipolar plate. In the description of the invention, this sub-layer is the so-called "cell spacer". This is a millimeter thick layer of large porosity along which (from cell inlet to cell exhaust) liquid water (PEM) or aqueous solutions of potassium hydroxide (AEM) can be pumped for cooling the anode compartment during electrolysis. For example, this can be a grid with open mesh pattern. It can also be a set of interconnected pads. Its porosity is adjusted by selecting the appropriate mesh or pad pattern in order to optimize its hydraulic resistance to distribute water homogeneously over the entire active area while minimizing the energy required for forced water circulation. In PEM water electrolysis, this is usually but not exclusively a titanium grid. In AEM water electrolysis, this is usually but not exclusively a stainless steel or a nickel grid.
- the second functional sub-layer is placed adjacent to the first functional sub-layer (cell spacer), on the side opposite the bipolar plate. This is usually a millimeter-thick metallic porous transport layer (called a PTL) of lower porosity than the first functional sub-layer. It is used to distribute homogeneously electricity over the anode and, at the same time, transport the electrolyte from the cell spacer to the anode to feed the electrolysis reaction and transport oxygen away from the anode back to the cell spacer for evacuation outside the cell. In PEM water electrolysis, this is usually but not exclusively a felt made of sintered titanium particles or titanium fibers. In AEM water electrolysis, this is usually but not exclusively a felt made of stainless steel or a nickel felt.
- a third functional sub-layer can be added to the top of the PTL. This third sublayer is a micrometer and low porosity layer called a microporous layer (MPL) which is used essentially to increase the density of contact points with the anode or (electro) catalyst layer on the anode side of the CCM in order to better distribute electricity over the anode but still sufficiently porous to let water and oxygen circulation through its pores. In PEM water electrolysis, this is usually but not exclusively a thin (sub-millimeter thick) and compact felt made of sintered titanium particles or titanium fibers. In AEM water electrolysis, this is usually but not exclusively a made of stainless steel or a nickel felt.

[0010] In such electrolysis cell component, there is a total continuity of material, which allows low electrical resistance between the different functional sub-layers and no interface subject to aging. The term 'continuity of material' means that the interface between two adjacent functional layers is no longer formed by mechanical compression of these layers against each other. The individual functional layers can be intimately bonded to each other, for example by welding (local spot welding or total welding) or controlled sintering by applying an adjusted compression force, additive manufacturing (3D printing) or by means of a conductive glue or any other technical solution which can be implemented to suppress (at least minimize) inter-sub-layer electrical resistances.

[0011] The single and multifunction composite cell component described in the present invention has several advantages over the existing state of the art:

- since the innovative component is one monolithic single component, made in only one block of material, there is no risk of formation of any insulating oxide layer at the interfaces between the different functional layers and the formation of parasite contact resistances. In other words, the electrically conductive sub-layers are no longer individual cell components. There is an excellent contact and no open space is left between the individual functional sub-layers to ensure good electrical conductivity. Therefore, the increasing ohmic resistance of the cell observed in state-of-art cells as a result of the formation of an insulating layer between individual components is suppressed or a least quite significantly reduced. The risk of oxide formation at the interface between the MPL of a given flowfield and its associated electrode can be reduced by surface coating. Water electrolysis cells equipped with such innovative cell component keep high electrical performances, either in-plane or through-plane electrical conductivity, during electrolysis, over long periods of time (up to a few hundred thousand hours).

- the different functional metal layers are interlocked homogeneously. The thickness of this single, multi-function component is more uniform and has a lower and better controlled level of tolerances than when the individual components are mechanically pressed against each other. As a result, current flows across the cells in a more homogeneous manner and cell ageing is significantly reduced.

- the total thickness of the component can be adjusted according to the thickness of the polymer membrane used in the cell; this is a serious advantage since the internal resistance of the polymer membrane is directly proportional to its thickness.

- Quite thin PTLs can be used. They are mechanically supported by the cell spacers, the design of which are adjusted to provide the necessary density of contact points. The pattern of the grid mesh are adapted to the thickness of the PTL used.

- as the thickness tolerances of the single multifunctional composite cell component are better adjusted, the risk of damaging the polymer membrane placed in the center of the cell is considerably reduced because the clamping forces used to achieve the stack are significantly reduced.

- compared to a conventional water electrolysis cell, the number of individual cell components is reduced. This limits the risks of cell stacking defects, for example misalignments, and favors the implementation of automated stacking procedures which are required for mass production.

- the multi-function electrolysis cell component described in the invention can also play a mechanical role: it is designed, in shape and thickness, to withstand the clamping pressure used to close, tighten and seal cells, and to withstand internal cell pressure during pressurized water electrolysis (whether operating in equipressure mode or in pressure differential mode between the anode and cathode compartments).

[0012] The cathodic flowfield placed on the opposite side of the bipolar plate can also be made of several functional sub-layers. It can be identical to the anodic flowfield. Alternatively, the metallic MPL and/or the PTL can be replaced by carbonaceous materials such as carbon fibers to form a single or multi-layer gas diffusion layer (GDL).

[0013] The central electrically conductive sheet can be of different types. The scope of the invention comprises a bipolar plate being a single metallic sheet or comprising a plurality of metallic sheets that are superimposed on each other. In other words, when designating this electric conductive sheet, the wording "metallic sheet" is used regardless of whether it comprises one sheet or a plurality of sheets. Here are some examples:

- It may be a simple metal sheet (for example titanium in PEM electrolysis or stainless steel in AEM electrolysis).

- It may be a simple metal sheet coated on the surface with an anti-corrosion coating, said anti-corrosion coating possibly being of a different nature depending on whether the surface is exposed to the anodic or cathodic side of the cell.

