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(54) ALLOY MEMBER

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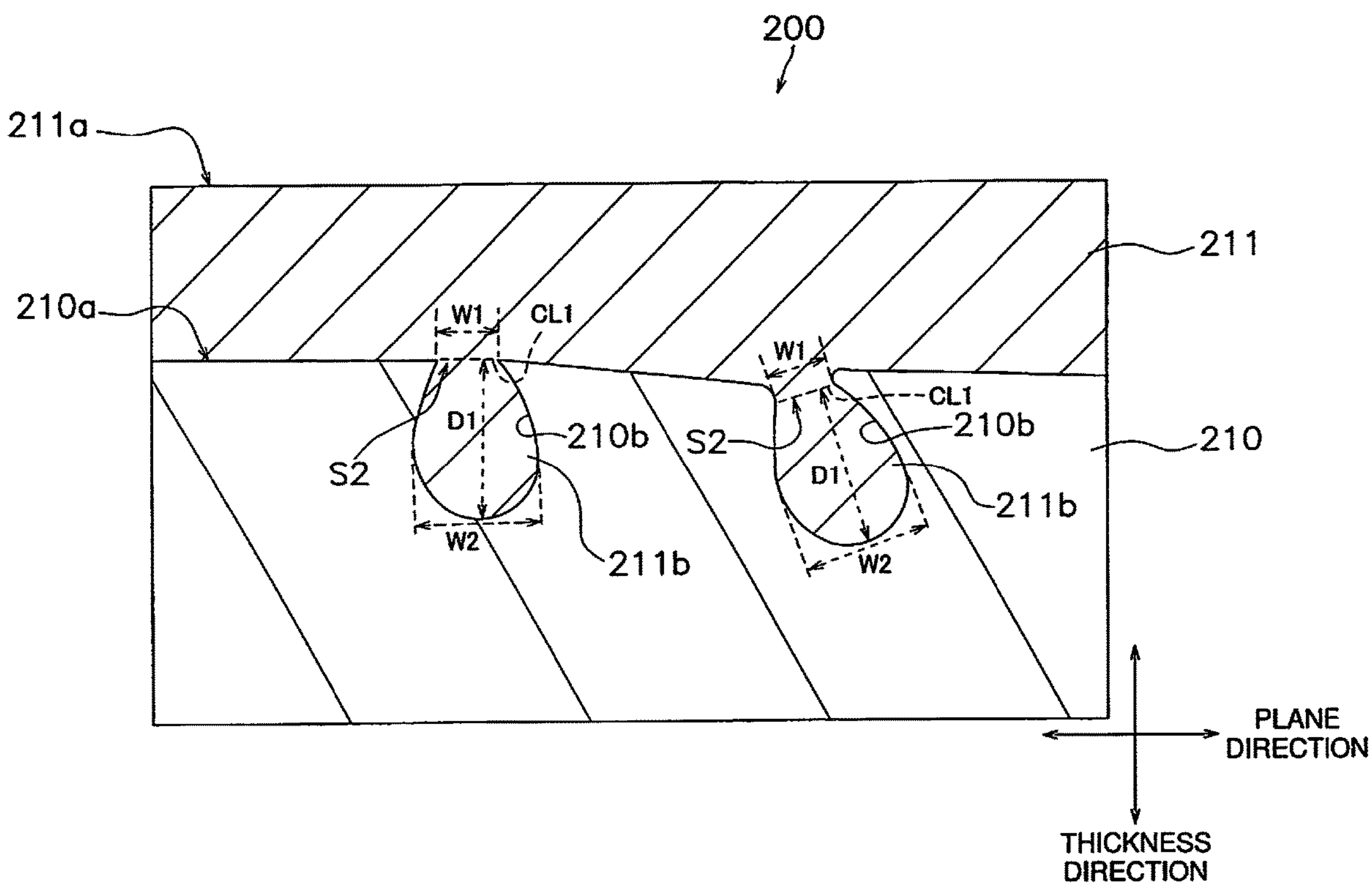
(57) **ABSTRACT**

The alloy member includes a base member constituted by an alloy material containing chromium, a chromium oxide layer for covering at least a portion of a surface of the base member, a pore that is formed in an interface region of the base member that is located 30 μm or less from an interface between the chromium oxide layer and the base member, and an extending portion extending from the pore into the base member. The pore is configured to inhibit separation of the chromium oxide layer from the base member The extending portion contains an oxide of an element whose equilibrium oxygen pressure is lower than that of a major element of the base member.



