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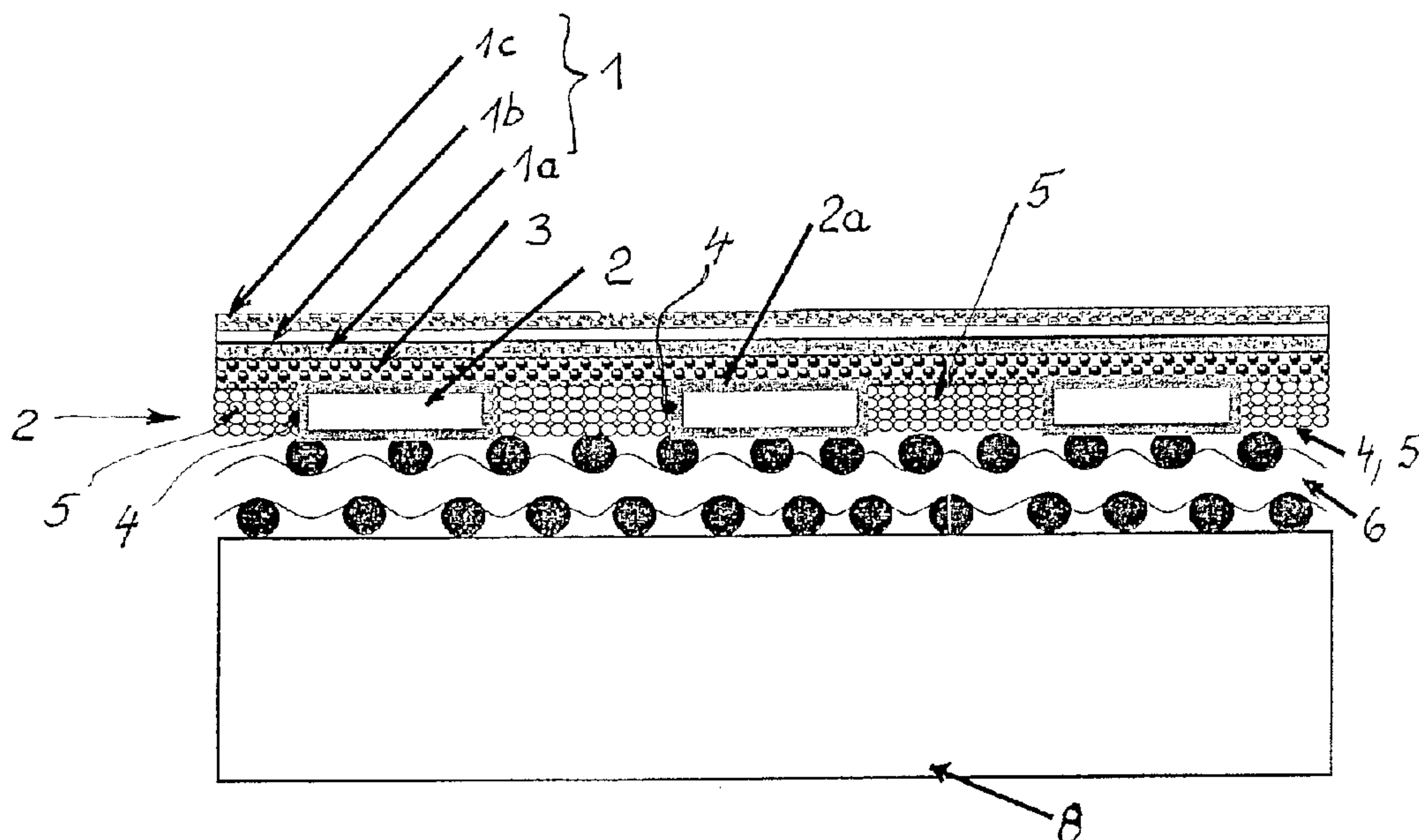
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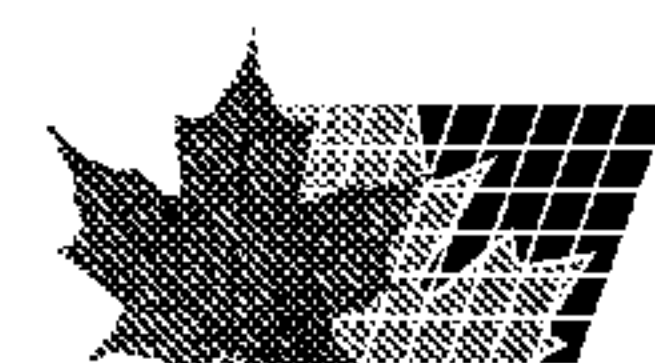
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(57) **Abrégé/Abstract:**