- It may be a multi-layer composite metal sheet, with or without one or more anti-corrosion coatings or inter-sheet linker.

- It may be a double metal sheet including an empty space (containing or not a cell spacer inside) between the two sheets in order to be able to circulate a refrigerant liquid there for cooling the cell during water electrolysis.

- It may be a metal sheet (anode side) on which a carbon black powder is compacted (cathode side) to form a composite bipolar plate.

[0014] It is to be noted that the central electrically conductive sheet called a bipolar plate and the first functional sub-layers or "cell spacers" of the flowfields can be merged and replaced by a non-flat bipolar plate which is a sheet equipped with machined channels through which liquid water can be pumped and gases can be collected. Such channels can be formed starting from a flat bipolar plate which is then either mechanically stamped or hydroformed. The design of the network of channels thus formed on the bipolar plate is optimized to homogenize water distribution over the active area of the cell while minimizing transverse electrical resistance.

[0015] It can also be noted that in PEM and AEM water electrolysis technologies, the electrodes or catalyst layers are usually deposited onto the polymer membrane to form a catalystcoated membrane or CCM. Alternatively, the catalyst layers can be deposited either at the surface of the PTL (which becomes a Porous Transport Electrode or PTE) or at the surface of the MPL (which becomes a Micro Porous Electrode or MPE). The PTE and MPE form two functional sublayers that can be integrated into the object of the invention. The component of the invention can be equipped with either type of functional sublayer.

[0016] There are several variations of the single and multifunctional composite cell component described in this invention.

[0017] According to another characteristic of the invention, at least one flowfield further comprises a porous transport layer or PTL placed against the so-called cell spacer. Advantageously, at least one of the at least one flowfield comprising a porous transport layer further comprises a microporous layer placed against said porous transport layer.

[0018] In another arrangement of the electrolysis cell component, the anodic so-called cell spacer and/or the cathodic so-called cell spacer are replaced by channels placed directly onto the bipolar plates, to form channel networks used for water distribution and gas collection through which liquid water can be pumped. For example, such mix functional layer can be manufactured by mechanical stamping of the electrically conductive sheet or by hydroformation. In such arrangement, the anodic so-called cell spacer and/or the cathodic so-called cell spacer are respectively adjacent to the anodic compartment and/or the cathodic compartment, but are not a part of them. In this configuration, at least one of the compartments comprises only the porous transport layer.

[0019] According to a characteristic of the invention, each so-called cell spacer defines ducts which are configured for a distribution of a fluid on the active areas of the anodic compartment and of the cathodic compartment. The ducts, or the channels, are designed in such a way that the reactive fluid is homogeneously distributed over the active areas of the anodic compartment and of the cathodic compartment. As described before, the flowfields are designed to distribute a fluid, like the reaction fluid or a mixture of reactive fluids. The ducts or channels integrated in the flowfields form a pathway which allows a homogeneous distribution of the fluid and transport the gases produced to outside the cell. Such homogeneous distribution allows to avoid some dysfunctions of the electrolysis cell, like water starvation in some areas, the formation of a temperature gradient between two portions of one of the flowfields for example.

[0020] According to a characteristic of the invention, the at least one flowfield disposed on one side of the electrically conductive sheet is an anodic flowfield disposed on the anodic side of the electrically conductive sheet or a cathodic flowfield disposed on the cathodic side of the electrically conductive sheet.

[0021] Such a configuration is an advantageous variant of the electrolysis cell component according to the invention, where both of the flowfields are made of a continuity of material with the electrically conductive sheet or bipolar plate, in order to form a multifunction electrolysis cell component with two flowfields and an electrically conductive sheet used as a bipolar plate separating the anodic and cathodic cell compartments of two adjacent cells.

[0022] Advantageously, the porous transport layers are an anodic porous transport layer stacked against the so-called cell spacer of the anodic flowfield and a cathodic porous transport layer placed against the so-called cell spacer of the cathodic flowfield.

[0023] Advantageously, the microporous layers are an anodic microporous layer placed against the anodic porous transport layer of the anodic flowfield and a cathodic microporous layer placed against the cathodic porous transport layer of the cathodic flowfield.

[0024] The optimal thicknesses of the different functional layers and sub-layers are determined to obtain optimal operation of electrolysis, i.e. to obtain maximum energy efficiency and compactness, in order to limit electrical consumption, size and footprint of the electrolysis cell(s) of the reactor or stack.

[0025] According to a characteristic of the invention, the continuity of material is electrically conductive. The electrically conductivity of the whole electrolysis cell component is insured essentially to operate the water electrolysis cells as efficiently as possible. For example, the component of the electrolysis cell may consist of metals that are chemically stable in the reaction medium (deionized water or alkaline aqueous solution, in the presence of H_2 or O_2). Non-exclusive examples are titanium, stainless steel and nickel.

[0026] According to a characteristic of the invention, the anodic flowfield and/or the cathodic flowfield have a thickness of 1.5mm +/- 1mm.

[0027] According to another characteristic of the invention, the so-called cell spacer has a maximum thickness of 2mm.

[0028] According to another characteristic of the invention, the porous transport layer has a thickness of 1.5mm +/- 1.4mm.

[0029] According to a characteristic of the invention, the anodic flowfield and the cathodic flowfield have, each in a cut plane parallel to the plane of the electrically conductive sheet, a cross section circular or polygonal in shape, the dimension of the cross section of the anodic flowfield being identical or superior to the cross section of the cathodic flowfield. Possibly, the cross section of the anodic and cathodic flowfield has the same dimensions. The form of the mechanical extension of the compartments can depend on the most advantageous form for an optimal arrangement of the electrolytic cell or of a stack of electrolytic cells in its environment.

