



Reduction of thermo mechanical tensions in a solid oxide fuel cell electrolyses cell stack

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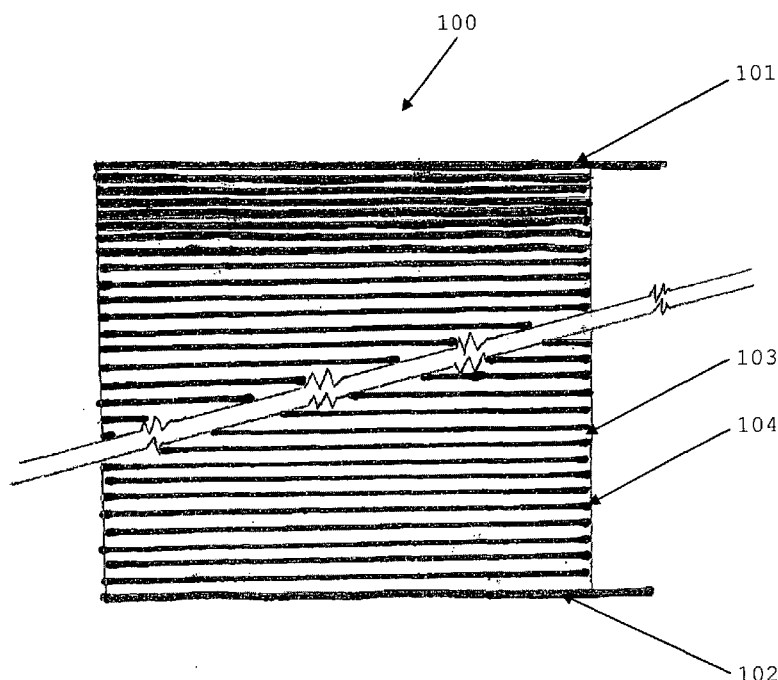
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[Continued on next page]

(54) Title: REDUCTION OF THERMO MECHANICAL TENSIONS IN A SOLID OXIDE FUEL CELL ELECTROLYSES CELL STACK



(57) Abstract: A dual end plate (101, 102) arrangement comprising a thin internal end plate for a fuel cell stack or electrolysis cell stack (100) reduces the internal thermo-mechanical tensions in the stack. The resulting stack integrity reduces or omits the need for an external stack compression force at room temperature and reduces the necessary stack compression force at operation.



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Title: Reduction of Thermo Mechanical Tensions in a Solid Oxide Fuel Cell or Electrolyses Cell Stack

5 The invention relates to reduction of the thermo mechanical tensions in fuel cell stacks or electrolysis cell stacks, in particular high temperature fuel cell stacks or electrolysis cell stacks.

10 In the following the invention will be explained in relation to a Solid Oxide Fuel Cell stack. The end plate according to the invention can, however, also be used for other types of fuel cell stacks such as Polymer Electrolyte Fuel cell (PEM) stacks or Direct Methanol Fuel Cell (DMFC) stacks. Further, the invention can also be used for electrolysis cell stacks such as Solid Oxide Electrolysis Cell stacks.

20 A Solid Oxide Fuel Cell (SOFC) comprises a solid electrolyte that enables the conduction of oxygen ions, a cathode where oxygen is reduced to oxygen ions and an anode where hydrogen is oxidised. The overall reaction in a SOFC is that hydrogen and oxygen electrochemically react to produce electricity, heat and water. In order to produce the required hydrogen, the anode normally possesses catalytic activity for the steam reforming of hydrocarbons, particularly natural gas, whereby hydrogen, carbon dioxide and carbon monoxide are generated. Steam reforming of methane, the main component of natural gas, can be described by the following equations:

30





During operation an oxidant such as air is supplied to the solid oxide fuel cell in the cathode region. Fuel such as hydrogen is supplied in the anode region of the fuel cell. Alternatively, a hydrocarbon fuel such as methane is supplied in the anode region, where it is converted to hydrogen and carbon oxides by the above reactions. Hydrogen passes through the porous anode and reacts at the anode/-electrolyte interface with oxygen ions generated on the cathode side that have diffused through the electrolyte. Oxygen ions are created in the cathode side with an input of electrons from the external electrical circuit of the cell.