The invention relates to a stack of solid oxide fuel cells comprising respectively a metal bearing structure (2) for a cathode-electrolyte-anode unit (1), which is provided with gas passage orifices and a bipolar plate (8) or the like disposed on the other side of the bearing structure. Said bearing structure (2) consists of a metal which forms a protective oxide layer (2a) which is electrically insulating and operates as a resistance heating element for adjusting the fuel cell temperature and makes it possible to guide electric current through the protective oxide layers (2a), wherein an electrically conductive material (5) is introduced in at least several passage orifices (4) of the bearing structure for providing an electrical connection between the bipolar plate (8) or the like and the associated cathode-electrolyte-anode unit (1) in such a way that the gas can pass through said passage orifices (4). In the preferred embodiment, an aluminium or silicon oxide former is used in the form of the bearing structure metal. In order to generate electrical conductivity in the passage orifice (4) area, a gas-permeable and electrically-conductive material, for example in the form of a suitably treated metal is introducible into said orifices or an electrically conductive coating is applied to the protective oxide layer (2a) of the bearing structure (2) at least in the area of several passage orifices (4).



Abstract

The invention relates to a stack of solid oxide fuel cells, of which each cell exhibits a metal bearing structure, which exhibits passage orifices for a gas and is intended for a cathode-electrolyte-anode unit, and a bipolar plate, which is provided on the other side of the bearing structure, or the like. The bearing structure is made of a metal, which forms a protective oxide layer, which is electrically insulating, and operates as an electric resistance heating element for adjusting the fuel cell temperature, to which end an electric current may be guided through the bearing structure between its protective oxide layers. An electrically conductive material is introduced in at least some of the passage orifices of the bearing structure for the purpose of providing an electric connection between the bipolar plate or the like; and the associated cathode-electrolyte-anode unit is introduced in such a way that the gas can pass through these passage orifices. Preferably the metal of the bearing structure is an aluminum oxide former or a silicon oxide former. To generate the electric conductivity in the area of the passage orifices, a gas permeable and electrically conductive material, for example, in the form of a suitably treated metal, may be introduced into said orifices; or an electrically conductive coating may be applied on the protective oxide layer of the bearing structure at least in the area of some of the passage orifices.

Solid Oxide Fuel Cell with a Metal Bearing Structure

The invention relates to a solid oxide fuel cell comprising a metal bearing structure, which exhibits passage orifices for a gas and is intended for a cathode-electrolyte-anode unit, and comprising a bipolar plate, which is provided on the other side of the bearing structure, or the like. For the technological environment reference is made not only to DE 102 38 860 A1, but also to EP 1 271 684 A1.

Solid oxide fuel cells (solid oxide fuel cell, SOFC) are used to convert the chemical energy of a combustible gas together with an oxidizer, e.g., atmospheric oxygen, on the direct way electrochemically into electric energy. The conversion of the combustible gas and the atmospheric oxygen into electric energy is carried out on and in ceramic layers (cathode, electrolyte, anode). In the planar fuel cell concepts a cell consists of a planar configuration of the ceramic layers. So-called bipolar plates are used to supply the combustible gas and the air, to dissipate the residual gases and to provide an electric connection between the individual fuel cells, which are stacked one above the other, in a serial arrangement, that is, in so-called stacks. The ceramic layers may also be a part of these bipolar plates. At the same time it must be guaranteed that the combustible gas and the air do not make direct contact with each other at any point in the stack of fuel cells. In particular, the bipolar plates may form together with the ceramic layers a cassette, which encloses one type of gas, in particular the combustible gas.