[0030] According to another characteristic of the invention, the thickness, shape and size of anodic and cathodic flowfields are asymmetrical and different.

[0031] The invention also claims an electrolysis module comprising a plurality of electrolysis cells equipped with a plurality of single and multifunctional composite cell components, as described previously, equipped with a plurality of anodic and cathodic flowfields, said flowfields being introduced inside a plurality of anodic compartments and a plurality of cathodic compartments, each of the plurality of the electrolysis cell components being placed between an anodic compartment and a cathodic compartment of an adjacent electrolysis cell, the anodic compartments and the cathodic compartments being stacked against each other. The cells which are planar in shape, are stacked plane-to-plane, in a direction perpendicular to the direction of motion of the charge carriers (electrons in metallic components, protons or hydroxyl ions in ionically conducting polymer membranes). Such stacking of a plurality of electrolysis cells allows to form a water electrolysis reactor or stack which is each able to operate a water electrolysis and to produce dioxygen and dihydrogen from feed water.

[0032] The anodic compartment and the cathodic compartment can be defined as a void volume in which the flowfields are introduced. The anodic compartment and the cathodic compartment of the same cell are separated by the cell separator. The anodic compartment and the cathodic compartment of two adjacent cells are separated by the bipolar plate. Hence, the flowfields of the innovative cell component are introduced into the cell compartments of two adjacent cells.

[0033] According to a characteristic of the invention, the electrolysis reactor comprises a plurality of cells and therefore a plurality of polymer electrolyte membranes, each polymer electrolyte membrane being disposed between an anodic compartment and an adjacent cathodic compartment, such polymer electrolyte membranes being catalyst coated membranes or non-coated membranes. During electrolysis, electrons circulate through metallic cell components and ions (protons or hydroxyl ions) which are ionic charge carriers, circulate through the polymer membranes. Half-cell reactions that produce oxygen and hydrogen take place in the catalyst layers or electrodes. Thus, an electrolysis cell comprises such polymer electrolyte membrane between an anodic compartment and a cathodic compartment, and at least one electrically conductive sheet adjacent to one of the compartments on the opposite of the polymer electrolyte membrane.

[0034] The invention also relates to a method of manufacturing such an electrolysis single and multi-function composite cell component. There are several ways to produce the component: either by assembling all the functional layers together in a single step, or by preparing separate sub-assemblies comprising at least two sublayers or sub-components which are then assembled together. The method for manufacturing the electrolysis cell component comprises a first step of providing an electrically conductive sheet and a second step of forming a continuity of material between the at least one flowfield and the electrically conductive sheet by a step of integrating the at least one flowfield on the electrically conductive sheet. The step of integrating may be one of welding, gluing, sintering, additive manufacturing the at least one flowfield on the electrically conductive sheet. For example, a manufacturing process may comprise a step of manufacturing the main functional layers and a step of forming a continuity of material between the at least one flowfield and the electrically conductive sheet or bipolar plate by a unification step. The unification step may consist of soldering, bonding, sintering or additively manufacturing the flow field(s) on the electrically conductive sheet.

Brief description of the figures

[0035] Other characteristics, details and advantages of the invention will become clearer on reading the following description, on the one hand, and several examples of realisation given as an indication and without limitation with reference to the schematic drawings annexed, on the other hand, on which:

[fig 1] is a representation of a first arrangement of an electrolysis cell component according to the invention,

[fig 2] illustrates an embodiment of an electrolysis cell component according to the invention,

[fig 3] is a representation of a second arrangement of the electrolysis cell component according to the invention,

[fig 4] is a representation of an electrolysis module comprising a plurality of electrolysis cell components.

Description of the embodiments

[0036] Figures 1 to 4 provide some illustrations of the single and multifunction composite cell component of the invention. The layers represented by solid lines correspond to the individual cell components (current state of the art), while the layers represented by dotted lines correspond to the single and multifunction composite cell component of the invention.

[0037] Figure 1 is a schematic representation of a first arrangement of an electrolysis cell component 1 according to the invention. Such electrolysis cell component 1 can be used for a water electrolysis, which consists in a dissociation of water molecules in order to generate dioxygen and dihydrogen. More precisely, the electrolysis cell component 1 is part of one or two adjacent electrolysis cells in which it is possible to carry out such electrolysis of water. The electrolysis cell component 1 comprises an electrically conductive sheet 2 intended to be placed between an anodic compartment 3 and a cathodic compartment 4 of two adjacent electrolysis cells, the electrically conductive sheet 2 being disposed between the anodic compartment 3 and the cathodic compartment 4 of the two adjacent electrolysis cells. The electrically conductive sheet 2 can be a metallic sheet used as an inter-cell separator. It is also called a bipolar plate because it separates a cathodic cell compartment from an anodic cell compartment of two adjacent cells. Such bipolar plate must be a good electrical conductor and is able to resist to an internal pressure and a potential pressure difference between the anodic and cathodic compartments generated by the electrolysis cell when the water electrolysis is carried out under pressure, with or without a pressure difference between anodic and cathodic compartments.

[0038] According to the invention, the electrolysis cell component comprises at least one flowfield 5, 8 disposed on either or both sides of the electrically conductive sheet 2, the at least one flowfield 5 or 8 comprising a so-called cell spacer 7, 10, and the electrically conductive sheet 2 and the at least one flowfield 5, 8 are made of a continuity of material. In another embodiment of the invention, at least one flowfield 5, 8 further comprises a porous transport layer 6, 9 stacked against the so-called cell spacer 7, 10.