To increase voltage, several cell units are assembled to form a stack and are linked together by interconnects. Interconnects serve as a gas barrier to separate the anode (fuel) and cathode (air/oxygen) sides of adjacent cell units, and at the same time they enable current conduction between the adjacent cells, i.e. between an anode of one cell with a surplus of electrons and a cathode of a neighbouring cell needing electrons for the reduction process. Further, interconnects are normally provided with a plurality of flow paths for the passage of reactant gasses: fuel gas on one side of the interconnect and oxidant gas on the opposite side.

A solid oxide fuel cell (SOFC) stack is thus a sandwich composed of ceramic fuel cells and steel interconnects and spacers. These different materials are "glued" together with glass seals to form a rigid structure. The use of such

different materials makes it impossible to avoid some differences in thermal expansion coefficients (TEC). During operation, the stack can be subjected to high temperatures up to approximately 1000 degrees Celsius causing temperature gradients in the stack and thus different thermal expansion of the different components of the stack. The resulting thermal expansion may lead to a reduction in the electrical contact between the different layers in the stack. The thermal expansion may also lead to cracks and leakage in the gas seals between the different layers leading to poorer functioning of the stack and a reduced power output. When the stack is cooled from the sealing temperature or the operation temperature, the mismatch in TEC values results in thermomechanic stresses and crack inducing energy. The potential energy which can be released when the endplate and the stack delaminates is approximately proportional to the thickness of the endplate and proportional to the square of the difference between the stack TEC and the endplate TEC. Hence both the match of TEC values and the thickness of the endplates are crucial for the integrity of the cell stack. With thick endplates integral with the stack ends, the crack inducing energy will result in delamination of the stack and loss of integrity unless the stack is protected by a compression system.

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US 5009968 seeks to solve the problem of deformation of the thick endplates themselves, by positioning these outside the stack separated by an insulation material. In addition an electrically conducting flexible membrane integral with a box-like wall structure is positioned at each end of the stack.

30

Though US 5009968 seek to solve the problem of deformation of the thick endplates outside the insulation and thus external relative to the hot stack, still the problem of differences in thermal expansion coefficients (TEC) within the stack including the internal end plates remains unsolved.

It is an object of the present invention to solve the mentioned problems by providing a new dual end plate principle according to the invention.

More specifically it is an object of the invention to provide an end plate which minimises the crack inducing energy, thereby avoiding stack delamination at reduced compression forces.

It is a further object of the invention to provide an end plate which avoids stack delamination even without compression of the stack.

More specifically it is an object of the invention to provide an end plate which omits the necessity for mechanical springs or other known extra external compression sources to compress a fuel cell stack or an electrolysis cell stack when not in operation, as well as under installation or under transportation.

It is a further object of the invention to reduce the need for stack compression whereby the compression system's pressure plate, springs etc. can be reduced in size and hence produced at a lower price. This also means that the cell stack will be lighter and more compact.

It is yet a further object of the invention to reduce the size of the compression system and/or omit a room temperature compression system which will result in a lower thermal mass of an SOFC/SOEC stack. This allows, in turn, for faster start-up, shut-down and changes in operation conditions.

These and other objects are achieved by the invention as described below.

10

Accordingly, an end plate to reduce the thermo mechanical tensions in a cell stack is provided for especially solid oxide fuel cell stacks or solid oxide electrolysis cell stacks, but also potentially to other known fuel cell types as already mentioned. In the following the cell stack will predominantly be regarded as a black box which generates electricity and heat when supplied with oxidation gas and fuel gas. The function and internal components of the fuel cell stack is considered known art and is not the subject of this invention.