The operating temperature of solid oxide fuel cells ranges from 600 deg. C to 900 deg. C. The temperature of solid oxide fuel cells is usually raised relatively slowly to their operating temperature in order to avoid damage due to the occurrence of thermomechanical stress between the ceramic layers with each other and/or between the ceramic composite and the bipolar plates. Thermomechanical stresses between the ceramic layers with each other and/or between the ceramic composite and the bipolar plates may lead, in particular, to micro-cracks in the ceramic layers as well as in the ceramic-ceramic interfaces and between the ceramic-metal interfaces and, thus, to the destruction of the SOFC.

For use in motor vehicles, fuel cells with very short start up times are necessary. A development, which considers this demand to some degree, is to apply the ceramic functional layers not in a self bearing manner (e.g., the electrolyte or the anode as a substrate), but rather as thin layers on a metal substrate (e.g., sintered metal or a perforated foil, see, for example, DE 102 38 860 A1). In addition to the thermomechanical stability, another limiting factor is the introduction of the necessary amount of heat. EP 1 271 684 A2 describes the possibility of raising the temperature of a solid oxide fuel cell to its operating temperature by means of an electric resistance heating element in that metal foils, which are provided between the ceramic layers, are put under electrical stress, thus generating heat by means of the resulting current flow. However, the above described solution requires an additional component, whose integration and contacting in the stack means a significant increase in the complexity of such a SOFC. Therefore, the described method runs the risk that, when the exterior side of the metal foil or of the other metal components is not electrically insulated, electric short circuiting ensues over the bipolar plates or the electrodes of the SOFC, thus electrically bridging the "heating foil" and, thus, becoming inactive.

It shall hereby be provided now a solid oxide fuel cell comprising a metal bearing structure, which exhibits passage orifices for a gas and is intended for a cathode-electrolyte-anode unit, and comprising a bipolar plate, which is provided on the other side of the bearing structure, or the like. With respect to raising the temperature of said cell, said cell can be electrically heated and yet is characterized by a simple and reliable construction (= object of the present invention).

The solution to this problem associated with a solid oxide fuel cell, as defined in the preamble of claim 1, is characterized in that the bearing structure is made of a metal, which forms a protective oxide layer, which is electrically insulating, and operates as an electric resistance heating element for adjusting the fuel cell temperature, to which end an electric current may be guided through the bearing structure between its protective oxide layers; and that an electrically conductive material is introduced in at least some of the passage orifices of the bearing structure for the purpose of providing an electric connection between the bipolar plate or the like; and the associated cathode-electrolyte-anode unit is introduced in such a way that the gas can pass through these passage orifices. Advantageous designs and further developments are the subject of the dependent claims.

Therefore, proposed is an embodiment of a SOFC fuel cell, which remedies the major drawbacks of the prior art and thereby makes it possible to realize a solid oxide fuel cell that can start up quickly. The basis of a fuel cell, according to the invention, is a thin metal bearing structure (for example, a metal foil in the thickness range of 30 to 500 μm as the carrier of the ceramic functional layers of a SOFC fuel cell, which is either perforated in the area of the ceramic functional layer or exhibits suitable passage orifices, formed in some other way, in order to enable the reaction gases to flow to the respective electrode. Preferably this metal bearing structure extends over the entire surface of the bipolar plate, including the gas guides, provided in the area on the edge, for the combustible gas and the air.

One feature of the proposed metal bearing structure is that this bearing structure is made of a material or rather a metal that constitutes in itself a protective oxide layer that is electrically insulating, i.e., in the sense of an auto-passivation. Such preferred materials are so-called aluminum oxide formers, for example, Aluchrom Y Hf, or silicon oxide formers. If now the metal foil, forming a protective oxide layer, or the like extends, as the bearing structure for the ceramic functional layers, over the entire cross sectional area of a stack of fuel cells, it is possible in an advantageous manner without any additional complexity to insert also a sealing material, which conducts electrically, as the sealing material for the purpose of making the reactants gas tight with respect to each another, between the individual fuel cells that are stacked one above the other, since the necessary electrical insulation between the individual cells is already guaranteed by the protective oxide layer of the said bearing structure. Furthermore, this enables said bearing structure to be used as the electric resistance heating element without having to be concerned about the risk of electric short-circuiting. The corresponding electric contacting, for the purpose of introducing electric current into the discharge of the electric current from the bearing structure, may be carried out, for example, by means of the corresponding electrical contacts on the outer periphery of the bearing structure. As the electric current passes through the bearing structure, said bearing structure heats up when suitably configured (to be discussed in detail below), so that the bearing structure itself may, therefore, operate as the electric resistance heating element.