[0039] Furthermore, at least one of the at least one flowfield 5, 8 comprising a porous transport layer 6, 9 may further comprise a microporous layer stacked against said porous transport layer 6, 9.

[0040] These embodiments of the invention are of particular interest as the various functional sublayers are joined together between them and with the bipolar plate. In addition to reducing the number of components in a cell, the invention offers a single electrolysis cell component in which the total thickness is better adjusted with tightest tolerances. In the prior art, when just stacking the layers on top of each other, such tolerances cannot be ensured. For example, a porous transport layer being pressed against a cell spacer according to the prior art leads to a sinking of one element inside the other, thereby damaging the components. Therefore, the invention results in an enhanced dimensional reproducibility while ensuring a homogeneous mechanical contact of the different cell components in order to guarantee the optimal operation of the stack.

[0041] In figure 1, the single and multifunction composite cell component of the invention is introduced in both the anodic compartment 3 and the cathodic compartment 4 of two different but adjacent cells. There is a metallic continuity along the thickness of this component and therefore during operation, this component operates at iso-potential on both sides.

[0042] The anodic flowfield 5 and the cathodic flowfield 8 may have either the same or a different thickness. Typically, the thickness of these flowfields is 1.5mm +/- 1mm. The anodic flowfield and the cathodic flowfield placed against the bipolar plate can have a surface which is either identical or different. For example in figure 1, the surface of the anodic flowfield 5 is larger than the surface of the cathodic flowfield 8.

[0043] The function of the anodic cell spacer 7 and the cathodic cell spacer 10 is to allow forced circulation of electrolyte in each cell compartment in order to fuel the reaction, collect the gases produced at the electrodes and to lead them towards the exhaust in order to extract them from the cell, but also to cool each cell in which heat is produced. At the inlet of the cell(s), a monophasic fluid (this can be ultra-pure and strongly deionized water in PEM cells or an aqueous solution of potassium hydroxide in AEM cells) is injected inside the cells. Inside the cell(s) and at the outlet of the cell(s), the fluid in circulation is a biphasic mixture of liquid water and one of the gases produced during the water electrolysis, which can be gaseous dioxygen or dihydrogen. The anodic cell spacer 7 and/or the cathodic cell spacer 10 have a typical thickness of 2mm or less. The anodic cell spacer 7 and the cathodic cell spacer 10 which are used to ensure efficient and homogeneous fluid circulation inside the cells over the active area are usually made of a grid. Alternatively, this can be ducts or channels, placed directly onto the bipolar plates 2. The plurality of ducts or channels 11 form a network through which the electrolyte can by pumped to feed the half-cell reactions at the electrodes, collect the gases formed and cool the cells down. These ducts 11 allow to distribute the electrolyte homogeneously over the active areas 12 of the anodic compartment 3 and of the cathodic compartment 4 up to the electrodes wherein half-cell reactions take place.

[0044] When the cells are stacked together, the anodic porous transport layer 6 and the cathodic porous transport layer 9 are pressed against a cell separator (e.g. a polymer membrane) not shown in figure 1. During water electrolysis, the role of the anodic porous transport layer 6 is to transport electricity between the anodic cell spacer 7 to the anode (the electrons which are the charge carriers are driven away from the anode) and to ensure a homogeneous distribution of the reactive fluid to the anode and to transport the oxygen produced at the anode to the rear side of the cell, the anodic cell spacer 7, where gas bubbles are driven out of the cell by circulating electrolyte. The role of the cathodic cell spacer 10 is to transport electricity between the cathodic cell spacer 10 and the cathode (the electrons which are the charge carriers are driven up to the cathode), and to collect and transport the electro-osmotic flow of water and the gas produced inside the cathodic compartment of the cell (hydrogen) to the exhaust of the cell. Therefore, these porous transport layers 6, 9 are essential for the operation of the water electrolysis. The anodic porous transport layer 6 and/or the cathodic porous transport layer 9 have a maximum thickness of 1.5mm.

[0045] It can be noted that the prior art has various disadvantages. Another dysfunction which could happen in the components of the prior art is a progressive oxidation of individual metallic cell components, in particular around the anodic flowfield, of the conductive components. Such oxidation can lead to a formation of an insulating oxide layer between the anodic layers of the flowfield or the cathodic layers of the flowfield for example. Such insulating layer increases the ohmic resistance of the electrolysis cell(s), that can inhibit the circulation of the electric current and decreases the performances of the electrolysis cell during water electrolysis. The electrolysis cell component 1 of the invention is made of a continuity of material between the electrically conductive sheet 2 and at least one flowfield among the anodic flowfield and the cathodic flowfield.

[0046] In figure 1, there is a continuity of material between the electrically conductive bipolar plate 2 and the flowfield 5, as illustrated by the dotted lines which delineates the anodic layers in the anodic compartment 3. Therefore, in figure 1, the continuity of material extends along the electrically conductive sheet 2 and all the anodic functional sub-layers of the anodic flowfield, which are the anodic so-called cell spacer 7, the anodic porous transport layer 6 and eventually a very thin microporous layer not shown in figure 1. In the arrangement illustrated in figure 1, the cathodic flowfield is not a part of the continuity of material and is stacked on the electrically conductive sheet 2 in a usual manner.

[0047] The term 'continuity of material' has to be understood in that all the components included in such continuity of material are monolithic and gathered in a unique block of material. The continuity of material participates in maintaining a high cell efficiency over time. Moreover, such continuity of material leads to a reduction of the number of cell components placed inside the cell(s), and as a consequence decreases the risks of cell stacking defects.