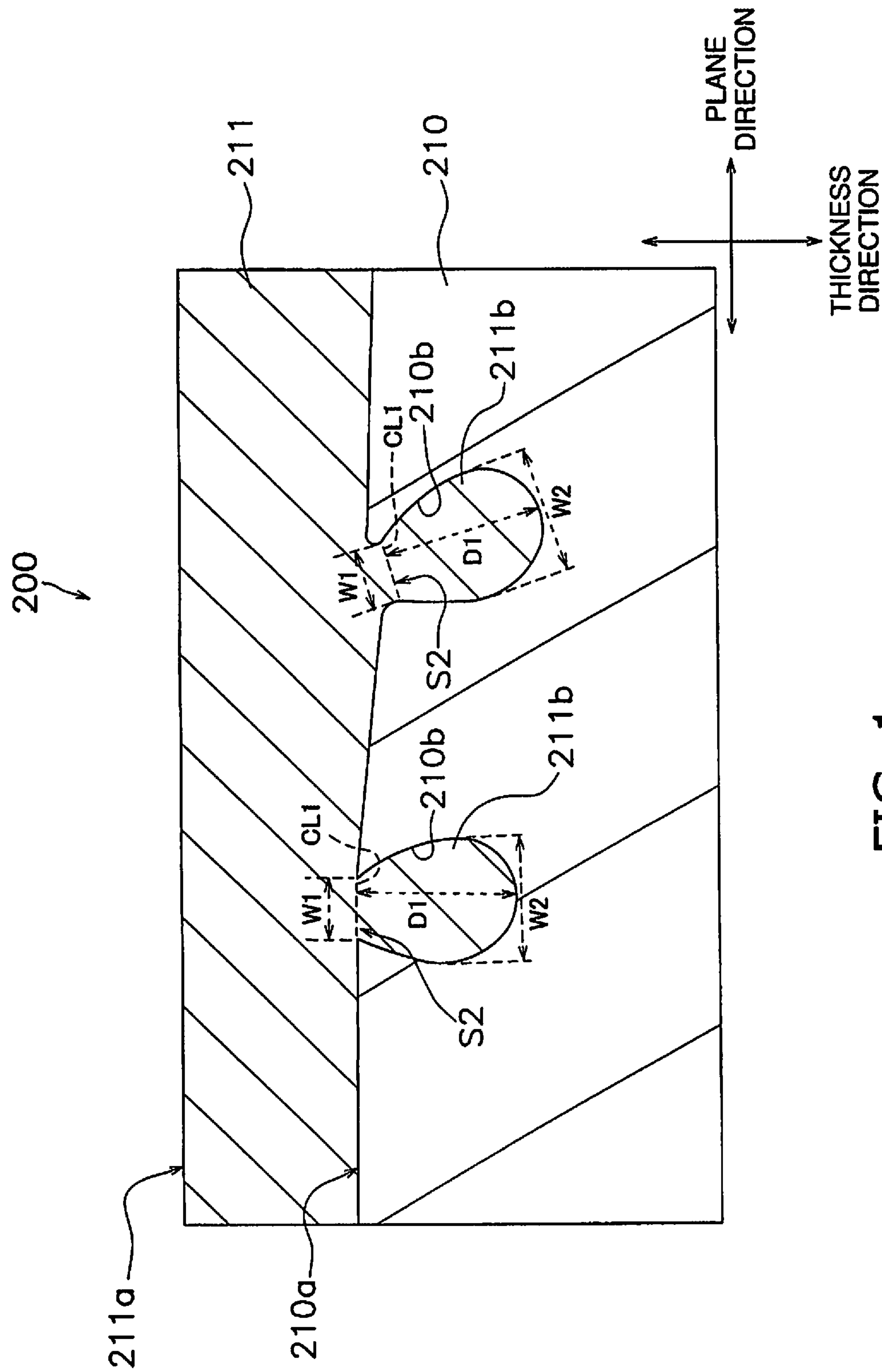

200
211
210
PLANE DIRECTION
THICKNESS DIRECTION
211b
210b
CL1
W1
W2
D1
S2
211b
210b
CL1
W1
W2
D1
S2
211a
210a

FIG. 1

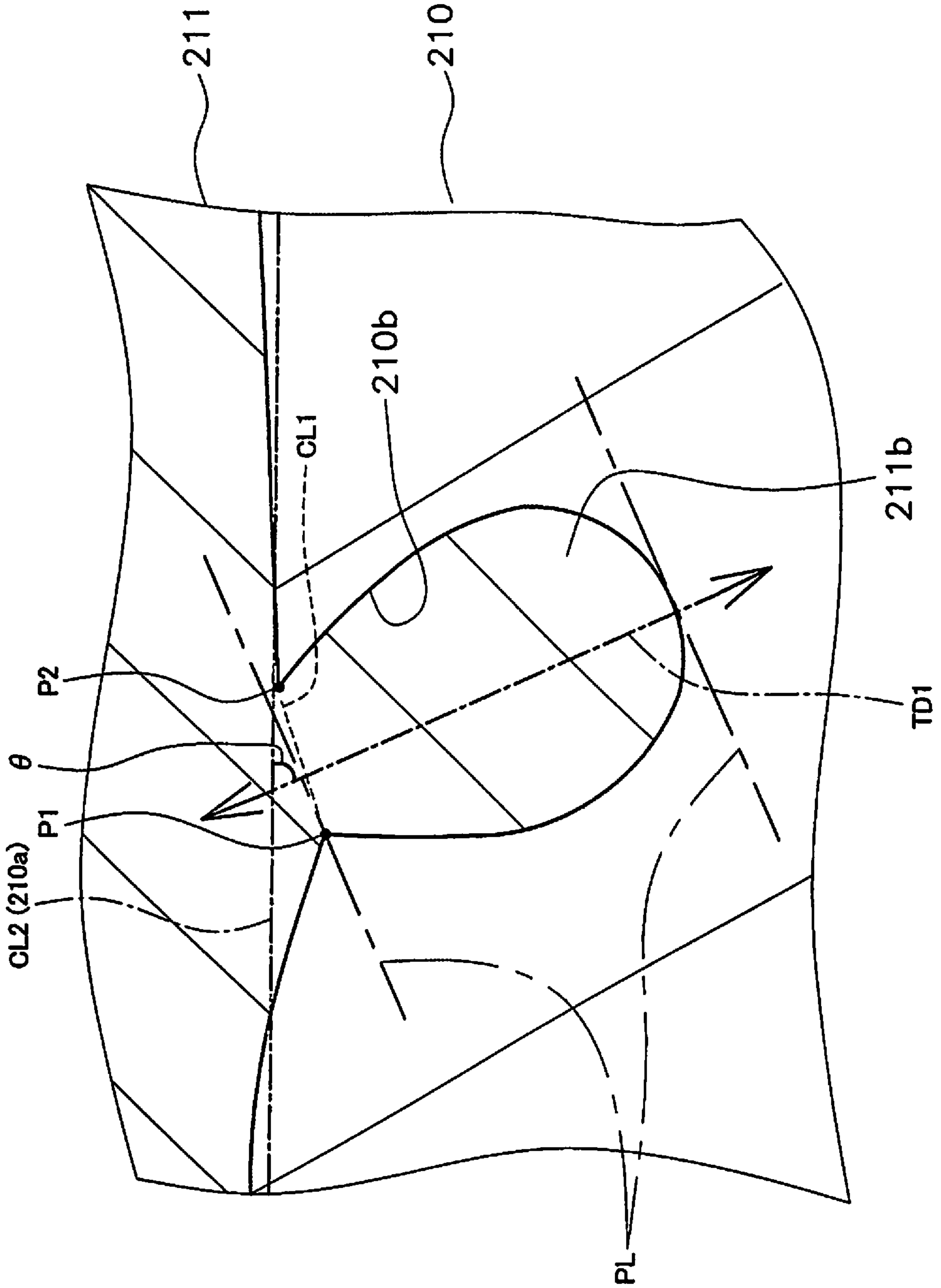


FIG. 2

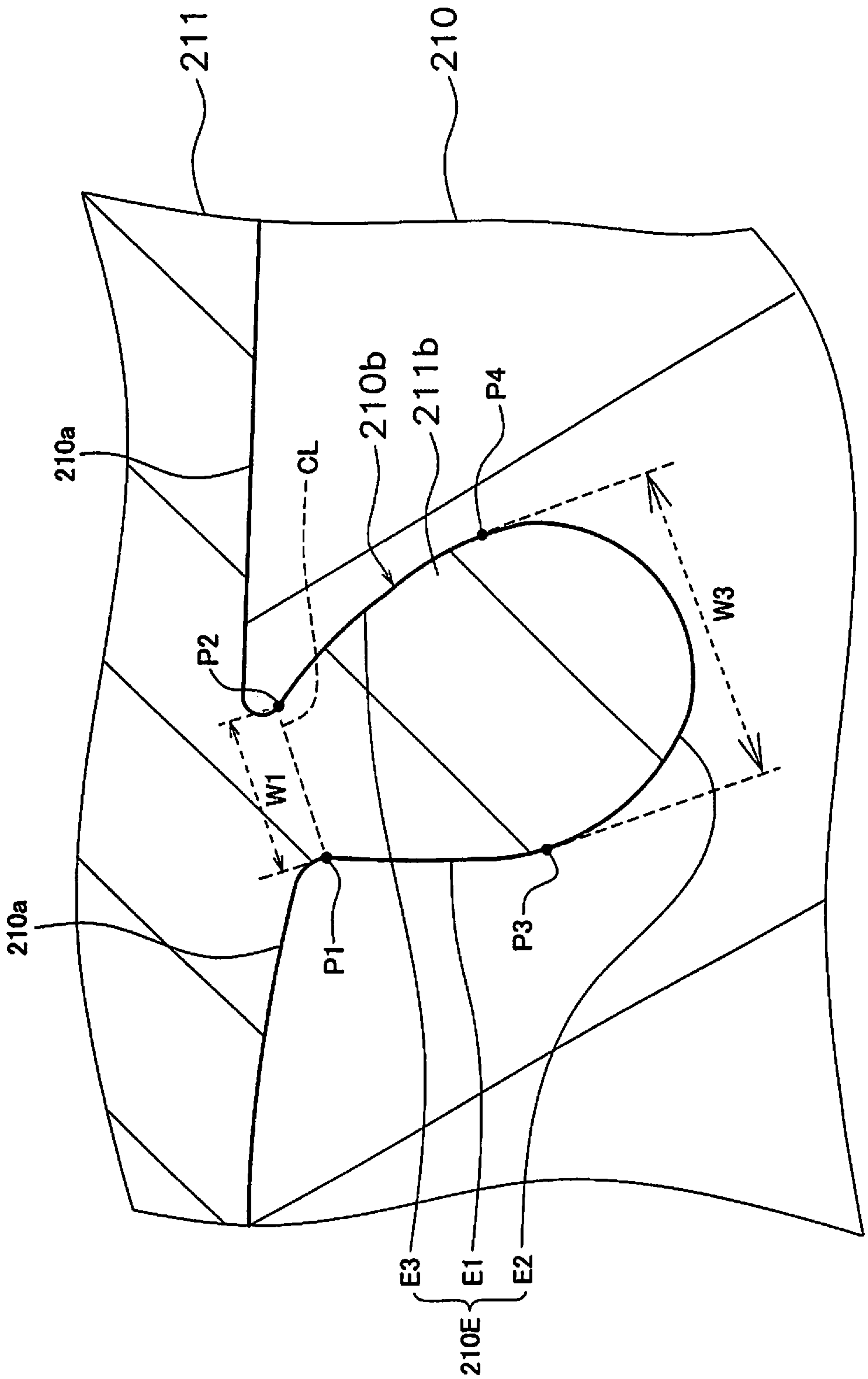


FIG. 3

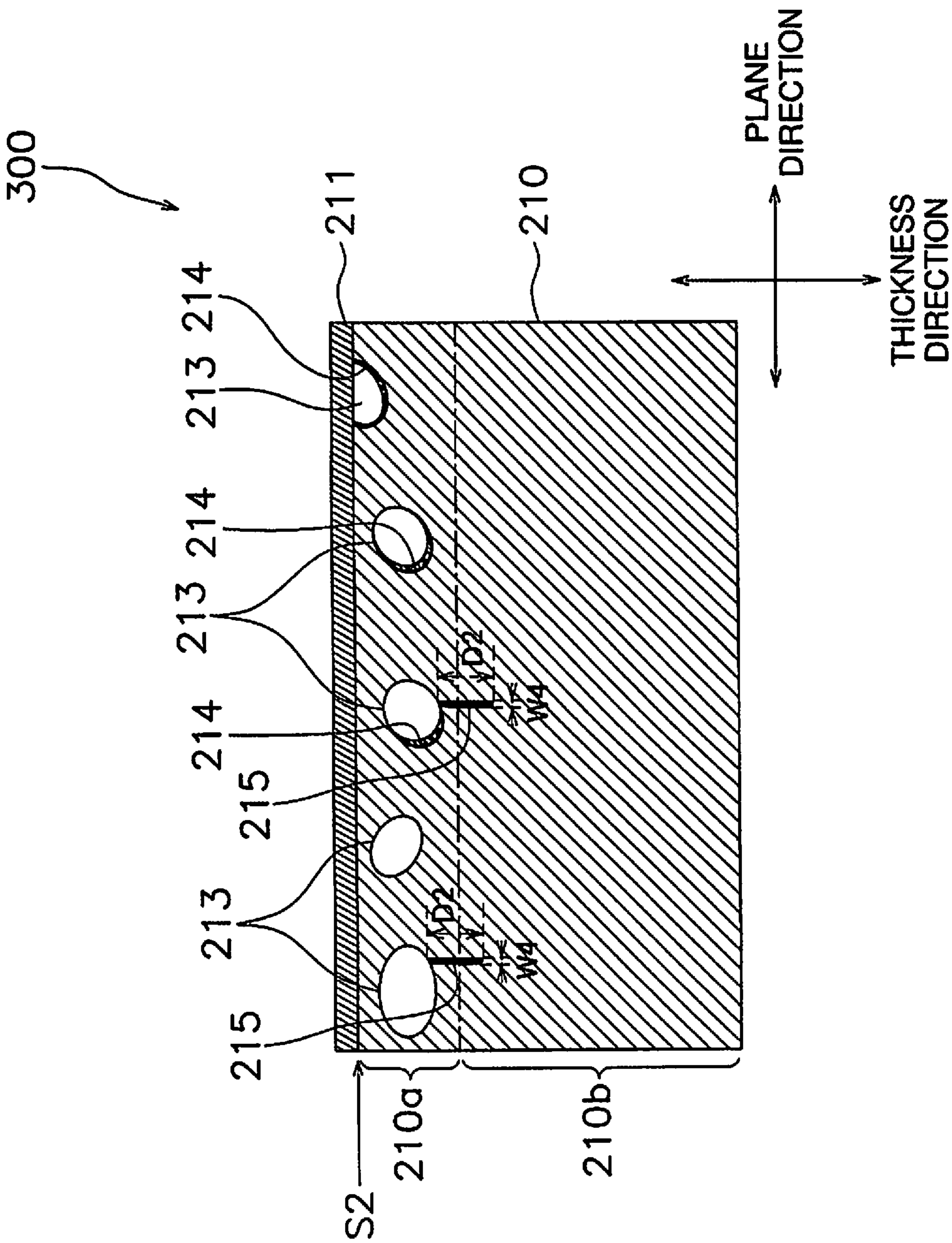

300
211
210
214
213
214
213
214
215
213
215
D2
W4
D2
W4
S2
210a
210b
PLANE
DIRECTION
THICKNESS
DIRECTION

FIG. 4

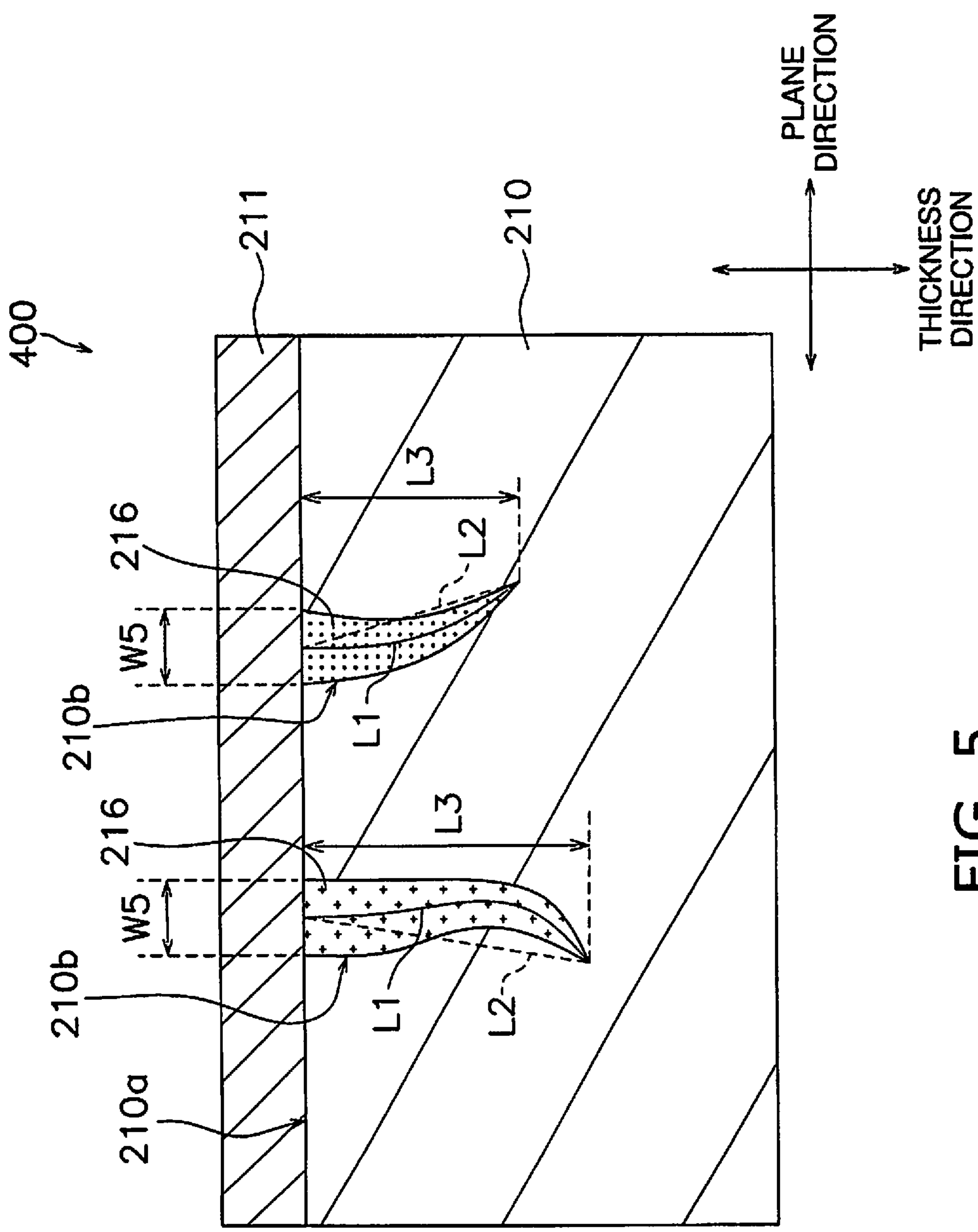

400
211
210
216
216
W5
W5
210b
210b
210a
L1
L1
L2
L2
L3
L3
PLANE DIRECTION
THICKNESS DIRECTION

FIG. 5

ALLOY MEMBER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation application of PCT/JP2019/034576, filed Sep. 3, 2019, which claims priority to Japanese Application No. 2019-009259, filed Jan. 23, 2019, Japanese Application No. 2018-197004, filed Oct. 18, 2018, and Japanese Application No. 2018-168073, filed Sep. 7, 2018, the entire contents all of which are incorporated hereby by reference.

TECHNICAL FIELD

[0002] The present invention relates to an alloy member.

