



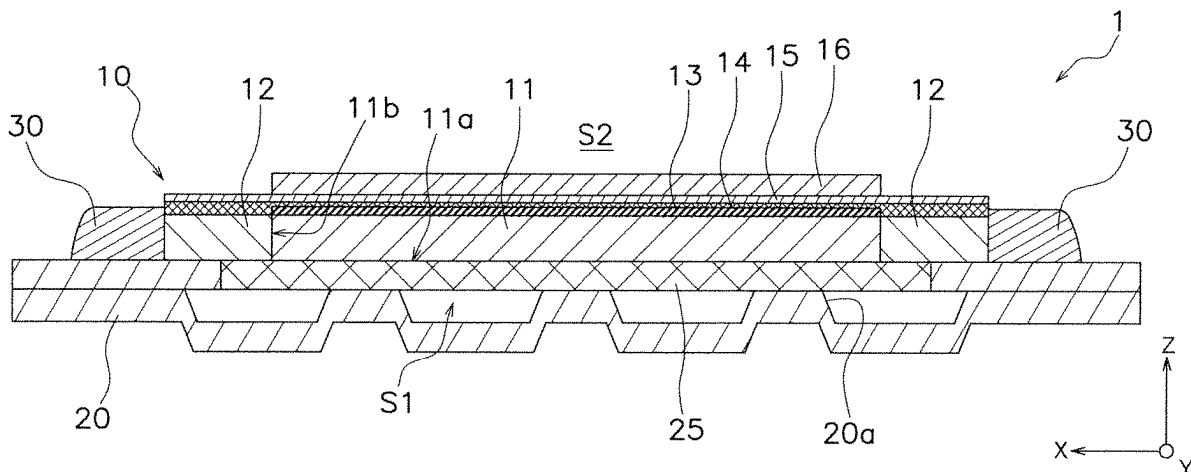
US 20250263851A1

(19) **United States**(12) **Patent Application Publication**
MIZUKI et al.(10) **Pub. No.: US 2025/0263851 A1**(43) **Pub. Date: Aug. 21, 2025**(54) **ELECTROCHEMICAL CELL AND
SEPARATOR-EQUIPPED
ELECTROCHEMICAL CELL**(30) **Foreign Application Priority Data**

Nov. 30, 2022 (JP) 2022-191610

Publication Classification(71) Applicant: **NGK INSULATORS, LTD.**,
Nagoya-shi (JP)(51) **Int. Cl.**
C25B 9/63 (2021.01)
C25B 11/031 (2021.01)
C25B 13/05 (2021.01)
H01M 8/0206 (2016.01)
H01M 8/0273 (2016.01)(72) Inventors: **Kazuhiro MIZUKI**, Kuwana-shi (JP);
Shiko IWASAKI, Nagoya-shi (JP);
Naoya AKIYAMA, Nagoya-shi (JP);
Masayuki SHINKAI, Kanie-cho (JP);
Shinji FUJISAKI, Kuwana-shi (JP);
Makoto OHMORI, Nagoya-shi (JP)(52) **U.S. Cl.**
CPC **C25B 9/63** (2021.01); **C25B 13/05**
(2021.01); **H01M 8/0206** (2013.01); **H01M**
8/0273 (2013.01); **C25B 11/031** (2021.01)(21) Appl. No.: **19/198,651**(57) **ABSTRACT**(22) Filed: **May 5, 2025**

An electrochemical cell includes a current collector layer; a frame body surrounding a side periphery of the current collector layer and having electronic insulating properties, a first electrode layer disposed on the current collector layer, an electrolyte layer disposed on the first electrode layer; and a second electrode layer disposed on an opposite side to the first electrode layer with respect to the electrolyte layer.

Related U.S. Application Data(63) Continuation of application No. PCT/JP2023/
041806, filed on Nov. 21, 2023.