[0048] The entire continuity of material is electrically conductive in order to allow the circulation of the electric current during the operation of the electrolysis cell. In order to avoid any electrical short circuit between two adjacent innovative cell components in the stack, these innovative cell components are mounted on insulating (usually made of thermoplastic material) spacers or frame 13. Such frame 13 supports at its periphery the seals used to seal the cells, and keep the different bipolar plates away from each other. Such insulating spacer or frame 13 also comprises an internal shoulder equipped with a groove 28, as illustrated for example in figure 1, in which is placed an inter compartment seal, which is used to press the periphery of the polymer membrane, and ensure sealing between the anode and cathode cell compartments.

[0049] The insulating spacer or frame 13 must be a good electrical insulator because it separates two electrically conductive bipolar plates 2 when a plurality of electrolysis cells are stacked together. The insulating spacer 13 must also be designed to be mechanically robust to withstand the clamping pressure and the internal pressure of the electrolysis cell when pressurized water electrolysis is performed. The insulating spacer 13 can comprise some gutters 14 or grooves where gaskets 15 can be disposed inside such gutters 14 in order to ensure the sealing of the electrolysis cell.

[0050] Figure 2 illustrates an embodiment of an electrolysis cell component 1 according to the invention. Figure 2 shows the anodic side of the innovative single and multi-function composite cell component 1, with a view on the central bipolar plate 2 and the anodic flowfield 8. The electrolysis cell component 1 comprises the electrically conductive sheet or bipolar plate 2, for example a titanium plate or a bi-layer sheet comprising a titanium layer placed on the anode side and a carbon layer placed on the cathode side, and a flowfield (in this embodiment an anodic flowfield 8). In this embodiment, the flowfield of the component 1 comprises a so-called cell spacer 10, and a porous transport layer 9. The so-called spacer is positioned between the sheet 2 and the porous transport layer 9. As explained above, the electrolysis cell component 1 of the invention forms a single component that comprises the electrically conductive sheet 2 and one flowfield on one side of the sheet 2 or two flowfields, one on both sides of the sheet 2. In a variant of the invention, the flowfield may further comprise a porous transport layer on a cell spacer, either one porous transport layer on one side, or two porous transport layers on both sides, each one being disposed on a so-called cell spacer. In other words, in this variant the component 1 comprises the bipolar plate and one or two so-called cell spacers and one or two porous transport layer(s). Similarly, each flowfield can further comprise a microporous layer disposed on the porous transport layer, either on one side or on both side of the component 1. Figure 2 shows the anodic side of the component. On the cathodic side, the electrolysis cell component 1 may have the same flowfield or a different and even simplified flowfield. An example of a simplified flowfield applicable to PEM water electrolysis cells is when there is no cell spacer, only a porous transport layer (with or without a MPL). The fact of not using a cell spacer on the cathode side is justified because most of the heat produced during electrolysis is released in the anodic cell compartment. In the cathodic cell compartments, the cooling requirements are therefore significantly less and it is possible to operate the cell without forced electrolyte circulation.

[0051] Therefore, there is no need for a cell spacer. Figure 2 does not show the cathodic flowfield. However, it can further be noted that the anodic flowfield and the cathodic flowfield may have different dimensions in terms of width, length and thickness. Such a configuration enables to place a seal between adjacent compartments.

[0052] Figure 3 is a representation of a second arrangement of the electrolysis cell component 1 according to the invention. In this second arrangement, the electrically conductive sheet 2, the anodic flowfield 5 and the cathodic flowfield 8 are made of a continuity of material. This second arrangement is different from the first arrangement illustrated in figure 1, in which only the electrically conductive sheet 2 and the anodic flowfield are made of a continuity of material. Such second arrangement is advantageous because the electrolysis cell component 1 contains less elements stacked against each other.

[0053] Thus, the electrolysis cell component 1 is a single component in which the electrically conductive sheet 2, the anodic flowfield and the cathodic flowfield are gathered together by the continuity of material.

[0054] The second arrangement of figure 3 is also different from the first arrangement of figure 1 in that the anodic cell spacer 7 and the cathodic cell spacer 10 are not respectively an anodic layer 5 and a cathodic layer 8. Indeed, the anodic cell spacer 7 and the cathodic cell spacer 10 are stamped in the electrically conductive sheet or bipolar plate 2, to form a network of channels. In such arrangement, the electrolyte is pumped through the channels along the anodic compartment 3 and the cathodic compartment 4. In this case, the anodic flowfield 5 comprises only one or two anodic functional sub-layers (the anodic porous transport layer 6 with or without an anodic MPL layer on top) and the cathodic flowfield 8 comprises only one or two cathodic functional sub-layers (the cathodic porous transport layer 9 with or without a cathodicMPL layer on top). All other structural and functional characteristics of the second arrangement of the electrolysis cell component 1 being the same as the first arrangement of the electrolysis cell component described in figure 1, all information concerning these characteristics in common can be found in the description of figure 1. Each characteristic which differs between the two arrangements can be combined together, independently from these arrangements.

[0055] Figure 4 is a representation of an electrolysis module 16 comprising a plurality of electrolysis cell components 1 according to the invention and a plurality of anodic compartments 3 and a plurality of cathodic compartments 4, each of the plurality of the electrolysis cell components being placed between an anodic compartment 3 and a cathodic compartment 4 of two adjacent cells, the anodic compartments 3 and the cathodic compartments 4 being stacked against each other. Such electrolysis module 16 consists in a plurality of electrolysis cells 17 which are stacked against each other in order to operate a plurality of water electrolysis cells at the same time and to improve an overall performance of the electrolysis module 16. In particular, the number of individual cells stacked together in the reactor or stack is dictated by the H_2/O_2 production capacity that this required.