BACKGROUND ART

[0003] In a cell stack provided with fuel cells, which is one type of electrochemical cell, conventionally, an alloy member has been used in a current collector member for collecting electrical current from the fuel cells, a separator for isolating the fuel cells, a manifold for supplying gas to the fuel cells, or the like (e.g., see Japanese Patent No. 6383003).

[0004] Usually, an alloy member includes a base member constituted by an alloy material containing chromium and a chromium oxide layer formed through the oxidation of the surface of the base member. The chromium oxide layer has a function of inhibiting chromium from vaporizing from the base member to the outside.

SUMMARY

[0005] When a chromium oxide layer separates from a base member, chromium is likely to vaporize from the base member to the outside, and thus there is a risk that electrodes of electrochemical cells will deteriorate through chromium poisoning.

[0006] Thus, there is demand for inhibiting separation of the chromium oxide layer from the base member.

[0007] An object of the present invention is to provide an alloy member capable of inhibiting separation of the chromium oxide layer from the base member.

[0008] An alloy member according to the present invention is used in an electrochemical cell stack. The alloy member includes a base member constituted by an alloy material containing chromium, a chromium oxide layer for covering at least a portion of a surface of the base member, a pore that is formed in an interface region of the base member that is located 30 μm or less from an interface between the chromium oxide layer and the base member, and an extending portion extending from the pore into the base member. The pore is configured to inhibit separation of the chromium oxide layer from the base member The extending portion contains an oxide of an element whose equilibrium oxygen pressure is lower than that of a major element of the base member.

[0009] According to the present invention, it is possible to provide an alloy member capable of inhibiting separation of the chromium oxide layer from the base member.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** is a cross-sectional view of an alloy member according to a first embodiment.

[0011] FIG. **2** is an enlarged cross-sectional view of an example of an embedded portion according to the first embodiment.

[0012] FIG. **3** is an enlarged cross-sectional view of an example of a recess according to the first embodiment.

[0013] FIG. **4** is a cross-sectional view of an alloy member according to a second embodiment.

[0014] FIG. **5** is a cross-sectional view of an alloy member according to a third embodiment.

DESCRIPTION OF EMBODIMENTS

1. First Embodiment

[0015] Configuration of Alloy Member **200**

[0016] An alloy member **200** according to this embodiment is used in a stack in which at least two electrochemical cells are stacked (referred to as an "electrochemical cell stack" hereinafter). An "electrochemical cell" is a device for changing chemical energy into electric energy, or a device for changing electric energy into chemical energy, and is a generic term for a pair of electrodes disposed to generate electromotive force from an overall redux reaction. Examples of the electrochemical cell include fuel cells in which protons serve as carriers, secondary cells (such as a nickel-zinc secondary battery and a zinc-air secondary battery), and electrolytic cells for generating hydrogen and oxygen from water vapor.

[0017] FIG. **1** is a cross-sectional view of the alloy member **200** according to the first embodiment. FIG. **1** shows an enlarged portion located near the surface of the alloy member **200**.

[0018] The alloy member **200** is used in a current collector member for collecting electrical current from the electrochemical cells, a separator for isolating the electrochemical cells, a manifold for supplying gas to the electrochemical cells, or the like. The alloy member **200** includes a base member **210** and a chromium oxide layer **211**.

[0019] The base member **210** is formed into a plate shape. The base member **210** may have a flat plate shape or a curved plate shape. Although there is no particular limitation on the thickness of the base member **210**, the thickness thereof may be 0.1 to 2.0 mm, for example.

[0020] The base member **210** is constituted by an alloy material containing Cr (chromium). An Fe—Cr-based alloy steel (stainless steel etc.), a Ni—Cr-based alloy steel, or the like may be used as such a metal material. Although there is no particular limitation on the Cr content in the base member **210**, the Cr content may be 4 to 30 mass %, for example.

[0021] The base member **210** may contain Ti (titanium) and Al (aluminum). Although there is no particular limitation on the Ti content in the base member **210**, the Ti content may be 0.01 to 1.0 at. %. Although there is no particular limitation on the Al content in the base member **210**, the Al content may be 0.01 to 0.4 at. %. The base member **210** may contain Ti as TiO_2 (titania), and Al as Al_2O_3 (alumina).

[0022] As shown in FIG. **1**, the base member **210** has a surface **210*a*** and a plurality of recesses **210*b***. The surface **210*a*** is an outer surface of the base member **210**. The base member **210** is bonded to the chromium oxide layer **211** on the surface **210*a***. Although the surface **210*a*** may be formed into a flat shape, the surface **210*a*** may be curved or bent entirely or partially, or may be provided with minute recesses and protrusions.

[0023] The recesses **210***b* are formed in the surface **210***a*. The recesses **210***b* extend from openings **S2** formed in the surface **210***a* toward an inner portion of the base member **210**. Embedded portions **211***b* (an example of a "separation inhibition portion"), which will be described later, are embedded in the recesses **210***b*.

[0024] The recesses **210***b* are narrower toward the openings **S2**. That is, the width of the recess **210***b* is narrower near the opening **S2**. A width **W1** of the opening **S2** indicates the length of a straight line CL connecting edges of the opening **S2** at the shortest distance in a cross-section thereof. Although there is no particular limitation on the width **W1** of the opening **S2**, the width **W1** may be 0.3 to 30 μm, for example. In consideration of providing the embedded portions **211***b*, which will be described later, with sufficient strength, it is preferable that the width **W1** is 0.5 μm or more.

[0025] Note that there is no particular limitation on the shape of the recess **210***b* as long as the width of the recess **210***b* is narrower near the opening **S2**.

[0026] The chromium oxide layer **211** is formed on the surface of the base member **210**. The chromium oxide layer **211** may cover a substantially entire surface of the base member **210**, or cover at least a portion of the surface of the base member **210**. The chromium oxide layer **211** contains a chromium oxide as the main component.

[0027] As shown in FIG. **1**, the chromium oxide layer **211** has a surface **211***a* and a plurality of embedded portions **211***b*. The surface **211***a* is an outer surface of the alloy member **200**. FIG. **1** shows a cross-section perpendicular to the surface **211***a* of the chromium oxide layer **211**.

[0028] The embedded portion **211***b* is an example of the "separation inhibition portion" for inhibiting separation of the chromium oxide layer **211** from the base member **210**. The embedded portions **211***b* are embedded in the recesses **210***b* of the base member **210**. The recess **210***b* may be entirely filled with the embedded portion **211***b*, or the embedded portion **211***b* may be partially disposed in the recess **210***b*.

[0029] The embedded portion **211***b* is constricted at the opening **S2** of the recess **210***b*. That is, the embedded portion **211***b* is locally small near the opening **S2**. The anchor effect arises as a result of the embedded portions **211***b* being locked to the recesses **210***b* due to such a bottleneck structure. As a result, the adhesive force of the chromium oxide layer **211** to the base member **210** is improved, and it is possible to inhibit separation of the chromium oxide layer **211** from the base member **210**. Thus, it is possible to inhibit vaporization of chromium from the base member **210** to the outside, and thus to inhibit the electrodes of the electrochemical cells from deteriorating through chromium poisoning. Also, if the alloy member **200** is used as a current collector member for collecting electrical current from the electrochemical cells, it is possible to inhibit a reduction in the electrical current path between the base member **210** and the chromium oxide layer **211**, and thus to inhibit an increase in the electric resistance of the alloy member **200**.

[0030] In this embodiment, "the embedded portion **211***b* being constricted at the opening **S2**" means that a width **W2** of the embedded portion **211***b* is larger than the width **W1** of the opening **S2** in a cross-section perpendicular to the surface **211***a* of the chromium oxide layer **211**. The width **W2** of the embedded portion **211***b* refers to the maximum size of the embedded portion **211***b* in a direction that is parallel to the straight line CL defining the width **W1** of the opening **S2**.

[0031] Size of Embedded Portion **211***b*

[0032] An average depth of the plurality of embedded portions **211***b* is preferably 0.7 μm or more. Accordingly, a sufficient anchor effect can be exerted as the plurality of embedded portions **211***b* overall, thus particularly improving the adhesive force of the chromium oxide layer **211** to the base member **210**. As a result, it is possible to further inhibit separation of the chromium oxide layer **211** from the base member **210**.