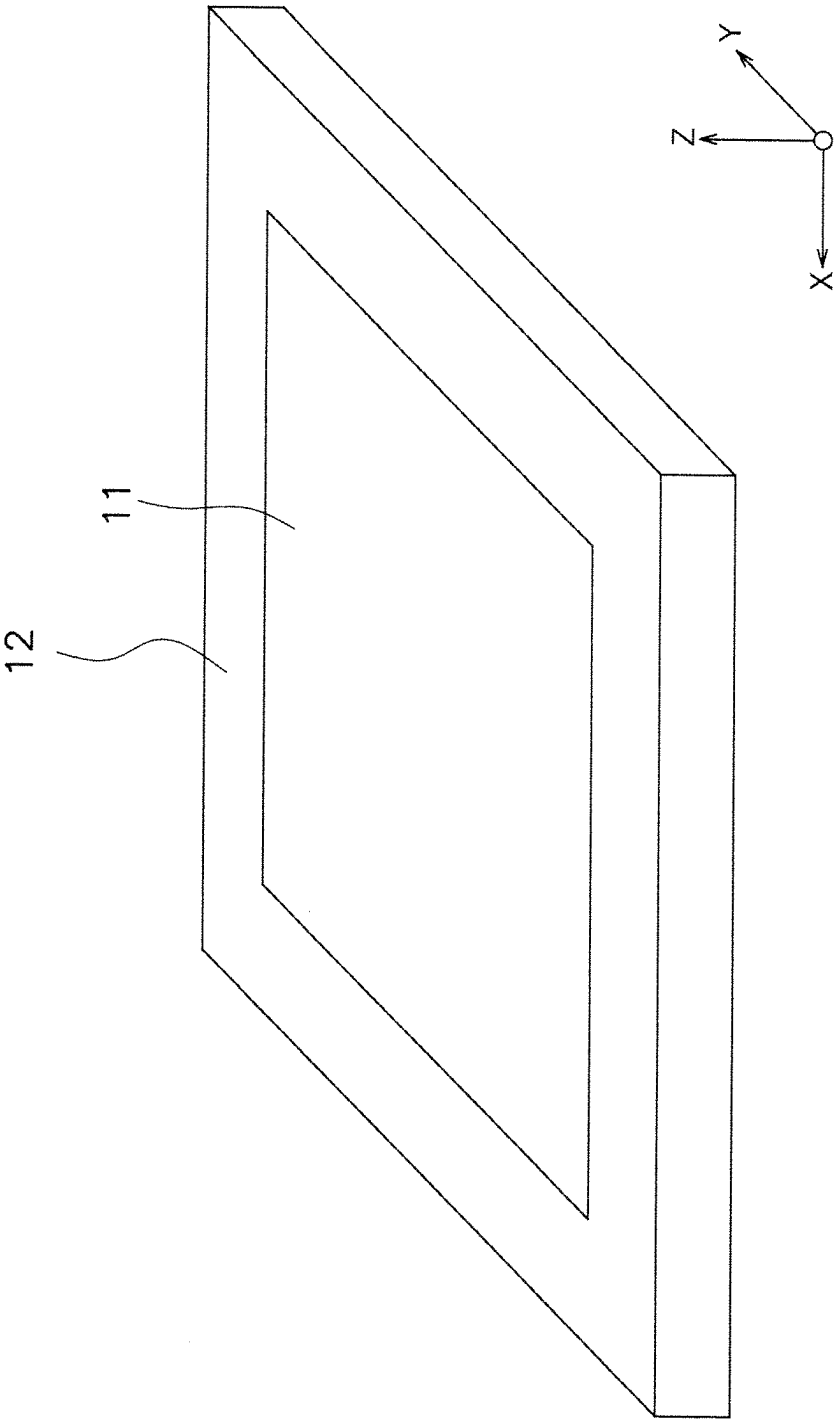


FIG. 2

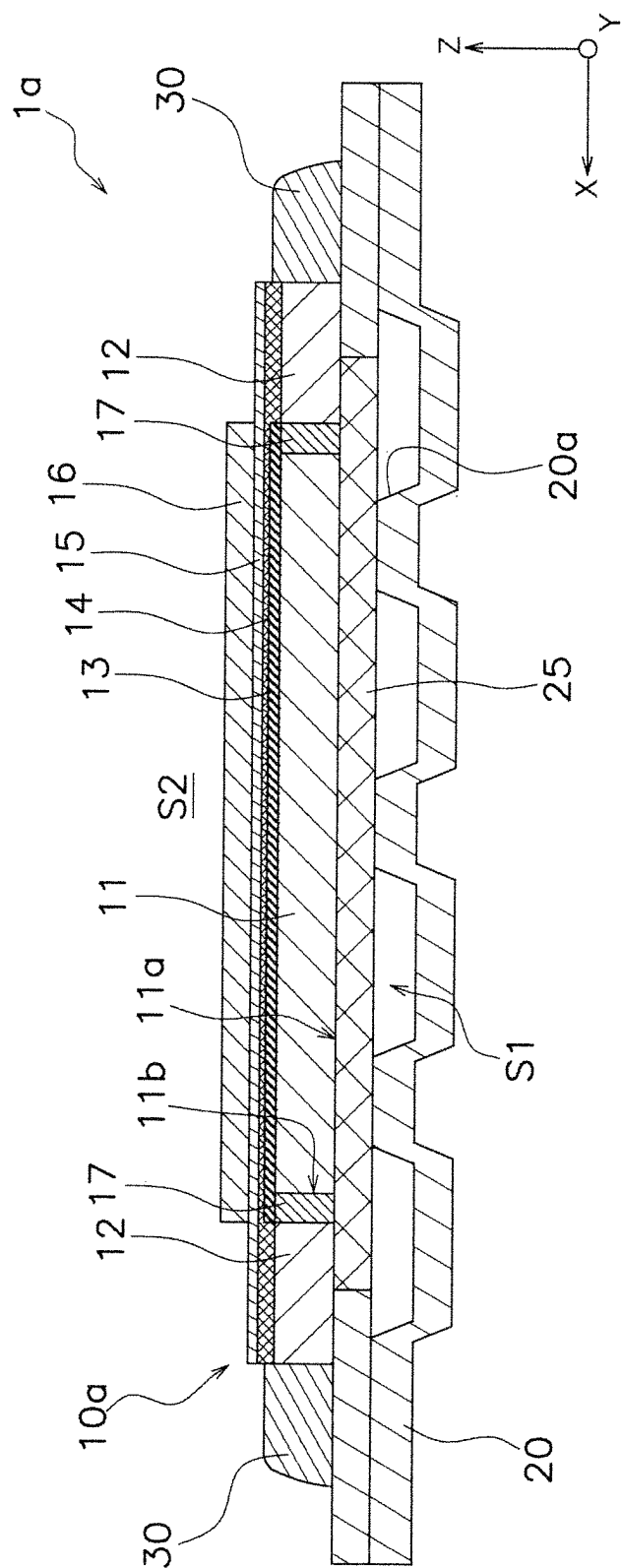


FIG. 3

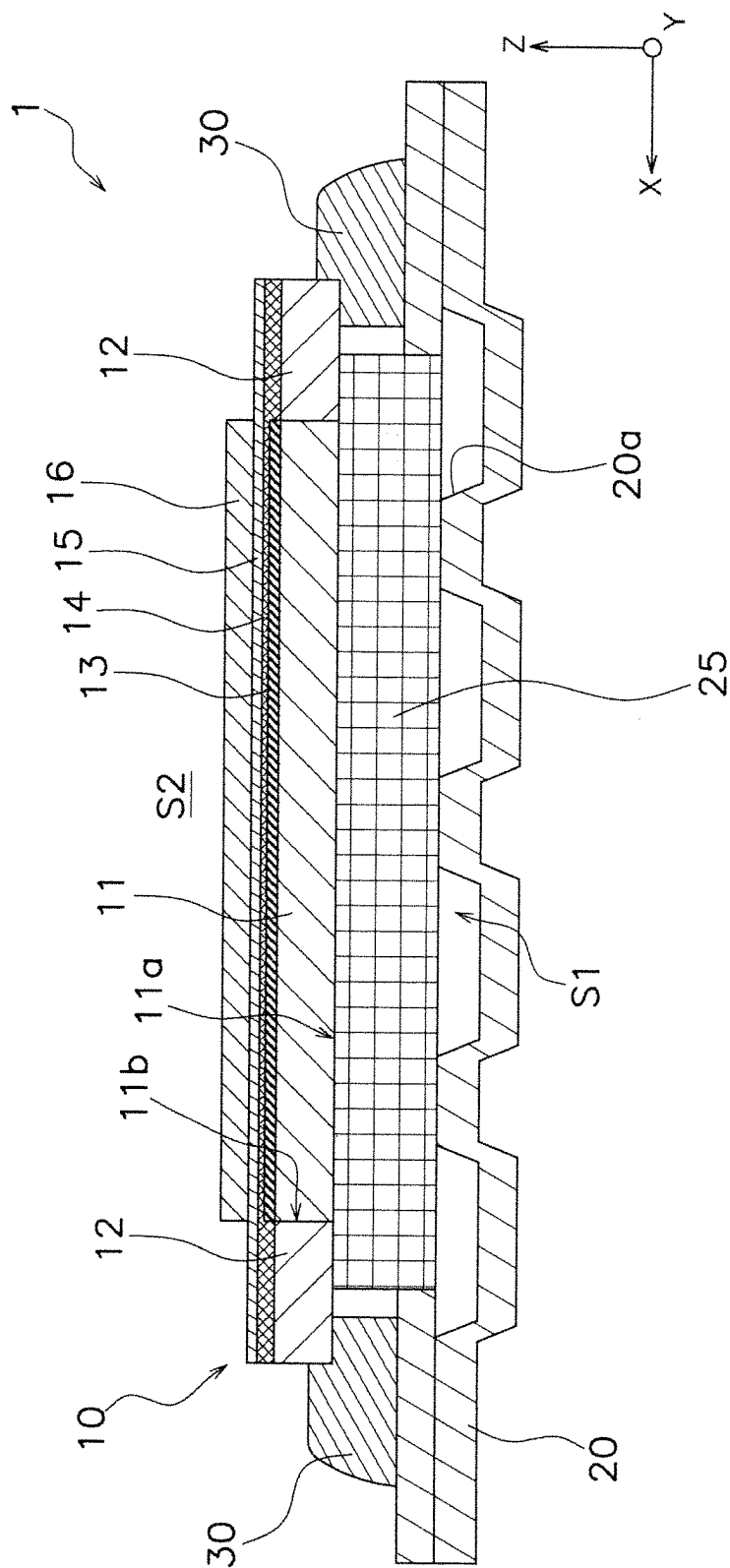


FIG. 5

ELECTROCHEMICAL CELL AND SEPARATOR-EQUIPPED ELECTROCHEMICAL CELL

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This is a continuation of PCT/JP2023/041806, filed Nov. 21, 2023, which claims priority from Japanese Application No. 2022-191610, filed Nov. 30, 2022 the entire content of which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] The present invention relates to an electrochemical cell and a separator-equipped electrochemical cell.

BACKGROUND ART

[0003] Conventionally, electrochemical cells each including an electrolyte layer disposed between a first electrode layer and a second electrode layer (e.g., electrolytic cells, fuel batteries) have been known. An electrochemical cell is bonded to a metal separator that separates a space on the first electrode layer side and a space on the second electrode layer side from each other and is electrically connected to the first electrode layer.

[0004] JP 2014-049322A discloses that a bonding portion and a sealing portion are disposed between an electrolyte layer and a metal separator. The bonding portion is made of a brazing material such as Ag brazing, and bonds an electrochemical cell to the metal separator. The sealing portion is made of an insulating material such as crystallized glass, and seals between a space on the first electrode layer side and a space on the second electrode layer side.

SUMMARY

[0005] The sealing portion described in JP 2014-049322A has not only a function of sealing between the space on the first electrode layer side and the space on the second electrode layer side, but also a function of preventing the occurrence of a short circuit between the first electrode layer and the metal separator. For this reason, in order to reliably prevent a short circuit between the first electrode layer and the metal separator, it is necessary to adjust the size and position of the sealing portion, and thus a complicated structure must be adopted.