[0056] Each electrolysis cell 17 is delimited by two electrically conductive sheets or bipolar plates 2. The anodic and cathodic flowfields of the innovative cell component are introduced inside the anodic compartment 3 and cathodic compartment 4 of two adjacent cells.

[0057] Each electrolysis cell component 1 is shared by two adjacent electrolysis cells. The top surface of each flowfield of the electrolysis cell is in contact with the polymer electrolyte membrane 18 of two adjacent cells.

[0058] Such polymer electrolyte membrane 18 ensures the transport of ions between the anodic compartment and the cathodic compartment of the same cell, and prevent of mixing of gaseous reaction products, like gaseous oxygen and hydrogen, formed in these two cell compartments, inside the electrolysis cell 17. Such polymer electrolyte membrane 18 is, on one side, in contact with the surface of the anodic flowfield of one electrolysis cell component 1, and, one the other side, in contact with the surface of the cathodic flowfield of the electrolysis cell component of the next cell, in order to perform water electrolysis. That is why the electrolysis module 16 comprises as many polymer electrolyte membranes 18 as the number of electrolysis cell 17 included in the electrolysis module 16. Each polymer electrolyte membrane 18 can be a catalyst coated membrane, also known as CCM, or an uncoated membrane against which are pressed a PTE on the anodic side and a GDE on the cathodic side, such forming a so-called "membrane electrode assembly". In such case, the uncoated membrane is clamped between two porous transport electrodes or between a porous transport electrode and a gas diffusion electrode.

[0059] In figure 4, the electrolysis cell components 1 are fully represented compared to the preceding figures. Therefore, each individual cell contains an insulating spacer 13 which maintains the electrically conductive sheets or bipolar plates 2 of adjacent cells apart from each other in the electrolysis module 16.

[0060] The electrolysis module 16 comprises other elements that are not illustrated in figure 4. For example, the electrolysis module 16 includes two end plates or current supply plates placed on each side of the stack of cells. These plates are electrically connected to the plus and minus poles of the rectifier used to supply the electrolysis cell stack 17 with electricity in order to be able to carry out the electrolysis of water in each of the electrolysis cells 17 of the electrolysis module 16. The electrolysis module 16 also comprises two water circuits which are designed to distribute the fluid in the cell spacers 7, 10 of each electrolysis cell 17. These two circuits are also designed to evacuate the dioxygen and the dihydrogen produced during the operation of water electrolysis out of the electrolysis module 16.

[0061] The present invention thus covers an electrolysis cell component comprising an electrically conductive sheet which can be used as a bipolar plate and at least a flowfield among an anodic flowfield and a cathodic flowfield, which are united to remove the contact resistances at layer interfaces and to obtain a continuity of material preventing the ohmic resistance increase over time.

[0062] The invention also concerns a method for manufacturing such an electrolysis cell component comprising a first step of providing an electrically conductive sheet and a second step of forming a continuity of material between the at least one flowfield and the electrically conductive sheet by a step of integrating the at least one flowfield on the electrically conductive sheet.

[0063] The step of integrating may be one of welding, gluing, sintering, additive manufacturing the at least one flowfield on the electrically conductive sheet. Additive manufacturing can be used as a direct method for manufacturing such an electrolysis cell component from metal powders or wires and using an energy source for melting powders or wires that can be either laser beam or electron beam.

[0064] Thanks to the method of the invention, the various functional sublayers of the flowfield(s) are unified/joined together with the bipolar plate. The flowfield may be manufactured separately and joined to the bipolar plate by welding or gluing by means of a conductive glue. Alternatively, the flowfield may be manufactured directly on the bipolar plate, layer after layer, for example by sintering each layer or by 3D printing the layers of the flowfield on the bipolar plate. When adding materials to form the flowfield (either on the bipolar plate or separately), the layers are integrated the one into the others, thereby enabling the advantages explained above in terms of thickness, tolerances and reduction of ohmic resistance.

[0065] Many modifications and other embodiments of the invention set forth herein will come to mind to those skilled in the art to which the invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. Electrolysis cell component (1) comprising an electrically conductive sheet (2) intended to be placed between an anodic compartment (3) and a cathodic compartment (4) of an adjacent electrolysis cell, the anodic compartment (3) and the cathodic compartment (4) each comprising an active area (12) for electrolysis, the electrically conductive sheet (2) separating the anodic compartment (3) and the cathodic compartment (4) of two adjacent electrolysis cells, **characterized in that** the electrolysis cell component comprises at least one flowfield (5, 8) disposed each on a side of the electrically conductive sheet (2), the at least one flowfield (5, 8) comprising a so-called cell spacer (7, 10), and **in that** the electrically conductive sheet (2) and the at least one flowfield (5, 8) are made of a continuity of material.

2. Electrolysis cell component (1) according to claim 1, wherein at least one flowfield (5, 8) further comprises a porous transport layer (6, 9) against the so-called cell spacer.

3. Electrolysis cell component (1) according to claim 2, wherein at least one of the at least one flowfield (5, 8) comprising a porous transport layer (6, 9) further comprises a microporous layer placed against said porous transport layer (6, 9).

4. Electrolysis cell component (1) according to any one of claims 1 to 3, wherein each cell spacer (7, 10) defines ducts (11) which are configured for a distribution of a fluid on the active areas (12) of the anodic compartment (3) and of the cathodic compartment (4).