[0033] An "average depth" of the plurality of embedded portions **211***b* indicates a value obtained by arithmetically averaging depths **D1** of ten embedded portions **211***b* selected at random from at least one image enlarged at a magnification of 1,000 to 20,000 times using a FE-SEM (Field Emission Scanning Electron Microscope). The depth **D1** of the embedded portion **211***b* refers to the maximum size of the embedded portion **211***b* in the direction that is perpendicular to the straight line CL defining the width **W1** of the opening **S2**. However, an embedded portion **211***b* having a depth **D1** of less than 0.1 μm is excluded when the average depth of the embedded portions **211***b* is calculated because such an embedded portion **211***b* has a slight anchor effect.

[0034] An average depth of the plurality of embedded portions **211***b* is preferably 1.0 μm or more, and more preferably 1.5 μm or more. Also, an average depth of the plurality of embedded portions **211***b* is preferably 30 μm or less.

[0035] Although there is no particular limitation on the depth **D1** of the embedded portions **211***b*, the depth **D1** may be 0.5 to 30 μm, for example. The standard deviation of the depths **D1** of the ten embedded portions **211***b* used to calculate the average depth is preferably 0.2 or more. Accordingly, the anchor effect of the embedded portions **211***b* overall can be further improved. Although there is no particular limitation on the ratio of the standard deviation of the depths **D1** to the average depth (so-called "coefficient of variation"), the ratio thereof may be 0.1 to 0.95, for example, and is preferably 0.2 to 0.9 inclusive.

[0036] Although there is no particular limitation on the difference between the maximum value and the minimum value of the depths **D1** in the ten embedded portions **211***b* used to calculate the average depth, the difference may be 0.5 to 29 μm, for example, and is preferably 1 to 25 μm.

[0037] Also, although there is no particular limitation on the average width of the embedded portions **211***b*, the average width thereof may be 0.5 to 35 μm, for example. An "average width" of the plurality of embedded portions **211***b* indicates a value obtained by arithmetically averaging the widths **W2** of the ten embedded portions **211***b* used to calculate the average depth.

[0038] In consideration of further improving the anchor effect of the plurality of embedded portions **211***b* overall, the average width of the plurality of embedded portions **211***b* is preferably 0.5 μm or more, and more preferably 0.7 μm or more.

[0039] Although there is no particular limitation on the width **W2** of the embedded portions **211***b*, the width **W2** may be 0.5 to 35 μm, for example. In consideration of further improving the anchor effect of the embedded portion **211***b*, the width **W2** of the embedded portion **211***b* is preferably

101% or more, more preferably 105% or more, and particularly preferably 110% or more of the width **W1** of the opening S**2**.

[0040] The standard deviation of the widths W**2** of the ten embedded portions **211***b* used to calculate the average width is preferably 0.2 or more. Accordingly, the anchor effect of the embedded portions **211***b* overall can be further improved. Although there is no particular limitation on the ratio of the standard deviation of the widths **W2** to the average width (so-called "coefficient of variation"), the ratio thereof may be 0.1 to 0.95, for example, and is preferably 0.2 to 0.9 inclusive.

[0041] Although there is no particular limitation on the difference between the maximum value and the minimum value of the widths W**2** in the ten embedded portions **211***b* used to calculate the average width, the difference may be 0.5 to 34 μm, for example, and is preferably 1 to 30 μm.

[0042] It is preferable that the number of embedded portions **211***b* present in the surface direction parallel to the surface **210***a* in a cross-section perpendicular to the surface **210***a* of the base member **210** is 3 or more/10 mm (that is, 3 or more embedded portions **211***b* for every 10 mm of the surface **210***a*). Accordingly, stress applied to the chromium oxide layer **211** can be distributed, and thus it is possible to inhibit minor defects from occurring in the chromium oxide layer **211**.

[0043] The "number" of embedded portions **211***b* present in the surface direction refers to the number of embedded portions **211***b* provided in the unit length of the surface **210***a* of the base member **210** in a cross-section perpendicular to the surface **211***a* of the chromium oxide layer **211**. The number of present embedded portions **211***b* indicates a value obtained by dividing the total number of embedded portions **211***b* by the total length of the surface **210***a* on the above-described FE-SEM image. When the number of embedded portions **211***b* is counted, an embedded portion **211***b* that partially appears in the FE-SEM image is also counted as one embedded portion **211***b*. However, an embedded portion **211***b* having a depth D**1** of less than 0.5 μm is excluded when the number of present embedded portions **211***b* is calculated because such an embedded portion **211***b* makes little contribution to the stress distribution effect.

[0044] The number of embedded portions **211***b* present in the surface direction is more preferably 100 or less/mm (that is, 100 or less embedded portions **211***b* per mm). This makes it possible to inhibit recesses **210***b* from being linked to each other, and thus to maintain the shapes of the recesses **210***b* for a long period of time.

[0045] Although there is no particular limitation on the average equivalent circle diameter of the plurality of embedded portions **211***b*, the average equivalent circle diameter thereof may be 0.5 to 35 μm. An "average equivalent circle diameter" of the plurality of embedded portions **211***b* indicates a value obtained by arithmetically averaging the equivalent circle dimeters of the ten embedded portions **211***b* used to calculate the average depth. An "equivalent circle diameter" is the diameter of a circle having the same area as an embedded portion **211***b* on the above-described FE-SEM image. It is assumed that when the area of the embedded portion **211***b* is obtained, the base end portion of the embedded portion **211***b* is defined by the straight line CL defining the width W**1** of the opening S**2**.

[0046] Angle of Embedded Portion **211***b*

[0047] FIG. **2** is an enlarged cross-sectional view of an example of the embedded portion **211***b*. FIG. **2** shows a cross-section perpendicular to the surface **211***a* of the chromium oxide layer **211**.

[0048] As shown in FIG. **2**, an angle θ formed by a depth direction TD**1** of the embedded portion **211***b* with respect to the surface **210***a* in a cross-section perpendicular to the surface **211***a* of the chromium oxide layer **211** is preferably an acute angle. That is, the embedded portion **211***b* is inclined with respect to the surface **210***a*. Accordingly, a larger anchor effect can be exerted, compared to the case where the embedded portion **211***b* is provided straight with respect to the surface **210***a*, and thus it is possible to improve the adhesive force of the chromium oxide layer **211** to the base member **210**. As a result, it is possible to further inhibit separation of the chromium oxide layer **211** from the base member **210**.

[0049] An "angle θ formed by the depth direction TD**1** of the embedded portion **211***b* with respect to the surface **210***a*" is defined as follows. First, as shown in FIG. **2**, a region of the embedded portion **211***b* is defined using the straight line CL**1** defining the width W**1** of the opening S**2** on the image enlarged at a magnification of 1,000 to 20,000 times by a FE-SEM. Then, a direction that is perpendicular to two parallel tangent lines PL that hold the embedded portion **211***b* and are fixed at positions at which the distance between the two parallel tangent lines PL is at the maximum when the two parallel tangent lines PL are rotated 180 degrees is set as the "depth direction TD**1**". The distance between the two parallel tangent lines PL at this time is so-called "the maximum Feret diameter" of the embedded portion **211***b*. Then, two points at which the straight line CL**1** intersects the surface **210***a* are set as reference points P**1** and P**2**. Then, a virtual approximate straight line CL**2** is drawn using the method of least squares with use of a 100 μm range of the surface **210***a* that starts from one reference point P**1** and a 100 μm range of the surface **210***a* that starts from the other reference point P**2**. The approximate straight line CL**2** indicates the surface **210***a* used to calculate the angle θ. That is, the approximate straight line CL**2** indicates the surface **210***a* in the calculation of the angle θ. Also, the angle of the depth direction TD**1** with respect to the approximate straight line CL**2** is the angle θ formed by the depth direction TD**1** of the embedded portion **211***b* with respect to the surface **210***a*.

[0050] Considering further improvement of the anchor effect of the embedded portion **211***b*, the angle θ formed by the depth direction TD**1** of the embedded portion **211***b* is preferably 89 degrees or less, more preferably 85 degrees or less, and further preferably 80 degrees or less.