However, an electric conductivity from an individual cell to the next adjoining individual cell is required for the fuel cell or rather a corresponding SOFC stack to function. This conductivity is usually generated by way of the so-called bipolar plate or the like. Therefore, there must be inside the individual cell an electric connection between the bipolar plate (or the like) and the side of the cathode-electrolyte-anode unit that faces said bipolar plate, whereupon there is an electric connection between the bipolar plate of a first individual cell

and the side of the cathode-electrolyte-anode unit that faces said bipolar plate and belongs to an adjacent second individual cell. At this stage inside the individual cell the electrically conducting connection between the bipolar plate and the cathode-electrolyte-anode unit cannot simply be generated continuously (as was the case to date) by way of the metal bearing structure of the cathode-electrolyte-anode unit, since said cathode-electrolyte-anode unit forms, of course, an oxide layer that is electrically non-conducting. For this described function of the electric conductivity inside an individual fuel cell, a first embodiment of the present invention proposes now a porous or rather gas-permeable and electrically conductive material, which is introduced into the passage orifices in the bearing structure and which supplies the electrode with the respective gaseous reactant. This electrically conductive material may be, for example, a metal that is suitably treated or even an anode material or a cathode material (of the cathode-electrolyte-anode unit) or in general an electrically conductive ceramic. Therefore, the required "filling" of the passage orifices in the bearing structure so as to effect the electric contact may be carried out with an electrically conductive and simultaneously gas-permeable material with the use of, for example, squeegees, screen printing, rollers or the like. According to an alternative embodiment, it is also possible to apply a coating on the protective oxide layer at least in the area of some of the passage orifices in order to generate the electric conductivity by way of the bearing structure, forming the protective oxide layer. If, therefore, an electrically conductive material is applied (a process that may be carried out by electroplating, physical vapor deposition or the like) on the protective oxide layer of the bearing structure at least in the area of some of the passage orifices, an electric conductivity with simultaneous gas permeability of the passage orifices is easily and positively guaranteed.

With respect to the metal bearing structure, the passage orifices in said bearing structure may be produced by etching, punching, slotting, piercing or similar procedures. The hole structure, i.e., the shape of the passage orifices may be

characterized, for example, by conical, elliptical, square, honeycomb-shaped or similar holes. The electric resistance and, thus, the heating power, which can be achieved at the bearing structure with the defined electrical voltage, may be adjusted to meet the respective requirements by, for example, a suitable choice of the thickness of the bearing structure as well as the structuring. Therefore, the electric resistance can be increased with a disproportionately high number of passage orifices, so that owing to the defined perforations, which vary locally, i.e., owing to the varying shape of the passage orifices, also locally variable amounts of heat may be introduced into the individual cell. In addition, owing to the choice and combination of the electrical interconnection, namely the series connection or the parallel connection of the individual "heating foils" in the fuel cell stack that is formed by the individual bearing structures of the individual cells, which are stacked one over the other, the overall electric resistance may be adjusted to the desired heating power and the supply voltage that is available.

The service life of an inventive SOFC, compared to that of the prior art, is advantageously longer, since the protective oxide layer, forming on the bearing structure, is not only electrically insulating, but also chemically significantly more resistant than the metal substrates that are used today and that rely on their own high electric conductivity and have—depending on the oxidation—a shorter lifespan. Chemical resistance is defined in this context as the corrosion resistance to the gases in the SOFC and the corrosion resistance to the material properties of the interfusing elements that exert an effect. Moreover, the SOFC, which is presented here within the scope of the invention, is independent of the special configuration of the ceramic functional layers on the described bearing structure. It is possible to apply a commensurate unit in both the order of sequence anode-electrolyte-cathode and vice versa in the order of sequence cathode-electrolyte-anode. The

SOFC, which is presented within the scope of the invention, is also independent of the precise method of conveying the gas and the subsequent electrical contacting in the stack, i.e., in the area of the bipolar plates or the like, the function of which may also be assumed, for example, by a metal knitted fabric.