[0006] An object of the present invention is to provide an electrochemical cell and a separator-equipped electrochemical cell with which the electrochemical cell can be easily insulated from a metal separator.

[0007] An electrochemical cell according to a first aspect of the present invention includes a current collector layer, a frame body surrounding a side periphery of the current collector layer and having electronic insulating properties, a first electrode layer disposed on the current collector layer, an electrolyte layer disposed on the first electrode layer, and a second electrode layer disposed on an opposite side to the first electrode layer with respect to the electrolyte layer.

[0008] An electrochemical cell according to a second aspect of the present invention is according to the first aspect, further including a bonding layer disposed between the current collector layer and the frame body and bonding the current collector layer to the frame body.

[0009] An electrochemical cell according to a third aspect of the present invention is according to the second aspect, in

which the bonding layer contains a first constituent element contained in the current collector layer and a second constituent element contained in the frame body.

[0010] An electrochemical cell according to a fourth aspect of the present invention is according to the third aspect, in which the bonding layer includes a composite oxide containing the first constituent element and the second constituent element.

[0011] An electrochemical cell according to a fifth aspect of the present invention is according to any one of the second to fourth aspects, in which a thermal expansion coefficient of the bonding layer is between a thermal expansion coefficient of the current collector layer and a thermal expansion coefficient of the frame body.