[0051] As shown in FIG. **1**, if the chromium oxide layer **211** has a plurality of embedded portions **211***b*, the embedded portions **211***b* may have different angles θ formed by the depth direction TD**1** of the embedded portions **211***b*, or may have the same angle θ. Also, the embedded portions **211***b* may have different depth directions TD**1** of the embedded portions **211***b*, or may have the same depth direction TD**1**. It is preferable that at least one of the angle θ and the depth direction TD**1** changes for each embedded portion **211***b* because the anchor effect of the embedded portions **211***b* overall can be significantly improved.

[0052] Shape of Outer Edge of Recess **210***b*

[0053] FIG. **3** is an enlarged cross-sectional view of an example of the recess **210***b*. FIG. **3** shows a cross-section perpendicular to the surface **211***a* of the chromium oxide layer **211**.

[0054] As shown in FIG. **3**, at least a portion of an outer edge **210**E of the recess **210***b* is preferably curved. Accordingly, stress is distributed in the curved region of the outer edge **210**E of the recess **210***b* when the alloy member **200** expands or contracts, and thus it is possible to inhibit stress from being locally concentrated. Therefore, it is possible to inhibit the embedded portions **211***b* embedded in the recesses **210***b* from being damaged, and thus to maintain the anchor effect resulting from the embedded portions **211***b* for a long period of time.

[0055] The outer edge **210**E of the recess **210***b* includes the first and second reference points P**1** and P**2** defining the opening width W**1** of the opening S**2**, and third and fourth reference points P**3** and P**4** defining a maximum width W**3** of the recess **210***b*.

[0056] The maximum width W**3** of the recess **210***b* indicates the maximum size of the recess **210***b* in a direction that is parallel to the straight line CL defining the opening width W**1**. Although the maximum width W**3** of the recess **210***b* is the same as the above-described width W**2** of the embedded portion **211***b* in this embodiment, the maximum width W**3** need not be the same as the width W**2** of the embedded portion **211***b*. Although there is no particular limitation on the maximum width W**3** of the recess **210***b*, the maximum width W**3** may be 0.5 to 35 μm, for example.

[0057] The outer edge **210**E of the recess **210***b* includes a first outer edge portion E**1** extending from the first reference point P**1** to the third reference point P**3**, a second outer edge portion E**2** extending from the third reference point P**3** to the fourth reference point P**4**, and a third outer edge portion E**3** extending from the fourth reference point P**4** to the second reference point P**2**.

[0058] The outer edge **210**E of the recess **210***b* is constituted as a result of the first to third outer edge portions E**1** to E**3** being successively connected to each other. The first outer edge portion E**1** indicates a side wall located on one side of the recess **210***b*. The third outer edge portion E**3** indicates a side wall located on the other side of the recess **210***b*. The second outer edge portion E**2** indicates the bottom wall of the recess **210***b*.

[0059] In this embodiment, the first to third outer edge portions E**1** to E**3** are each entirely curved. Thus, it is possible to effectively inhibit stress from being concentrated at the first to third outer edge portions E**1** to E**3**, and thus to entirely protect the embedded portion **211***b* of the chromium oxide layer **211**.

[0060] However, it is not necessary for all of the first to third outer edge portions E**1** to E**3** to be curved, and it is sufficient that at least one of the first to third outer edge portions E**1** to E**3** is curved. Also, the first to third outer edge portions E**1** to E**3** may each partially include a linear region.

[0061] In this embodiment, the first outer edge portions E**1** and the second outer edge portion E**2** are smoothly connected to each other at the third reference point P**3**. Specifically, the first outer edge portion E**1** and the second outer edge portion E**2** are connected to each other while curving. Thus, it is possible to effectively inhibit stress from being concentrated at the boundary between the side wall and the bottom surface of the recess **210***b* where stress is likely to be concentrated, and thus to further inhibit the embedded portion **211***b* from being damaged.

[0062] Also, the second outer edge portion E**2** and the third outer edge portion E**3** are smoothly connected to each other at the fourth reference point P**4**. Specifically, the second outer edge portion E**2** and the third outer edge portion E**3** are connected to each other while curving. Thus, it is possible to effectively inhibit stress from being concentrated at the boundary between the side wall and the bottom surface of the recess **210***b* where stress is likely to be concentrated, and thus to further inhibit the embedded portion **211***b* from being damaged.

[0063] Also, the first outer edge portion E**1** and the surface **210***a* of the base member **210** are smoothly connected to each other at the first reference point P**1**. Specifically, the first outer edge portion E**1** and the surface **210***a* are connected to each other while curving. Thus, it is possible to effectively inhibit stress from being concentrated at the boundary between the side wall of the recess **210***b* and the surface **210***a* of the base member where stress is likely to be concentrated, and thus to further inhibit the embedded portion **211***b* from being damaged.

[0064] Also, the third outer edge portion E**3** and the surface **210***a* of the base member **210** are smoothly connected to each other at the second reference point P**2**. Specifically, the third outer edge portion E**3** and the surface **210***a* are connected to each other while curving. Thus, it is possible to effectively inhibit stress from being concentrated at the boundary between the side wall of the recess **210***b* and the surface **210***a* of the base member where stress is likely to be concentrated, and thus to further inhibit the embedded portion **211***b* from being damaged.

[0065] In this embodiment, the second outer edge portion E**2** protrudes toward the base member **210**. That is, the bottom surface of the recess **210***b* is formed into a shape protruding into the base member **210**. Thus, it is possible to effectively inhibit stress from being concentrated near the bottom surface of the recess **210***b*, and thus to effectively protect a leading end portion of the embedded portion **211***b* that is most likely to be damaged.

[0066] Method for Manufacturing Alloy Member **200**

[0067] First, a plurality of recesses are formed in the surface **210***a* of the base member **210**. It is possible to efficiently form recesses having a predetermined shape using shot peening, sand blasting, or wet blasting, for example. The average depth, angle θ, and the like of the embedded portions **211***b*, which will be formed in a downstream process, can be controlled by adjusting the depth and the angle of the recesses. Also, the number of embedded portions **211***b* present in the surface direction can be controlled by adjusting the number of recesses in the surface direction.

[0068] Then, by rolling a roller on the surface **210***a* of the base member **210**, the openings S**2** are narrowed while the peripheries of the openings S**2** of the recesses **210***b* are flattened. At this time, the width W**1** of the openings S**2** can be adjusted by adjusting a pressing force of the roller.

[0069] Then, the chromium oxide layer **211** is formed on the surface **210***a* of the base member **210** and in the recesses **210***b* as a result of applying a chromium oxide paste onto the surface **210***a* of the base member **210** to fill the recesses **210***b* with the chromium oxide paste, and subjecting the base member **210** to heat treatment (800° C. to 900° C., 5 to 20 hours) in an atmosphere. Accordingly, the embedded portions **211***b* embedded in the recesses **210***b* are formed.

2. Second Embodiment

[0070] An alloy member **300** according to a second embodiment will be described with reference to the drawings. FIG. **4** is a cross-sectional view of the alloy member **300** according to the second embodiment. FIG. **4** shows an enlarged portion located near the surface of the alloy member **300**.

[0071] The alloy member **300** includes a base member **210** and a chromium oxide layer **211**.

[0072] The base member **210** is formed into a plate shape. The base member **210** may have a flat plate shape or a curved plate shape. Although there is no particular limitation on the thickness of the base member **210**, the thickness thereof may be 0.1 to 2.0 mm, for example.

[0073] The base member **210** is constituted by an alloy material containing Cr (chromium). An Fe—Cr-based alloy steel (stainless steel etc.), a Ni—Cr-based alloy steel, or the like may be used as such a metal material. Although there is no particular limitation on the Cr content in the base member **210**, the Cr content may be 4 to 30 mass %.

[0074] The base member **210** may contain Ti (titanium) and Al (aluminum). Although there is no particular limitation on the Ti content in the base member **210**, the Ti content may be 0.01 to 1.0 at. %. Although there is no particular limitation on the Al content in the base member **210**, the Al content may be 0.01 to 0.4 at. %. The base member **210** may contain Ti as TiO_2 (titania), and Al as Al_2O_3 (alumina).