20

The thick end plate for known art cell stacks has two functions; A: to close the stack, and B: to distribute load from the compression system. In the present invention this functionality is divided onto two end plates; a thin end plate for A (e.g. 0.3 mm vs. 8 mm in a known stack) and a thick external compression plate for B. The thin end plate reduces the crack inducing energy by more than a factor of 50 and improves the stack integrity significantly. In order to obtain this, it is essential that the thick compression plate which distributes the compression force can expand and contract independently of the stack. Part of the im-

25
30

proved stack integrity is contributed by the use of the same steel type in the thin end plates as in the interconnect plates (better TEC-matching); this is not possible with the current thick end-plate design. Further the thin
5 endplates are in one embodiment made in a corresponding thickness as the interconnect plates.

1. End plate for reduction of the thermo mechanical tensions in a cell stack, at least one of said end plate is
10 arranged in connection to at least one end of the cell stack, said stack further comprising at least one cell, the at least one cell comprising an anode, a cathode and an electrolyte, said at least one cell is either a Solid Oxide Fuel Cell or a Solid Oxide Electrolysis Cell, wherein said
15 end plate is planar, the material of said end plate has a thermal expansion coefficient corresponding the thermal expansion coefficient of the material of said cell, preferably within the range $9 \cdot 10^{-6} \text{ K}^{-1}$ to $14 \cdot 10^{-6} \text{ K}^{-1}$ and the thickness of said end plate is within the range 0.001 mm to 1
20 mm, preferably within the range 0.05 mm to 0.3 mm.

2. End plate according to feature 1, wherein said stack further comprises at least one pressure plate to distribute a compression force to said stack, said at least one pressure
25 plates is arranged on the opposite side of said at least one end plate relative to the cells.

3. End plate according to feature 2, wherein said stack further comprises at least one insulation member located
30 between said at least one end plate and said at least one corresponding pressure plate.

4. End plate according to any of the preceding features, wherein said at least one end plate is made of a metal with high chrome content.

5 5. End plate according to any of the preceding features, wherein said at least one end plate has side lengths corresponding the side lengths of said at least one cell in said cell stack.

10 6. End plate according to any of the preceding features, said cell stack comprises at least two cells and further comprises at least one Inter Connect plate interposed between said cells, wherein said at least one end plate has a thickness corresponding the thickness of said Inter Connect
15 plate.

7. A Solid Oxide Fuel Cell Stack or a Solid Oxide Electrolysis Stack comprising at least one end plate according to any of the features 1 to 6.

20

Fig. 1 shows a side view of a fuel cell stack or an electrolysis cell stack according to one embodiment of the invention including a thin top end plate and a thin bottom end plate.

25

Fig. 2 shows a side view of a fuel cell stack or an electrolysis cell stack according to one embodiment of the invention including thin endplates, insulation and thick compression plates.

30

Fig. 3 shows a side view of a conventional fuel cell stack with thick end plates and transportation rods.

Position number overview:

5	100, 200, 300	Solid Oxide Fuel or Electrolysis Cell stack
	101, 201	Thin end plate (top).
	102, 202	Thin end plate (bottom).
	103, 203, 303	Solid oxide fuel or electrolysis cells.
	104, 204, 304	Interconnect.
10	205	Compression plate external to stack (top).
	206	Compression plate external to stack (bottom).
15	207	Thermal and electrical insulation external to stack
	208	Gasket and thermal and electrical insulation external to stack.
	305	Thick end plate part of stack (top).
	306	Thick end plate part of stack (bottom).
20	309	Transportation rod for stack compression at room temperature.
	310	Compression springs.

One embodiment of the invention is shown on figure 1. The embodiment shows a fuel cell stack or an electrolysis cell stack (100) with thin internal endplates provided at the top (101) and the bottom (102) of the stack. The stack is an assembly of alternating layers of fuel cells or electrolysis cells (103) and metal interconnects (104). The risk of delamination between the stack and the end plates is reduced by using end plate material and thickness corre-

sponding to the material and thickness of the interconnects.

The stack according to the embodiment shown in figure 1 can
5 preserve its integrity at room temperature as it is shown
on the figure, i.e. with no need for further external compression forces applied to ensure that thermomechanic stresses and crack inducing energy occurs. Thus, the simple
stack with reduced components as compared to known art cell
10 stacks is a robust unit which can be handled, transported
and installed at room temperatures without the risk of delamination as it is pictured on figure 1, no protecting
compression system is necessary.