[0012] An electrochemical cell according to a sixth aspect of the present invention is according to any one of the second to fifth aspects, in which the electrochemical cell according to the second aspect, and a porosity of the bonding layer is 10% or less.

[0013] An electrochemical cell according to a seventh aspect of the present invention is according to any one of the first to sixth aspects, in which a porosity of the frame body is 15% or less.

[0014] An electrochemical cell according to an eighth aspect of the present invention is according to any one of the first to seventh aspects, in which a thickness of the current collector layer is greater than a thickness of the first electrode layer, a thickness of the electrolyte layer, and a thickness of the second electrode layer.

[0015] A separator-equipped electrochemical cell according to a ninth aspect of the present invention includes the electrochemical cell according to any one of aspects 1 to 8, a metal separator electrically connected to the current collector layer, and a sealing portion sealing a gap between the electrolyte layer and the metal separator.

[0016] According to the present invention, it is possible to provide an electrochemical cell and a separator-equipped electrochemical cell with which the electrochemical cell can be easily insulated from a metal separator.

BRIEF DESCRIPTION OF DRAWINGS

[0017] FIG. 1 is a cross-sectional view of a separator-equipped electrolytic cell according to Embodiment 1.

[0018] FIG. 2 is a perspective view of a frame body according to Embodiment 1.

[0019] FIG. 3 is a cross-sectional view of a separator-equipped electrolytic cell according to Embodiment 2.

[0020] FIG. 4 is a cross-sectional view of a separator-equipped electrolytic cell according to Variation 2.

[0021] FIG. 5 is a cross-sectional view of the separator-equipped electrolytic cell according to Variation 2.

DESCRIPTION OF EMBODIMENTS

1. Embodiment 1

[0022] FIG. 1 is a cross-sectional view of a separator-equipped electrolytic cell 1 according to Embodiment 1. The separator-equipped electrolytic cell 1 is an example of the "separator-equipped electrochemical cell" according to the present invention.

[0023] The separator-equipped electrolytic cell 1 includes an electrolytic cell 10, a metal separator 20, a current collector member 25, and a sealing portion 30. The electro-

lytic cell 10 is an example of the “electrochemical cell” according to the present invention. A cell stack (not shown) can be formed by stacking a plurality of separator-equipped electrolytic cells 1 in the Z-axis direction perpendicular to the X-axis direction and the Y-axis direction.

Electrolytic Cell 10

[0024] As shown in FIG. 1, the electrolytic cell 10 has a hydrogen electrode current collector layer 11, a frame body 12, a hydrogen electrode active layer 13, an electrolyte layer 14, a reaction prevention layer 15, and an oxygen electrode layer 16. The hydrogen electrode current collector layer 11 is an example of the “current collector layer” according to the present invention. The hydrogen electrode active layer 13 is an example of the “first electrode layer” according to the present invention. The oxygen electrode layer 16 is an example of the “second electrode layer” in the present invention.

[0025] The hydrogen electrode current collector layer 11, the hydrogen electrode active layer 13, the electrolyte layer 14, the reaction prevention layer 15, and the oxygen electrode layer 16 are stacked in this order in the Z-axis direction. The hydrogen electrode current collector layer 11, the frame body 12, the hydrogen electrode active layer 13, the electrolyte layer 14, and the oxygen electrode layer 16 are essential components, and the reaction prevention layer 15 is an optional component.

Hydrogen Electrode Current Collector Layer 11

[0026] The hydrogen electrode current collector layer 11 has a plate shape. The hydrogen electrode current collector layer 11 has a main surface 11a and a side surface 11b. The main surface 11a faces the metal separator 20. The side surface 11b is continuous with the main surface 11a. The side surface 11b is covered with the frame body 12. In the present embodiment, the side surface 11b is substantially perpendicular to the main surface 11a, but may be inclined inward or outward relative to the main surface 11a.

[0027] The hydrogen electrode current collector layer 11 is electrically connected to the metal separator 20 via the current collector member 25. A hydrogen electrode side space S1 is formed between the hydrogen electrode current collector layer 11 and the metal separator 20.

[0028] The hydrogen electrode current collector layer 11 has, in addition to the current collecting function, a gas diffusion function of diffusing the source gas supplied to the hydrogen electrode side space S1 toward the hydrogen electrode active layer 13.

[0029] The hydrogen electrode current collector layer 11 is a porous body having electron conductivity. The hydrogen electrode current collector layer 11 contains nickel (Ni). In the case of co-electrolysis, Ni functions as an electron-conducting material, and also functions as a thermocatalyst that promotes a thermal reaction between H₂ generated in the hydrogen electrode active layer 13 and CO₂ contained in the source gas to maintain a gas composition suitable for methanation, Fischer-Tropsch (FT) synthesis, or the like. The Ni contained in the hydrogen electrode current collector layer 11 is basically present in the state of metal Ni during the operation of the electrolytic cell 10, but a part thereof may be present in the state of nickel oxide (NiO).

[0030] The hydrogen electrode current collector layer 11 contains ceramic in addition to nickel (Ni). The ceramic may

have ionic conductivity. Examples of the ceramic that can be used include yttria (Y₂O₃), magnesia (MgO), ferric oxide (Fe₂O₃), zirconia (ZrO₂, including partially stabilized zirconia), yttria-stabilized zirconia (YSZ), calcia-stabilized zirconia (CSZ), scandia-stabilized zirconia (ScSZ), gadolinium-doped ceria (GDC), samarium-doped ceria (SDC), and a mixed material obtained by combining two or more of these.

[0031] The porosity of the hydrogen electrode current collector layer 11 is not particularly limited, but may be, for example, 20% or more and 40% or less.