[0075] The chromium oxide layer **211** is formed on the base member **210**. The chromium oxide layer **211** covers at least a portion of the base member **210**. Although it is sufficient that the chromium oxide layer **211** covers at least a portion of the base member **210**, the chromium oxide layer **211** may cover a substantially entire surface of the base member **210**. The chromium oxide layer **211** contains a chromium oxide as the main component. In this embodiment, a composition X containing a substance Y "as the main component" means that the substance Y accounts for 70 wt % or more of the entire composition X. Although there is no particular limitation on the thickness of the chromium oxide layer **211**, the thickness thereof may be 0.1 to 20 μm, for example.

[0076] Here, the base member **210** includes an interface region **210***a* and an inner region **210***b*. The interface region **210***a* is a region of the base member **210** located 30 μm or less from an interface S**2** between the base member **210** and the chromium oxide layer **211**. The inner region **210***b* is a region located more than 30 μm away from the interface S**2**.

[0077] The base member **210** has pores **213** formed in the interface region **210***a*. The pore **213** is an example of the "separation inhibition portion" for inhibiting separation of the chromium oxide layer **211** from the base member **210**. As a result of the pores **213** being formed in the interface region **210***a*, it is possible to inhibit separation of the chromium oxide layer **211** from the base member **210** when the alloy member **300** expands or contracts. Specifically, because flexibility of the interface region **210***a* is increased as a result of disposing the pores **213** in the interface region **210***a* of the base member **210**, it is possible to reduce stress occurring at the interface between the base member **210** and the chromium oxide layer **211**. As a result, it is possible to inhibit separation of the chromium oxide layer **211** from the base member **210**. Thus, it is possible to inhibit vaporization of chromium from the base member **210** to the outside, and thus to inhibit the electrodes of the electrochemical cells from deteriorating through chromium poisoning. Also, if the alloy member **300** is used as a current collector member for collecting electrical current from the electrochemical cells, it is possible to inhibit a reduction in the electrical current path between the base member **210** and the chromium oxide layer **211**, and thus to inhibit an increase in the electric resistance of the alloy member **300**.

[0078] As shown in FIG. **4**, the base member **210** preferably has a plurality of pores **213**. This makes it possible to reduce stress occurring at the interface S**2** in a wide range, and thus to further inhibit separation of the chromium oxide layer **211**.

[0079] If the base member **210** has a plurality of pores **213**, there is no particular limitation on the intervals between the pores **213**, and the intervals therebetween need not be constant. Although the pores **213** are disposed one-by-one in the thickness direction of the base member **210** in FIG. **4**, two or more pores **213** may be disposed in the thickness direction. Also, the pores **213** may be in contact with the interface S**2**, or may be separated from the interface S**2**.

[0080] If the base member **210** has a plurality of pores **213**, the average equivalent circle diameter of the pores **213** is preferably 0.5 μm to 20 μm inclusive. As a result of the pores **213** having an average equivalent circle diameter of 0.5 μm or more, it is possible to sufficiently improve the flexibility of the interface region **210***a* and to sufficiently reduce stress that occurs at the interface S**2**. Also, as a result of the pores **213** having an average equivalent circle diameter of 20 μm or less, it is possible to inhibit local deformation of the peripheries of the pores **213**, and thus to further inhibit separation of the chromium oxide layer **211**.

[0081] An "equivalent circle diameter" of a pore **213** refers to the diameter of a circle having the same area as a pore **213** in an image obtained by enlarging a cross-section of the interface region **210***a* in the thickness direction at a magnification of 1,000 to 20,000 times using a FE-SEM (Field Emission-Scanning Electron Microscope). An "average equivalent circle diameter" indicates a value obtained by arithmetically averaging the equivalent circle diameters of ten pores **213** selected at random from the above-described FE-SEM image. When the average equivalent circle diameter is obtained, ten pores **213** having a pore size of more than 0.1 μm are selected at random from FE-SEM images obtained at ten portions of the interface region **210***a*.

[0082] The pores **213** preferably have an average aspect ratio of 3 or less. Accordingly, the pores **213** are more likely to deform. The aspect ratio of a pore **213** is a value obtained by dividing the maximum Feret diameter of the pore **213** by the minimum Feret diameter thereof. The maximum Feret diameter is the distance between two parallel straight lines when the pore **213** is held such that the distance between the two parallel straight lines is at the maximum on the above-described FE-SEM image. The minimum Feret diameter is the distance between two parallel straight lines when the pore **213** is held such that the distance between the two parallel straight lines is at the minimum on the above-described FE-SEM image. An average aspect ratio is a value obtained by arithmetically averaging aspect ratios of ten pores **213** whose average equivalent circle diameter is to be measured.

[0083] The number of pores **213** present in the surface direction is preferably 5 or more/mm (that is, 5 or more pores **213** per mm). Accordingly, it is possible to further reduce stress occurring at the interface S**2** as a result of further improving the flexibility of the interface region **210***a*, and thus to inhibit minor defects from occurring in the chromium oxide layer **211**. Also, the number of pores **213** present in the surface direction is more preferably 100 or less/mm (that is, 100 or less pores **213** per mm). Accordingly, it is possible to inhibit the pores **213** from being linked to each other, and thus to more easily control the shapes of the pores **213**.

[0084] The number of present pores **213** is the number of pores **213** disposed in the unit length. The number of present pores **213** is a value obtained by dividing the total number of pores **213** by the total length of the interface S2 on the above-described FE-SEM image. When the total number of pores **213** is counted, a pore **213** that partially appears in the FE-SEM image is also counted as one pore **213**.

[0085] Note that although the pores **213** are not formed in the inner region **210***b* in FIG. **4**, the pores **213** may also be formed in the inner region **210***b*.

[0086] Metal Oxide **214** in Pore **213**

[0087] As shown in FIG. **4**, the base member **210** preferably includes metal oxides **214** disposed on inner surfaces of the pores **213**.

[0088] The metal oxides **214** cover at least portions of the inner surfaces of the pores **213**. Accordingly, even if a phenomenon occurs in which a portion of the chromium oxide layer **211** grows to extend toward the inner portion of the base member **210** (referred to as an "abnormal oxidation phenomenon" hereinafter), it is possible to maintain the forms of the metal oxides **214**, as a result of which it is possible to maintain the shapes of the pores **213**. Thus, it is possible to maintain the stress reduction effect resulting from the pores **213** for a long period of time.

[0089] An "abnormal oxidation phenomenon" refers to a phenomenon occurring as a result of oxidation of the base member **210** being locally progressed in a case where minute defects are present in the chromium oxide layer **211**, for example. When an abnormal oxidation phenomenon occurs, if the pores **213** are not protected by the metal oxides **214**, the pores **213** are reduced in size or disappear as a result of the peripheries of the pores **213** in the base member **210** being oxidized and undergoing volume expansion.

[0090] Although the metal oxide **214** can be constituted by oxides of a single metal element (FeO, Fe_2O_3, Fe_3O_4, Cr_2O_3, CaO, Al_2O_3, MnO, Mn_3O_4, SiO_2, Al_2O_3, and TiO_2), complex oxides constituted by a plurality of metal elements ($(Fe, Cr)_3O_4$, $(Mn, Cr)_3O_4$), and the like, for example, the metal oxide **214** is not limited thereto.

[0091] The metal oxide **214** is preferably an oxide of an element whose equilibrium oxygen pressure is lower than that of the major element of the base member **210** (referred to as a "low-equilibrium oxygen pressure element" hereinafter). Because the low-equilibrium oxygen pressure element has a greater affinity for oxygen than the major element of the base member **210**, it is possible to maintain the form of a more stable oxide in the base member **210**.

[0092] Although examples of the low-equilibrium oxygen pressure element include Ti, Al, Ca, Si, Mn, and Cr, the low-equilibrium oxygen pressure element is not limited thereto. Although an example of an oxide of a low-equilibrium oxygen pressure element is at least one selected from TiO_2, Al_2O_3, CaO, SiO_2, manganese oxides (e.g., MnO and Mn_3O_4), $(Mn, Cr)_3O_4$, chromium oxides (e.g., CrO and Cr_2O_3), and the like, the oxide thereof is not limited thereto.

[0093] It is preferable that the metal content in the metal oxide **214** is 0.3 or more in terms of a cation ratio when a molar ratio of the elements to the sum of all constituent elements excluding oxygen is defined as the cation ratio. This makes it possible to inhibit the pores **213** from being reduced through an abnormal oxidation phenomenon. The metal content in the metal oxide **214** is more preferably 0.4 or more, and particularly preferably 0.5 or more, in terms of the cation ratio.