15 A further embodiment of the invention is shown on figure 2.
This embodiment shows a fuel cell stack or an electrolysis
cell stack (200) with thin internal endplates provided at
the top (201) and bottom (202) corresponding the cell stack
according to figure 1. The cell stack comprises alternating
20 layers of fuel cells or electrolysis cells (203) and inter-
connects (204). Where figure 1 shows a cell stack in a
situation at room temperature and in a mode where the stack
can be handled however, figure 2 shows a cell stack according
to the invention in a situation which can be the operation
25 mode. In operation mode an external compression force
(**F**), though reduced according to the invention, can be
needed. According to the invention, the integrity of the
cell stack is maintained even though the external compression
force is applied via thick rigid compression plates.
30 This is achieved by separation the thin internal end plates
(201 and 202) from the thick external rigid compression
plates (205 and 206). The separation is both mechanical,

electrical and thermal. On figure 2 the separation is achieved by an intermediate thermal and electrical insulation layer (207) positioned between the top end plate and the top compression plate and a gasket and thermal and electrical insulation layer (208) positioned between the
5 bottom end plate and the bottom compression plate. This decoupling of the thick compression plates from the stack unit including the thin endplates allows for relative free movement between the stack unit and the compression plates as compared to the known art thick endplates which are integral with, and fixed to the stack. Hence, the integrity of the cell stack is ensured, and as the TEC of the stack components *including* the thin end plates are matched by corresponding thicknesses and materials, the thermomechanic stresses and crack inducing energy in the stack unit also
10 in the operation mode according to figure 2 is reduced. The risk of delamination of the stack is thus reduced significantly.

20 On figure 3 a prior art fuel cell stack or electrolysis cell stack (300) is shown. The stack comprises alternating layers of fuel cells or electrolysis cells (303) and interconnects (304). Endplates are positioned at the top (305) and at the bottom (306) of the stack. These endplates serve to close the stack as well as to distribute load from the
25 compression system and even though they are integral with the thin layers of the stack they thus have to be thick and rigid. Even in the non-operation mode, this prior art fuel cell stack has to be subjected to a compression force. On
30 figure 3 the compression force is provided by transporting rods (309) and compression springs (310) for stack compression at room temperature. If no compression force is ap-

plied to the stack at room temperature, the stack will de-laminate due to the internal thermomechanic stresses and crack inducing energy caused by the mismatch in TEC values of the stack components: the cells, the thin interconnects
5 and the thick rigid endplates.

CLAIMS

1. End plate for reduction of the thermo mechanical tensions in a cell stack, at least one of said end plate is
5 arranged in connection to at least one end of the cell stack, said stack further comprising at least one cell, the at least one cell comprising an anode, a cathode and an electrolyte, said at least one cell is either a Solid Oxide Fuel Cell or a Solid Oxide Electrolysis Cell, wherein said
10 end plate is planar, the material of said end plate has a thermal expansion coefficient corresponding the thermal expansion coefficient of the material of said cell, preferably within the range $9 \times 10^{-6} \text{ K}^{-1}$ to $14 \times 10^{-6} \text{ K}^{-1}$, and the thickness of said end plate is within the range 0.001 mm to
15 1 mm, preferably within the range 0.05 mm to 0.3 mm.
2. End plate according to claim 1, wherein said stack further comprises at least one pressure plate to distribute a compression force to said stack, said at least one pressure
20 plates is arranged on the opposite side of said at least one end plate relative to the cells.
3. End plate according to claim 2, wherein said stack further comprises at least one insulation member located
25 between said at least one end plate and said at least one corresponding pressure plate.
4. End plate according to any of the preceding claims, wherein said at least one end plate is made of a metal with
30 high chrome content.

5. End plate according to any of the preceding claims, wherein said at least one end plate has side lengths corresponding the side lengths of said at least one cell in said cell stack.