[0032] The thickness of the hydrogen electrode current collector layer 11 is not particularly limited, but may be, for example, 150 μm or more and 1000 μm or less. In the present embodiment, the hydrogen electrode current collector layer 11 functions as a support of the electrolytic cell 10 together with the frame body 12. In the Z-axis direction, the thickness of the hydrogen electrode current collector layer 11 may be larger than the thickness of each of the hydrogen electrode active layer 13, the electrolyte layer 14, the reaction prevention layer 15, and the oxygen electrode layer 16. The electrolytic cell 10 according to the present embodiment is a so-called anode-supported cell. However, the electrolytic cell 10 may be a so-called electrolyte-supported cell or a so-called cathode-supported cell.

[0033] The method for forming the hydrogen electrode current collector layer 11 is not particularly limited, and tape molding, screen printing, cast molding, dry pressing, or the like can be used.

Frame Body 12

[0034] As shown in FIG. 1, the frame body 12 is disposed on the metal separator 20. The frame body 12 is positioned relative to the metal separator 20 by the sealing portion 30.

[0035] FIG. 2 is a perspective view of the frame body 12 surrounding the side periphery of the hydrogen electrode current collector layer 11. The frame body 12 has a frame-like shape. The frame body 12 surrounds the side periphery of the hydrogen electrode current collector layer 11. The “side periphery of the hydrogen electrode current collector layer 11” means the periphery of the side surface 11b described later. In the present embodiment, the frame body 12 functions as a support of the electrolytic cell 10 together with the hydrogen electrode current collector layer 11. In the present embodiment, the frame body 12 covers the entire side surface 11b of the hydrogen electrode current collector layer 11.

[0036] In the present embodiment, the planar shape of the frame body 12 is a rectangular shape, but may be a circular shape, an elliptical shape, a polygonal shape having three or more corners, or the like depending on the planar shape of the hydrogen electrode current collector layer 11.

[0037] The frame body 12 has electronic insulating properties. The frame body 12 has a function of preventing a short circuit from occurring between the hydrogen electrode current collector layer 11 and the metal separator 20. The frame body 12 is made of an electronically insulating material. Examples of the insulating material include forsterite (Mg₂SiO₄), magnesium silicate (MgSiO₃), zirconia (ZrO₂, including partially stabilized zirconia), magnesia (MgO), spinels (MgAl₂O₄ and NiAl₂O₄), yttria-stabilized zirconia (YSZ), calcia-stabilized zirconia (CSZ), nickel (Ni), nickel oxide (NiO), alumina (Al₂O₃), nickel oxide-

magnesia solid solutions ($\text{Mg}_x\text{Ni}_{(1-x)}\text{O}$ [$0 < x < 1$]), and mixed materials obtained by combining two or more of these materials.

[0038] The electronic conductivity of the frame body **12** is not particularly limited as long as it is sufficiently low, but may be 0.1 S/m or less.

[0039] The porosity of the frame body **12** is not particularly limited, but may be, for example, 0.1% or more and 15% or less. The porosity of the frame body **12** is preferably 5% or less. As a result, gas sealing properties can be imparted to the frame body **12**, and therefore, it is possible to prevent the source gas flowing into the hydrogen electrode current collector layer **11** from the hydrogen electrode side space **S1** from passing through the frame body **12** and returning to the hydrogen electrode side space **S1**. Therefore, the efficiency of gas supply from the hydrogen electrode current collector layer **11** to the hydrogen electrode active layer **13** can be improved.

[0040] The width of the frame body **12** in the X-axis direction is not particularly limited, and may be, for example, 0.5 mm or more and 10 mm or less.

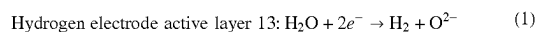
[0041] The method for forming the frame body **12** is not particularly limited, and tape molding, screen printing, cast molding, a dry pressing method, or the like can be used.

Hydrogen Electrode Active Layer **13**

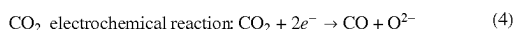
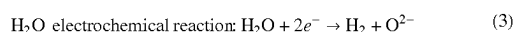
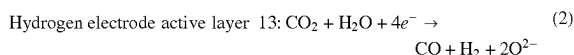
[0042] The hydrogen electrode active layer **13** functions as a cathode. The hydrogen electrode active layer **13** is disposed on the hydrogen electrode current collector layer **11**. The hydrogen electrode active layer **13** is covered with the electrolyte layer **14**.

[0043] The source gas is supplied to the hydrogen electrode active layer **13** via the hydrogen electrode current collector layer **11**. In the present embodiment, the source gas contains at least H_2O .

[0044] When the source gas contains only H_2O , the hydrogen electrode active layer **13** generates H_2 from the source gas in accordance with the electrochemical reactions of water electrolysis represented by the following formula (1).



[0045] When the source gas contains CO_2 in addition to H_2O , the hydrogen electrode active layer **13** generates H_2 , CO , and O^{2-} from the source gas according to the electrochemical reactions of co-electrolysis shown in the following formulae (2), (3), and (4).



[0046] The hydrogen electrode active layer **13** is a porous body having electronic conductivity. The hydrogen electrode active layer **13** may have ionic conductivity. The hydrogen electrode active layer **13** can be made of, for example, YSZ, CSZ, ScSZ, GDC, (SDC), (La, Sr) (Cr, Mn) O_3 , (La, Sr) TiO_3 , Sr_2 (Fe, Mo) O_6 , (La, Sr) VO_3 , (La,

Sr) FeO_3 , a mixed material obtained by combining two or more of these materials, or a composite of one or more of these materials and NiO.

[0047] The porosity of the hydrogen electrode active layer **13** is not particularly limited, and may be, for example, 20% or more and 40% or less. The thickness of the hydrogen electrode active layer **13** is not particularly limited, but may be, for example, 5 μm or more and 50 μm or less.

[0048] The method for forming the hydrogen electrode active layer **13** is not particularly limited, and tape molding, screen printing, cast molding, dry pressing, or the like can be used.