The attached schematic drawing depicts a preferred embodiment. **Figure 1** is an exploded cross section of an individual fuel cell, according to the invention; whereas **Figure 2** is a top view of a bearing structure (without the ceramic functional layers).

The reference numeral 1 refers to the ceramic functional layers of an individual fuel cell in the form of a cathode-electrolyte-anode unit, whereas the anode layer bears the reference numeral 1a; the applied electrolyte, the reference numeral 1b; and the cathode, which is applied on said electrolyte, the reference numeral 1c. This cathode-electrolyte-anode unit 1 is applied on a bearing structure 2, but here a so-called anode substrate 3 is interposed. The bearing structure 2 is a thin metal foil or the like, into which the passage orifices 4 are introduced. Into these passage orifices 4 a gas-permeable, electrically conductive material 5 is introduced. In Figure 1 below the bearing structure 2 there is a net structure 6 or the like, by way of which a gaseous reactant (combustible gas) may flow from the side to the underside of the bearing structure 2 and through its passage orifices 4, which are filled with a gas-permeable material 5, and may pass through the porous anode substrate 3 to the anode 1a of the cathode-electrolyte-anode unit 1. Adjoining the underside of this net structure 6 there is a bipolar plate 8; and under this bipolar plate there follows in turn—as typical—the next fuel cell with its cathode layer (1c) (not illustrated). Similarly the next individual cell with its bipolar plate (8) (also not illustrated) may also be connected to the cathode layer 1c of the individual fuel cell, depicted in the figure.

The foil-like metal bearing structure 2 is made of a metal, which in itself forms a protective layer, which is electrically insulating and which is labelled with the reference numeral 2a in Figure 1. Therefore, this bearing structure 2 operates—as explained in detail prior to the description of the figures—as an electric resistance heating element. For this reason suitable power connection lugs 9a, 9b are provided—as follows from Figure 2—on the bearing structure 2 in the corner areas, which lie diagonally opposite each other and belong to the flat bearing structure. Furthermore, Figure 2 depicts the flat shape of the bearing structure 2, which extends over the entire area of the individual fuel cell and also encompasses its edge sections, in which combustible gas passage orifices 10a and/or air passage orifices 10b are provided with respect to a gas conveyance that is integrated into the stack of fuel cells. Figure 2 shows very clearly the perforated area 2b of the bearing structure with a plurality of passage orifices 4, which are filled—as explained with reference to Figure 1—with a gas-permeable, electrically conductive material.

A fuel cell in accordance with the invention allows a defined introduction of heat to start up the fuel cell and is, therefore, characterized by a significantly reduced start-up time while simultaneously heating up efficiently. At the same time only negligible thermomechanical stresses occur, among other things, also due to the thin, light-weight bearing structure, which makes it possible to construct the cell by means of thin film technology. Finally the edges, which insulate virtually semi-automatically owing to the protective oxide layer that forms, facilitate the construction of the stack, therefore, permitting in its design a plurality of details that depart from the above explanations without abandoning the subject of the patent claims.

Patent Claims

1. Solid oxide fuel cell comprising a metal bearing structure (2), which exhibits passage orifices (4) for a gas and is intended for a cathode-electrolyte-anode unit (1), and comprising a bipolar plate (8), which is provided on the other side of the bearing structure (2), or the like, characterized in that the bearing structure (2) is made of a metal, which forms a protective oxide layer, which is electrically insulating, and operates as an electric resistance heating element for adjusting the fuel cell temperature, to which end an electric current may be guided through the bearing structure (2) between its protective oxide layers (2a); and that an electrically conductive material (5) is introduced in at least some of the passage orifices (4) of the bearing structure (2) for the purpose of providing an electric connection between the bipolar plate (8) or the like; and the associated cathode-electrolyte-anode unit (1) is introduced in such a way that the gas can pass through these passage orifices (4).
2. Solid oxide fuel cell, as claimed in claim 1, characterized in that the metal of the bearing structure (2) is an aluminum oxide former or a silicon oxide former.