5

6. End plate according to any of the preceding claims, said cell stack comprises at least two cells and further comprises at least one Inter Connect plate interposed between said cells, wherein said at least one end plate has a thickness corresponding the thickness of said Inter Connect plate.

10

7. A Solid Oxide Fuel Cell Stack or a Solid Oxide Electrolysis Stack comprising at least one end plate according to any of the claims 1 to 6.

15

Figure 1/3

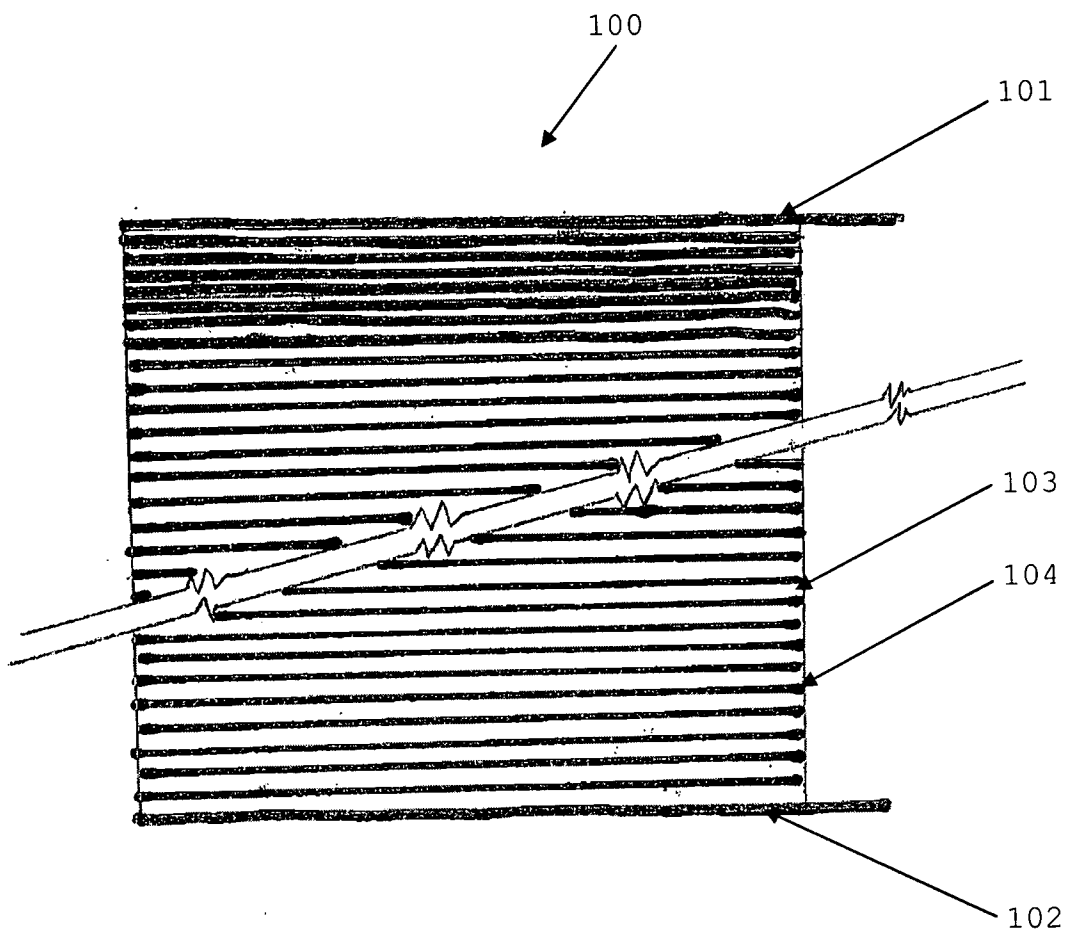