Electrolyte Layer **14**

[0049] The electrolyte layer **14** is disposed between the hydrogen electrode active layer **13** and the oxygen electrode layer **16**. In the present embodiment, since the reaction prevention layer **15** is disposed between the electrolyte layer **14** and the oxygen electrode layer **16**, the electrolyte layer **14** is disposed between the hydrogen electrode active layer **13** and the reaction prevention layer **15**, and is connected to the hydrogen electrode active layer **13** and the reaction prevention layer **15**.

[0050] The electrolyte layer **14** covers the hydrogen electrode active layer **13**. As shown in FIG. 1, the electrolyte layer **14** preferably covers the entire surface of the hydrogen electrode active layer **13**. The outer peripheral portion of the electrolyte layer **14** is connected to the frame body **12**.

[0051] The electrolyte layer **14** has a function of transmitting O^{2-} generated in the hydrogen electrode active layer **13** to the oxygen electrode layer **16** side. The electrolyte layer **14** is a dense body having ionic conductivity and not having electronic conductivity. The electrolyte layer **14** may be made of, for example, YSZ, GDC, ScSZ, SDC, or lanthanum gallate (LSGM).

[0052] The porosity of the electrolyte layer **14** is not particularly limited, but may be, for example, 0.1% or more and 7% or less. The thickness of the electrolyte layer **14** is not particularly limited, but may be, for example, 1 μm or more and 100 μm or less.

[0053] The method for forming the electrolyte layer **14** is not particularly limited, and tape molding, screen printing, cast molding, dry pressing, or the like can be used.

Reaction Prevention Layer **15**

[0054] The reaction prevention layer **15** is disposed between the electrolyte layer **14** and the oxygen electrode layer **16**. The reaction prevention layer **15** is disposed on the opposite side to the hydrogen electrode active layer **13** with respect to the electrolyte layer **14**. The reaction prevention layer **15** prevents constituent elements of the electrolyte layer **14** from reacting with constituent elements of the oxygen electrode layer **16** to form a layer having a large electric resistance.

[0055] The reaction prevention layer **15** is made of an ion conductive material. The reaction prevention layer **15** can be made of GDC, SDC, or the like.

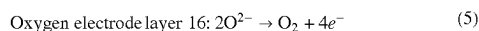
[0056] The porosity of the reaction prevention layer **15** is not particularly limited, but may be, for example, 0.1% or more and 50% or less. The thickness of the reaction prevention layer **15** is not particularly limited, and may be, for example, 1 μm or more and 50 μm or less.

[0057] The method for forming the reaction prevention layer 15 is not particularly limited, and tape molding, screen printing, cast molding, a dry pressing method, or the like can be used.

Oxygen Electrode Layer 16

[0058] The oxygen electrode layer 16 functions as an anode. The oxygen electrode layer 16 is disposed on the opposite side to the hydrogen electrode active layer 13 with respect to the electrolyte layer 14. In the present embodiment, since the reaction prevention layer 15 is disposed between the electrolyte layer 14 and the oxygen electrode layer 16, the oxygen electrode layer 16 is connected to the reaction prevention layer 15. In a case where the reaction prevention layer 15 is not disposed between the electrolyte layer 14 and the oxygen electrode layer 16, the oxygen electrode layer 16 is connected to the electrolyte layer 14.

[0059] The oxygen electrode layer 16 generates O₂ from O²⁻ transferred from the hydrogen electrode active layer 13 via the electrolyte layer 14, according to the chemical reactions of the following formula (5). The O₂ generated in the oxygen electrode layer 16 is released to an oxygen electrode side space S2.



[0060] The oxygen electrode layer 16 is a porous body having ionic conductivity and electronic conductivity. The oxygen electrode layer 16 can be made of, for example, a composite material of one or more of (La, Sr) (Co, Fe)O₃, (La, Sr)FeO₃, La(Ni, Fe)O₃, (La, Sr)CoO₃, and (Sm, Sr)CoO₃ and an ion conductive material (e.g., GDC).

[0061] The porosity of the oxygen electrode layer 16 is not particularly limited, but may be, for example, 20% or more and 60% or less. The thickness of the oxygen electrode layer 16 is not particularly limited, and may be, for example, 1 μm or more and 100 μm or less.

[0062] The method for forming the oxygen electrode layer 16 is not particularly limited, and tape molding, screen printing, cast molding, dry pressing, or the like can be used.

Metal Separator 20

[0063] The metal separator 20 is electrically connected to the hydrogen electrode current collector layer 11 via the current collector member 25. The metal separator 20 has a connection portion 20a that is in contact with the current collector member 25.

[0064] The metal separator 20 is made of a metal material having electronic conductivity. The metal separator 20 can be made of, for example, an alloy material containing Cr (chromium). Examples of such an alloy material include Fe—Cr alloy steel (e.g., stainless steel) and Ni—Cr alloy steel. The content of Cr in the metal separator 20 is not particularly limited, but may be 4 mass % or more and 30 mass % or less.

[0065] The metal separator 20 may also contain Ti (titanium) or Zr (zirconium). The content of Ti in the metal separator 20 is not particularly limited, but may be 0.01 mol % or more and 1.0 mol % or less. The content of Al in the metal separator 20 is not particularly limited, but may be 0.01 mol % or more and 0.4 mol % or less. The metal

separator 20 may contain Ti in the form of TiO₂ or may contain Zr in the form of ZrO₂ (zirconia).

[0066] The metal separator 20 may have, on its surface, an oxide film formed by oxidation of constituent elements of the metal separator 20. A typical example of the oxide film is a chromium oxide film. The chromium oxide film covers at least a part of the surface of the metal separator 20.

Current Collector Member 25

[0067] The current collector member 25 electrically connects the hydrogen electrode current collector layer 11 and the metal separator 20. As shown in FIG. 1, the current collector member 25 is disposed in the of the hydrogen electrode side space S1 between the hydrogen electrode current collector layer 11 and the metal separator 20. The current collector member 25 is in contact with the main surface 11a of the hydrogen electrode current collector layer 11 and the connection portion 20a of the metal separator 20.