3. Solid oxide fuel cell, as claimed in claim 1 or 2, characterized in that a gas permeable and electrically conductive material (5) in the form of a suitably treated metal or an electrically conductive ceramic or in the form of an electrode material is introduced into at least some of the passage orifices (4) of the bearing structure (2).
4. Solid oxide fuel cell, as claimed in claim 1 or 2, characterized in that an electrically conductive coating is applied on the protective oxide layer (2a) of the bearing structure (2) at least in the area of some of the passage orifices (4).
5. SOFC stack comprising a plurality of solid oxide fuel cells, which are stacked one above the other, as claimed in any one of the preceding claims.

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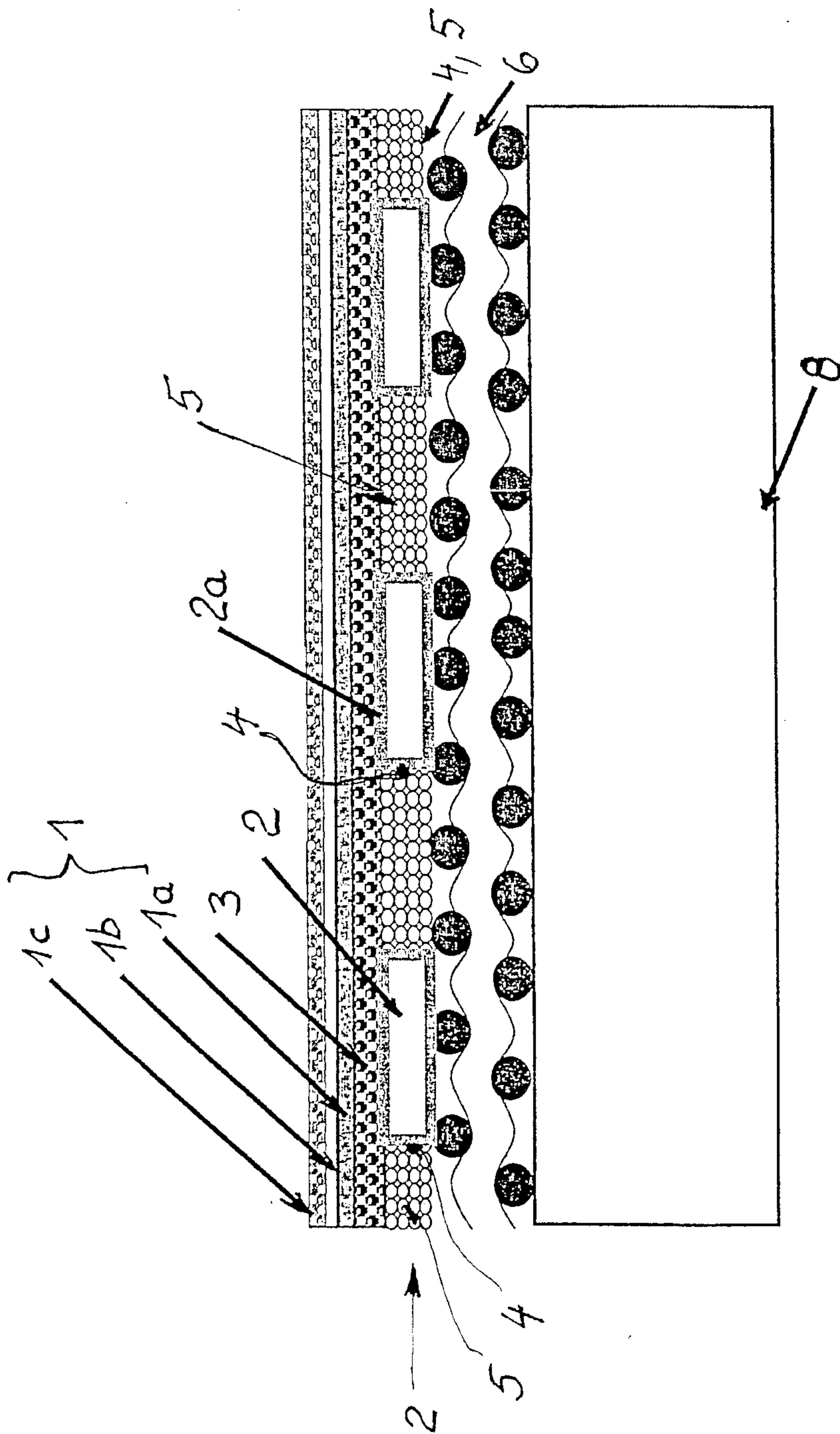


