US Patent & Trademark Office
Patent Public Search | Text View

United States Patent Application Publication	20250263851
Kind Code	A1
Publication Date	August 21, 2025
Inventor(s)	MIZUKI; Kazuhiro et al.

ELECTROCHEMICAL CELL AND SEPARATOR-EQUIPPED ELECTROCHEMICAL CELL

Abstract

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.

Inventors: **MIZUKI; Kazuhiro (Kuwana-shi, JP), IWASAKI; Shiko (Nagoya-shi, JP), AKIYAMA; Naoya (Nagoya-shi, JP), SHINKAI; Masayuki (Kanie-cho, JP), FUJISAKI; Shinji (Kuwana-shi, JP), OHMORI; Makoto (Nagoya-shi, JP)**

Applicant: **NGK INSULATORS, LTD.** (Nagoya-shi, JP)

Family ID: **1000008617550**

Appl. No.: **19/198651**

Filed: **May 05, 2025**

Foreign Application Priority Data

JP	2022-191610	Nov. 30, 2022

Related U.S. Application Data

parent WO continuation PCT/JP2023/041806 20231121 PENDING child US 19198651

Publication Classification

Int. Cl.: **C25B9/63** (20210101); **C25B11/031** (20210101); **C25B13/05** (20210101); **H01M8/0206** (20160101); **H01M8/0273** (20160101)

U.S. Cl.:

CPC **C25B9/63** (20210101); **C25B13/05** (20210101); **H01M8/0206** (20130101); **H01M8/0273** (20130101); C25B11/031 (20210101)

Background/Summary

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.

Description

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 electrolytic 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 **11***a* and a side surface **11***b*. The main surface **11***a* faces the metal separator **20**. The side surface **11***b* is continuous with the main surface **11***a*. The side surface **11***b* is covered with the frame body **12**. In the present embodiment, the side surface **11***b* is substantially perpendicular to the main surface **11***a*, but may be inclined inward or outward relative to the main surface **11***a*.

[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 S**1** 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 S**1** 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 H.sub.2 generated in the hydrogen electrode active layer **13** and CO.sub.2 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 (Y.sub.2O.sub.3), magnesia (MgO), ferric oxide (Fe.sub.2O.sub.3), zirconia (ZrO.sub.2, 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 **11***b* 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 **11***b* 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 (Mg_2SiO_4), magnesium silicate ($MgSiO_3$), zirconia (ZrO_2, including partially stabilized zirconia), magnesia (MgO), spinels ($MgAl_2O_4$ and $NiAl_2O_4$), yttria-stabilized zirconia (YSZ), calcia-stabilized zirconia (CSZ), nickel (Ni), nickel oxide (NiO), alumina (Al_2O_3), nickel oxide-magnesia solid solutions ($Mg_xNi_{(1-x)}O[0<x<1]$), 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 S**1** from passing through the frame body **12** and returning to the hydrogen electrode side space S**1**. 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).

[00001] Hydrogen electrode active layer 13: $H_2O+2e^- \rightarrow H_2+O^{2-}$ (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).

[00002]

Hydrogen electrode active layer 13: $CO_2 + H_2O + 4e^-$ .fwdarw. $CO + H_2 + 2O^{2-}$ (2)

H_2O electrochemical reaction: $H_2O + 2e^-$ .fwdarw. $H_2 + O^{2-}$ (3)

CO_2 electrochemical reaction: $CO_2 + 2e^-$ .fwdarw. $CO + O^{2-}$ (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.sub.3, (La, Sr) TiO.sub.3, Sr.sub.2 (Fe, Mo).sub.2O.sub.6, (La, Sr)VO.sub.3, (La, Sr)FeO.sub.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.sup.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 O.sub.2 from O.sup.2− transferred from the hydrogen electrode active layer **13** via the electrolyte layer **14**, according to the chemical reactions of the following formula (5). The O.sub.2 generated in the oxygen electrode layer **16** is released to an oxygen electrode side space S**2**.

[00003] Oxygen electrode layer 16: $2O^{2-}$ .fwdarw. $O_2 + 4e^-$ (5)

[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)O.sub.3, (La, Sr)FeO.sub.3, La(Ni, Fe)O.sub.3, (La, Sr)CoO.sub.3, and (Sm, Sr)CoO.sub.3 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 **20***a* 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 ZrO.sub.2 (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 S**1** 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 **11***a* of the hydrogen electrode current collector layer **11** and the connection portion **20***a* 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 S**1** and the oxygen electrode side space S**2** 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 **1***a* according to Embodiment 2. The separator-equipped electrolytic cell **1***a* according to the present embodiment differs from the separator-equipped electrolytic cell **1** according to Embodiment 1 in that the electrolytic cell **10***a* has a bonding layer **17**. Hereinafter, the difference will be mainly described.

[0077] The electrolytic cell **10***a* 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 **10***a*, 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 S**1** can be prevented from returning to the hydrogen electrode side space S**1** from the side surface **11***b* 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.sub.2O.sub.3), magnesia (MgO), ferric oxide (Fe.sub.2O.sub.3), zirconia (ZrO.sub.2, including partially stabilized zirconia), alumina (Al.sub.2O.sub.3), calcia (CaO), silica (Si.sub.2O.sub.3), spinels (MgAl.sub.2O.sub.4, NiAl.sub.2O.sub.4), YAG (Y.sub.3Al.sub.5O.sub.12), YAM (Y.sub.4Al.sub.2O.sub.9), a nickel oxide-magnesia solid-solution (Mg.sub.xNi.sub.(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**, **1***a* Separator-equipped electrolytic cell [0092] **10**, **10***a* 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

Claims

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.