[0068] The current collector member 25 has electronic conductivity and air permeability. As the current collector member 25, for example, a member of nickel, a nickel alloy, stainless steel, or the like can be used. The size, shape, and position of the current collector member 25 can be changed as appropriate. For example, in the present embodiment, the current collector member 25 is in contact with both the hydrogen electrode current collector layer 11 and the frame body 12, but does not need to be in contact with the frame body 12.

Sealing Portion 30

[0069] The sealing portion 30 positions the frame body 12 with respect to the metal separator 20. The sealing portion 30 is a dense body. The sealing portion 30 seals a gap between the electrolytic cell 10 and the metal separator 20. This prevents gases from mixing between the hydrogen electrode side space S1 and the oxygen electrode side space S2 through the gap between the electrolytic cells 10 and the metal separator 20. In addition, in a case where the frame body 12 has air permeability, mixing of gas through the frame body 12 itself is prevented by the sealing portion 30.

[0070] In the present embodiment, the sealing portion 30 is connected to the frame body 12 and the electrolyte layer 14 of the electrolytic cell 10, but when the frame body 12 does not have air permeability, the sealing portion 30 does not need to be connected to the electrolyte layer 14.

[0071] The sealing portion 30 preferably has electronic insulating properties. This makes it possible to more reliably prevent the occurrence of a short circuit between the hydrogen electrode current collector layer 11 and the metal separator 20. However, as described above, the frame body 12 can prevent a short circuit between the hydrogen electrode current collector layer 11 and the metal separator 20. As a result, even if the sealing portion 30 has a short circuit preventing function, the sealing portion 30 may be auxiliary.

[0072] The sealing portion 30 can be formed of, for example, glass, glass ceramics (crystallized glass), a composite of glass and ceramics, or the like.

Features

[0073] The electrolytic cell 10 includes the frame body 12 surrounding the side periphery of the hydrogen electrode current collector layer 11. Therefore, a short circuit between the hydrogen electrode current collector layer 11 and the

metal separator 20 can be prevented. As a result, as long as the sealing portion 30 has a gas sealing function, the sealing portion 30 does not need to have a short circuit preventing function, so that the configuration of the sealing portion 30 can be simplified. And thus, the electrolytic cell 10 can be easily insulated from the metal separator 20.

[0074] In addition, since the hydrogen electrode current collector layer 11 and the frame body 12 function as a support of the electrolytic cell 10, the strength of the electrolytic cell 10 can be improved. Therefore, it is possible to prevent the electrolytic cell 10 from being damaged by an external force when the electrolytic cell 10 is assembled to the metal separator 20 or a thermal stress generated during the operation of the electrolytic cell 10.

[0075] Furthermore, when Ni contained in the hydrogen electrode current collector layer 11 aggregates during the operation of the electrolytic cell 10, the hydrogen electrode current collector layer 11 is likely to be deformed, but since the hydrogen electrode current collector layer 11 is surrounded by the frame body 12, the deformation of the hydrogen electrode current collector layer 11 can be suppressed.

2. Embodiment 2

[0076] FIG. 3 is a cross-sectional view of a separator-equipped electrolytic cell 1a according to Embodiment 2. The separator-equipped electrolytic cell 1a according to the present embodiment differs from the separator-equipped electrolytic cell 1 according to Embodiment 1 in that the electrolytic cell 10a has a bonding layer 17. Hereinafter, the difference will be mainly described.

[0077] The electrolytic cell 10a according to the present embodiment has the bonding layer 17. The bonding layer 17 is disposed between the hydrogen electrode current collector layer 11 and the frame body 12. The bonding layer 17 is preferably disposed over the entire gap between the hydrogen electrode current collector layer 11 and the frame body 12, but may be disposed at at least a portion of the gap between the hydrogen electrode current collector layer 11 and the frame body 12.

[0078] The bonding layer 17 bonds the hydrogen electrode current collector layer 11 to the frame body 12. As a result, expansion and contraction of the hydrogen electrode current collector layer 11 caused by oxidation reduction of the hydrogen electrode current collector layer 11 can be suppressed, so that the bondability between the hydrogen electrode current collector layer 11 and the frame body 12 can be maintained over a long period of time.

[0079] The bonding layer 17 preferably contains a first constituent element contained in the hydrogen electrode current collector layer 11 and a second constituent element contained in the frame body 12. This can further improve the bondability between the bonding layer 17 and each of the hydrogen electrode current collector layer 11 and the frame body 12.

[0080] In this case, the bonding layer 17 may include a composite oxide containing the first constituent element and the second constituent element. When the bonding layer 17 contains such a composite oxide, the progress of reaction at the time of sintering due to the eutectic point is promoted, and a stronger interface is formed.

[0081] A thermal expansion coefficient of the bonding layer 17 is preferably a value between a thermal expansion coefficient of the hydrogen electrode current collector layer

11 and a thermal expansion coefficient of the frame body 12. As a result, during the operation of the electrolytic cell 10a, the thermal stress generated due to the difference in thermal expansion coefficient between the hydrogen electrode current collector layer 11 and the frame body 12 can be alleviated in the bonding layer 17, so that the bondability between the bonding layer 17 and each of the hydrogen electrode current collector layer 11 and the frame body 12 can be further improved.

[0082] The bonding layer 17 is preferably a dense body having gas sealing properties. As a result, the source gas flowing into the hydrogen electrode current collector layer 11 from the hydrogen electrode side space S1 can be prevented from returning to the hydrogen electrode side space S1 from the side surface 11b of the hydrogen electrode current collector layer 11. Therefore, the efficiency of gas supply from the hydrogen electrode current collector layer 11 to the hydrogen electrode active layer 13 can be improved. In addition, since the bonding area between the bonding layer 17 and each of the hydrogen electrode current collector layer 11 and the frame body 12 can be increased, the bondability between the bonding layer 17 and each of the hydrogen electrode current collector layer 11 and the frame body 12 can be further improved. From these viewpoints, the porosity of the bonding layer 17 is preferably 10% or less, and more preferably 5% or less.