5. Electrolysis cell component (1) according to any one of the preceding claims, wherein the at least one flowfield (5, 8) disposed each on a side of the electrically conductive sheet (2) are an anodic flowfield (5) disposed on an anodic side of the electrically conductive sheet (2) and a cathodic flowfield (8) disposed on a cathodic side of the electrically conductive sheet (2).

6. Electrolysis cell component (1) according claim 5, in combination with claim 2, wherein the porous transport layer (6, 9) is an anodic porous transport layer (6) placed against the so-caller cell spacer of the anodic flowfield (5) and a cathodic porous transport layer (9) placed against the so-called cell spacer of the cathodic flowfield (8).

7. Electrolysis cell component (1) according claim 6, in combination with claim 3, wherein the microporous layer is an anodic microporous layer placed against the anodic porous transport layer (6) of the anodic flowfield (5) and a cathodic microporous layer placed against the cathodic porous transport layer (9) of the cathodic flowfield (8).

8. Electrolysis cell component (1) according to any one of the preceding claims, wherein the continuity of material is electrically conductive.

9. Electrolysis cell component (1) according to any one of the preceding claims, wherein the anodic flowfield (5) and/or the cathodic flowfield (8) have a thickness of 1.5mm +/- 1mm.

10. Electrolysis cell component (1) according to the preceding claim, wherein the so-called cell spacer (7, 10) has a maximum thickness of 2mm.

11. Electrolysis cell component (1) according to the claim 9 or 10, in combination with claim 2, wherein

the porous transport layer (6, 9) has a maximum thickness of 1.5mm.

12. Electrolysis cell component (1) according to any one of the preceding claims, wherein the anodic flowfield (5) and the cathodic flowfield (8) have, each in a cut plane parallel to the plane of the electrically conductive sheet (2), a cross section circular or polygonal in shape, the dimension of the cross section of the anodic flowfield (5) being identical or superior to the cross section of the cathodic flowfield (8), and/or the anodic flowfield (5) and the cathodic flowfield (8) have a different thickness.

13. Electrolysis module (16) comprising a plurality of electrolysis cell components (1) according to any one of the precedent claims, a plurality of anodic compartments (3) and a plurality of cathodic compartments (4), each of the plurality of the electrolysis cell components being placed between an anodic compartment (3) and a cathodic compartment (4) of an adjacent electrolysis cell, the anodic compartments (3) and the cathodic compartments (4) being stacked against each other.

14. Electrolysis module (16) according to the preceding claim, comprising a plurality of polymer electrolyte membranes (18), each polymer electrolyte membrane (18) being disposed between an anodic compartment (3) and an adjacent cathodic compartment (4), such polymer electrolyte membranes (18) being catalyst coated membranes or single membranes.

15. Method for manufacturing an electrolysis cell component (1) according to any one of claims 1 to 12 comprising:

- A first step of providing an electrically conductive sheet (2);
- A second step of forming a continuity of material between the at least one flowfield and the electrically conductive sheet (2) by a step of integrating the at least one flowfield on the electrically conductive sheet.

16. Method of manufacturing according to claim 15, wherein the step of integrating is one of welding, gluing, sintering, additive manufacturing the at least one flowfield on the electrically conductive sheet (2).