Figure 2/3

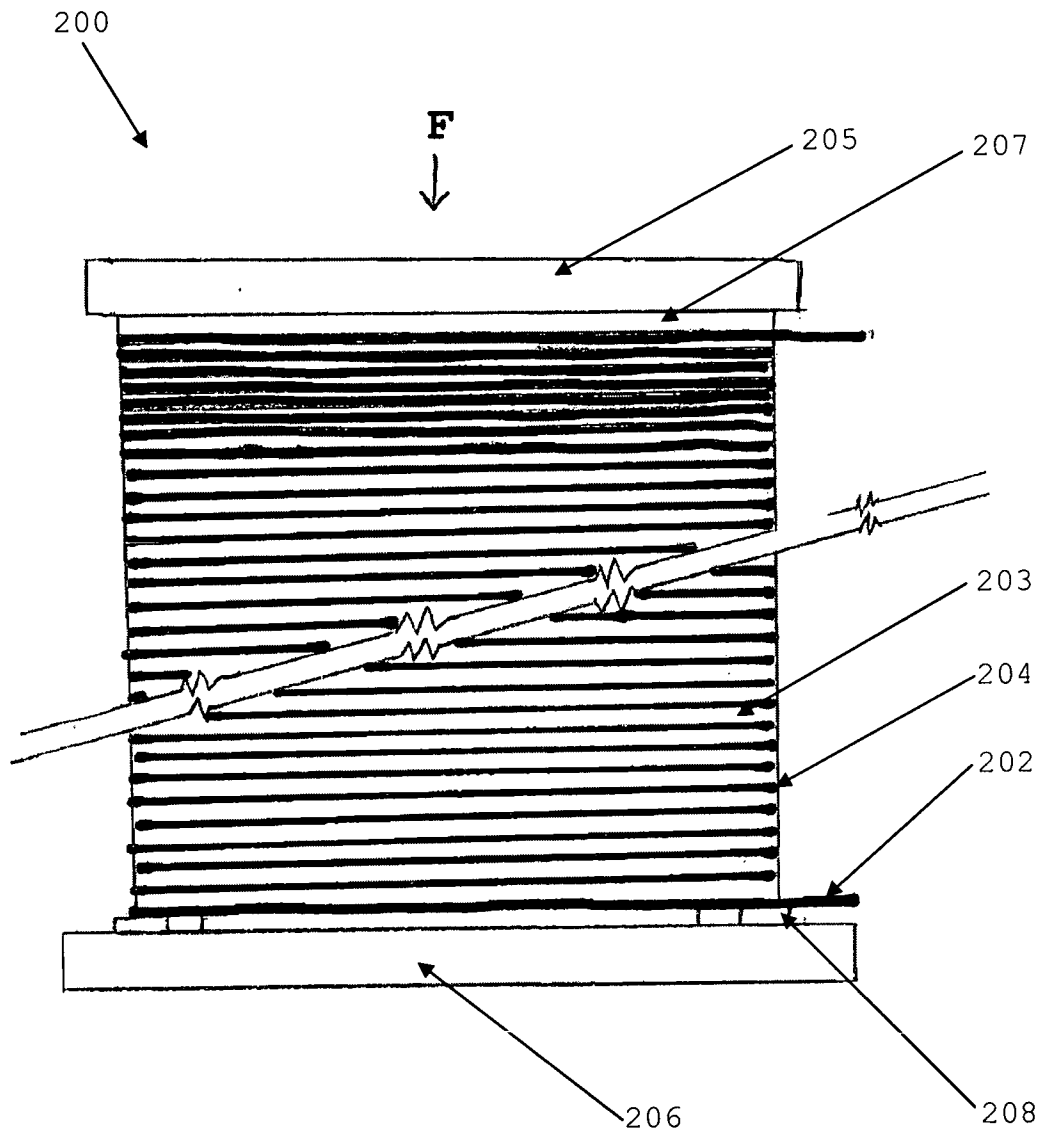
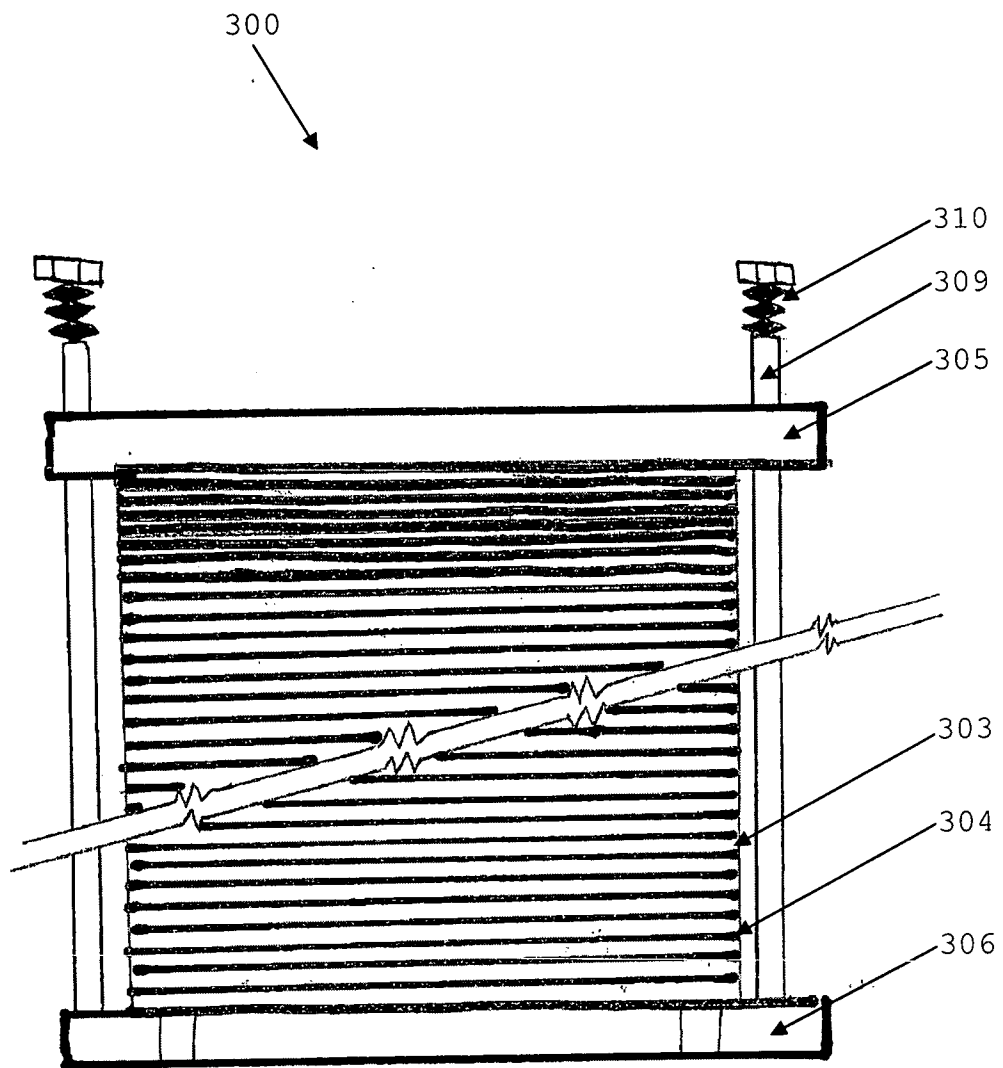


Figure 3/3



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/001938

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01M8/02 H01M8/12 H01M8/24 C25B1/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01M C25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2007 273429 A (DAINIPPON PRINTING CO LTD) 18 October 2007 (2007-10-18)	1-3, 5, 7
Y	paragraphs [0007], [0018] - [0024] figure 1	4, 6
Y	----- WO 2005/029618 A2 (TIAX LLC [US]; SRIRAMULU SURESH [US]; SINGH ANANT [US]; THIJSEN JOHAN) 31 March 2005 (2005-03-31) page 4, line 23 - page 5, line 29 page 9, line 18; table 1	4
Y	----- US 2004/101733 A1 (YAMANIS JEAN [US] ET AL) 27 May 2004 (2004-05-27) paragraphs [0023], [0028], [0037] - [0040]; figures 2, 3 ----- -/-	6

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2010/001938

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