Fig. 1

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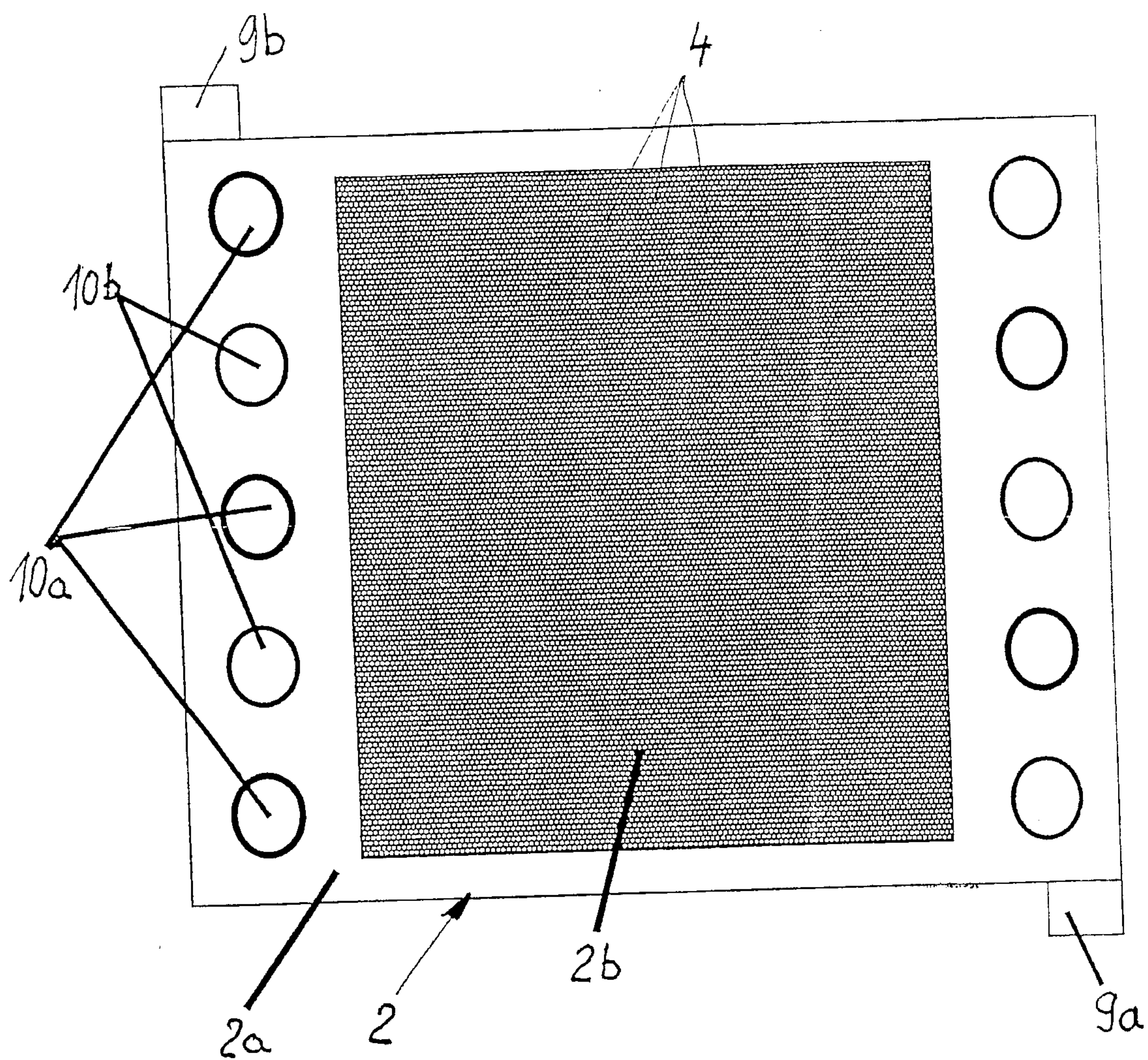


Fig. 2