[0083] The bonding layer 17 can be made of, for example, nickel (Ni), nickel oxide (NiO), yttria (Y_2O_3), magnesia (MgO), ferric oxide (Fe_2O_3), zirconia (ZrO_2 , including partially stabilized zirconia), alumina (Al_2O_3), calcia (CaO), silica (Si_2O_3), spinels ($MgAl_2O_4$, $NiAl_2O_4$), YAG ($Y_3Al_5O_{12}$), YAM ($Y_4Al_2O_9$), a nickel oxide-magnesia solid-solution ($Mg_xNi_{(1-x)}O[0 < x < 1]$), a mixed material obtained by combining two or more of these materials, or the like.

[0084] The method for forming the bonding layer 17 is not particularly limited, and tape molding, screen printing, cast molding, dry pressing, or the like can be used.

[0085] In the present embodiment as well, the frame body 12 surrounds the side periphery of the hydrogen electrode current collector layer 11. "The frame body 12 surrounding the side periphery of the hydrogen electrode current collector layer 11" is a concept including not only a case where the frame body 12 is in direct contact with the hydrogen electrode current collector layer 11 as in Embodiment 1 described above, but also a case where the bonding layer 17 interposed between the frame body 12 and the hydrogen electrode current collector layer 11 is in direct contact with the hydrogen electrode current collector layer 11 as in the present embodiment.

Variations of Embodiments

[0086] Although the embodiments of the present invention have been described thus far, the present invention is not limited thereto, and various variations can be made without departing from the gist of the present invention.

Variation 1

[0087] In Embodiments 1 and 2, the frame body 12 surrounds only the side periphery of the hydrogen electrode current collector layer 11 of the electrolytic cell 10, but the present invention is not limited thereto. The frame body 12

may surround the side periphery of the hydrogen electrode active layer 13, or may surround the side periphery of the electrolyte layer 14.

Variation 2

[0088] Although the frame body 12 is disposed on the metal separator 20 in Embodiments 1 and 2, the frame body 12 may alternatively be disposed on the sealing portion 30 as shown in FIG. 4. Further, when the frame body 12 does not have air permeability, the sealing portion 30 may be connected to the frame body 12 and need not connected to the electrolyte layer 14, as shown in FIG. 5.

Variation 3

[0089] In Embodiments 1 and 2, the hydrogen electrode active layer 13 functions as a cathode and the oxygen electrode layer 16 functions as an anode, but the hydrogen electrode active layer 13 may function as an anode and the oxygen electrode layer 16 may function as a cathode. In this case, the constituent materials of the hydrogen electrode active layer 13 and the oxygen electrode layer 16 are exchanged, and the source gas is caused to flow on the outer surface of the hydrogen electrode active layer 13. The hydrogen electrode current collector layer 11 functions as an oxygen electrode current collector layer, while the configuration and function of the oxygen electrode current collector layer are the same as the configuration and function of the hydrogen electrode current collector layer 11 described in Embodiment 1.

Variation 4

[0090] In Embodiments 1 and 2, the electrolytic cell 10 has been described as an example of the electrochemical cell, but the electrochemical cell is not limited to the electrolytic cell. An electrochemical cell is a general term for an element in which a pair of electrodes are arranged so that an electromotive force is generated from an overall oxidation reduction reaction in order to convert electric energy into chemical energy, and an element for converting chemical energy into electric energy. Accordingly, the electrochemical cell includes, for example, a fuel cell using oxide ions or protons as carriers.

REFERENCE SIGNS LIST

- [0091] 1, 1a Separator-equipped electrolytic cell
- [0092] 10, 10a Electrolytic cell
- [0093] 11 Hydrogen electrode current collector layer
- [0094] 12 Frame body
- [0095] 13 Hydrogen electrode active layer
- [0096] 14 Electrolyte layer

- [0097] 15 Reaction prevention layer
 - [0098] 16 Oxygen electrode layer
 - [0099] 17 Bonding layer
 - [0100] 20 Metal separator
 - [0101] 30 Sealing portion
1. An electrochemical cell comprising:
 - a current collector layer;
 - a frame body surrounding a side periphery of the current collector layer and having electronic insulating properties;
 - a first electrode layer disposed on the current collector layer;
 - an electrolyte layer disposed on the first electrode layer; and
 - a second electrode layer disposed on an opposite side to the first electrode layer with respect to the electrolyte layer.
 2. The electrochemical cell according to claim 1, further comprising
 - a bonding layer disposed between the current collector layer and the frame body and bonding the current collector layer to the frame body.
 3. The electrochemical cell according to claim 2, wherein the bonding layer contains a first constituent element contained in the current collector layer and a second constituent element contained in the frame body.
 4. The electrochemical cell according to claim 3, wherein the bonding layer includes a composite oxide containing the first constituent element and the second constituent element.
 5. The electrochemical cell according to claim 2, wherein a thermal expansion coefficient of the bonding layer is between a thermal expansion coefficient of the current collector layer and a thermal expansion coefficient of the frame body.
 6. The electrochemical cell according to claim 2, wherein a porosity of the bonding layer is 10% or less.
 7. The electrochemical cell according to claim 1, wherein a porosity of the frame body is 15% or less.
 8. The electrochemical cell according to claim 1, wherein a thickness of the current collector layer is greater than a thickness of the first electrode layer, a thickness of the electrolyte layer, and a thickness of the second electrode layer.
 9. A separator-equipped electrochemical cell comprising: the electrochemical cell according to any one of claim 1; a metal separator electrically connected to the current collector layer; and a sealing portion sealing a gap between the electrochemical cell and the metal separator.

* * * * *