FIGURE 1

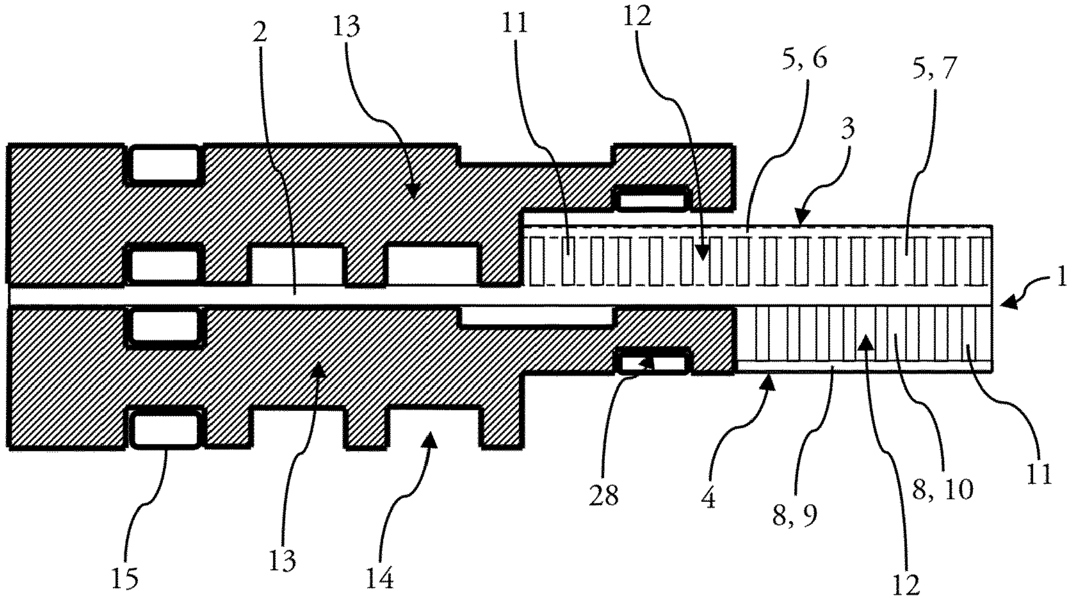


FIGURE 2

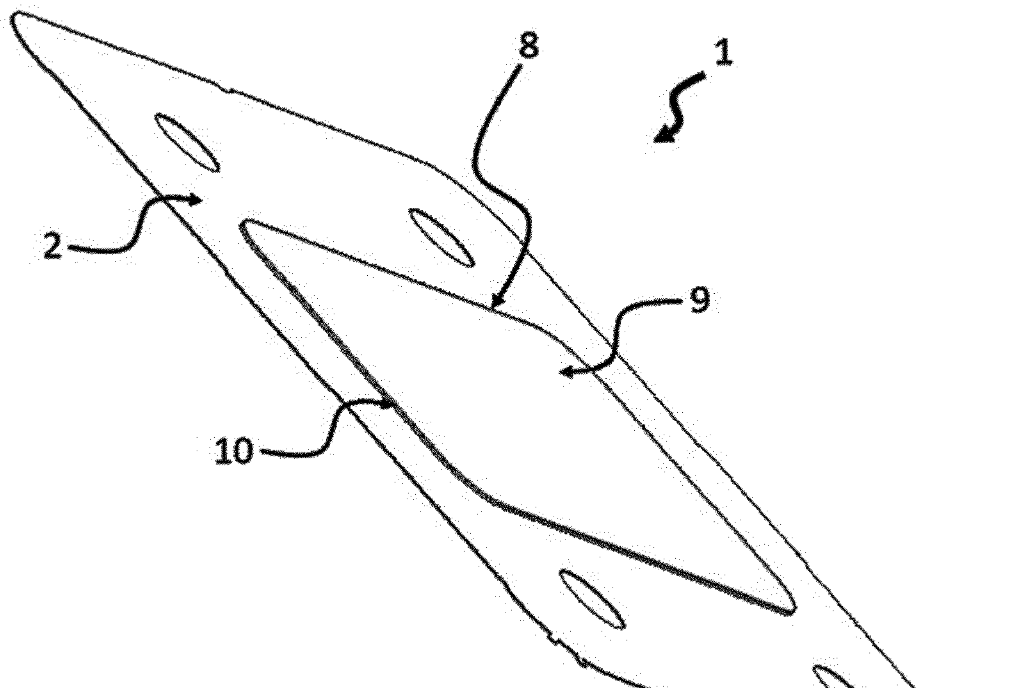


FIGURE 3

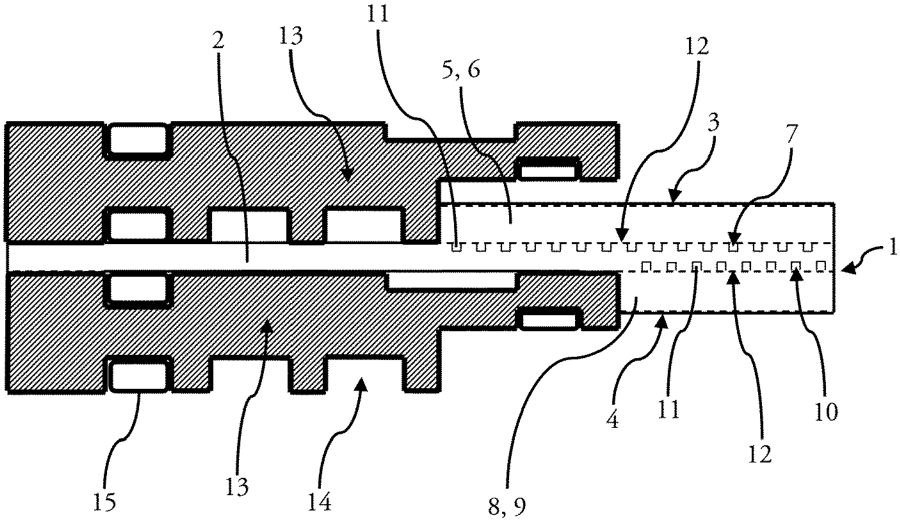
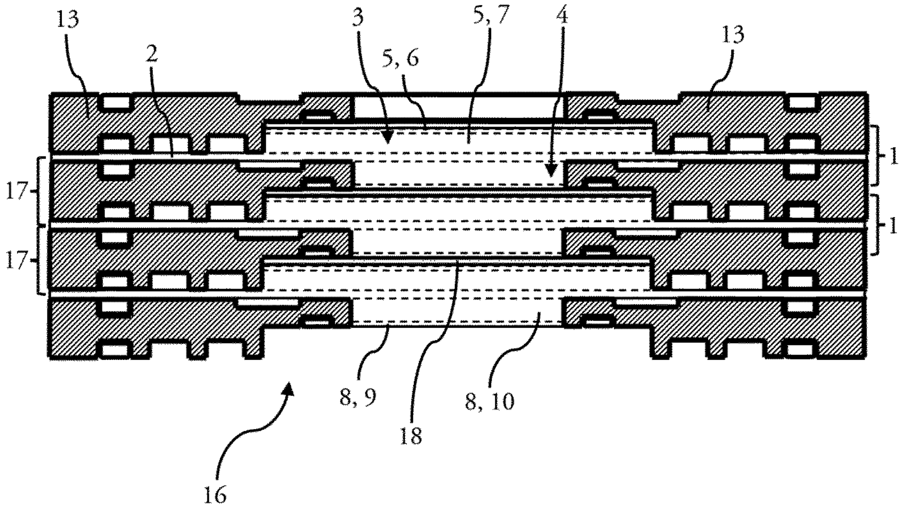


FIGURE 4



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RAPPORT DE RECHERCHE EUROPEENNE

Numéro de la demande
EP 23 30 7271

DOCUMENTS CONSIDERES COMME PERTINENTS

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Le présent rapport a été établi pour toutes les revendications

Lieu de la recherche	Date d'achèvement de la recherche	Examinateur
Munich	10 mai 2024	Juhart, Matjaz

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