[0094] The metal content in the metal oxide **214** can be obtained as a result of measuring, using EDX of a STEM (Scanning Transmission Electron Microscope), in terms of the cation ratio, the metal contents at ten portions selected at random from the metal oxides **214** disposed on the inner surfaces of the pores **213**, and arithmetically averaging the values measured at the ten portions.

[0095] The metal oxide **214** may contain only one type of metal oxide, or may contain two or more types thereof. If the metal oxide **214** contains two or more types of metal oxides, the metal oxides may constitute a mixture in which the metal oxides are mixed together.

[0096] The metal oxides **214** may be present in the form of particles that are dispersed on the inner surfaces of the pores **213**, or may substantially form a layer. Thus, the metal oxides **214** may cover the entire inner surfaces of the pores **213**, or may cover only portions of the inner surfaces of the pores **213**. Even if the metal oxides **214** cover only portions of the inner surfaces of the pores **213**, it is possible to obtain the effect of maintaining the shapes of the pores **213**, compared to the case where no metal oxides **214** are present. Although there is no particular limitation on the thickness of the metal oxide **214** when the metal oxide **214** forms a layer, the thickness thereof may be 0.1 to 5 μm, for example.

[0097] Extending Portion **215** that Extends from Pore **213**

[0098] As shown in FIG. **4**, the base member **210** preferably has an extending portion **215** extending from a pore **213**. Substantially the entire extending portion **215** is embedded in the base member **210**, and one end portion thereof is exposed at the inner surface of the pore **213**. The extending portion **215** contains an oxide of an element whose equilibrium oxygen pressure is lower than that of the major element of the base member **210** (referred to as a "low-equilibrium oxygen pressure element" hereinafter). Because the low-equilibrium oxygen pressure element has a greater affinity for oxygen than the major element of the base member **210**, oxygen that permeates the base member **210** and remains in the pores **213** can be preferentially taken into the extending portion **215**. Thus, it is possible to inhibit oxidation of portions of the base member **210** that surround the pores **213**, and thus to maintain the shapes of the pores **213** for a long period of time. As a result, it is possible to maintain the stress reduction effect resulting from the pores **213** for a long period of time.

[0099] Although examples of the low-equilibrium oxygen pressure element include Ti, Al, Ca, Si, Mn, and Cr, the low-equilibrium oxygen pressure element is not limited thereto. Although an example of an oxide of the low-equilibrium oxygen pressure element is at least one selected from manganese oxides (e.g., MnO and Mn_3O_4), $(Mn, Cr)_3O_4$, and chromium oxides (e.g., CrO and Cr_2O_3), TiO_2, Al_2O_3, CaO, SiO_2, manganese oxides (e.g., MnO and Mn_3O_4), $(Mn, Cr)_3O_4$, chromium oxides (e.g., CrO and Cr_2O_3), and the like, the oxide thereof is not limited thereto.

[0100] It is preferable that the content of low-equilibrium oxygen pressure elements in the extending portion **215** is 0.3 or more in terms of a cation ratio when a molar ratio of the elements to the sum of all constituent elements excluding oxygen is defined as the cation ratio. Accordingly, oxygen in the pores **213** can be preferentially taken into the extending portions **215**. The content of the low-equilibrium oxygen pressure elements in the extending portion **215** is more preferably 0.4 or more, and particularly preferably 0.5 or more, in terms of the cation ratio.

[0101] The content of the low-equilibrium oxygen pressure elements in an extending portion **215** can be obtained as a result of measuring, using EDX of a STEM, in terms of the cation ratio, the contents of the low-equilibrium oxygen pressure elements at ten points at which the total length of the extending portion **215** extending from a pore **213** is divided into eleven portions, and arithmetically averaging the values measured at the ten points.

[0102] The extending portion **215** may contain only one type of oxide of a low-equilibrium oxygen pressure element, or may contain two or more types thereof. If the extending portion **215** contains two or more types of oxides of a low-equilibrium oxygen pressure element, the two or more types of oxides may constitute a mixture in which the oxides are mixed together.

[0103] As shown in FIG. **4**, the extending portion **215** preferably extends from a pore **213** in a direction away from the chromium oxide layer **211**. That is, the extending portion **215** preferably extends from the pore **213** in the opposite direction to the chromium oxide layer **211**. Accordingly, it is possible to inhibit the extending portion **215** from coming into contact with the chromium oxide layer **211** as a result of the extending portion **215** growing and becoming exposed from the base member **210**, and thus to maintain adherence between the base member **210** and the chromium oxide layer **211**.

[0104] Although the extending portion **215** is formed into a linear shape extending in the thickness direction perpendicular to the interface S**2** in this embodiment, there is no particular limitation on the shape of the extending portion **215**. The extending portion **215** may be curved or bent entirely or partially.

[0105] Although there is no particular limitation on a length D**1** of the extending portion **215**, the length D**1** may be 0.5 to 30 μm, for example. The length D**1** of the extending portion **215** refers to the maximum size of the extending portion **215** in the thickness direction perpendicular to the interface S**2**. The length D**1** of the extending portion **215** is preferably 1.5 to 20 μm. The entire extending portion **215** may be disposed in the interface region **210***a*, or a portion of the extending portion **215** may be disposed in the inner region **210***b*. That is, a portion of the extending portion **215** may be located 30 μm or more away from the interface S**2**.

[0106] Although there is no particular limitation on a width W**4** of the extending portion **215**, the width W**4** may be 0.2 to 4.0 μm, for example. The width W**4** of the extending portion **215** refers to the maximum size of the extending portion **215** in the surface direction parallel to the interface S**2**. The width W**4** of the extending portion **215** is preferably smaller than the length D**1**. The width W**4** of the extending portion **215** is preferably 0.5 μm to 3.0 μm.

[0107] Method for Manufacturing Alloy Member **300**

[0108] First, if extending portions **215** are provided in pores **213**, small holes are formed in the surface of the base member **210**. It is possible to efficiently form small holes having a desired diameter through laser radiation, for example. At this time, the size of small holes can be adjusted by controlling the laser output and the radiation time, and appropriately selecting a lens to be used. A YAG laser, a carbon dioxide laser, or the like can be used as the laser, for example.

[0109] Then, the small holes are filled with a paste obtained by adding ethyl cellulose and terpineol to a powder of oxides of low-equilibrium oxygen pressure elements.

[0110] Then, large holes whose diameter is larger than that of the small holes are formed. It is possible to efficiently form large holes having a desired diameter through laser radiation, for example. At this time, the size of large holes can be adjusted by controlling the laser output and the radiation time, and appropriately selecting a lens to be used. In particular, the size of the large holes are adjusted such that the paste with which the small holes are filled remains at the leading end portions of the small holes. A YAG laser, a carbon dioxide laser, or the like can be used as the laser, for example.

[0111] Then, degreasing heat treatment is performed at 350° C. for 1 hour in order to completely remove ethyl cellulose and terpineol included in the paste with which the small holes are filled. Because oxidation does not progress on the surface of the base member **210** under these heat treatment conditions, ductility of the base member **210** is maintained.

[0112] Note that if no extending portion **215** is provided in the pores **213**, it is sufficient to form only large holes without forming small holes.

[0113] Then, if the metal oxide **214** is formed in the pore **213**, the metal oxide **214** is formed on the inner surface of each large hole through sputtering with the metal oxide targeted. VS-R400G manufactured by SCREEN Finetech Solutions Co., Ltd. can be used in sputtering.

[0114] Then, the pores **213** are formed as a result of covering openings of the large holes by rolling a roller on the surface of the base member **210**. At this time, the openings of the large holes may be completely covered, or the openings may be kept open.

[0115] Then, as a result of performing heat treatment (800° C. to 900° C., 5 to 20 hours) on the base member **210** in an atmosphere, the paste is solidified to form the extending portions **215**, and the chromium oxide layer **211** is formed on the surface of the base member **210**.

3. Third Embodiment

[0116] An alloy member **400** according to a third embodiment will be described with reference to the drawings. FIG. **5** is a cross-sectional view of the alloy member **400** according to the third embodiment. FIG. **5** shows an enlarged portion located near the surface of the alloy member **400**.

[0117] The alloy member **400** includes a base member **210**, a chromium oxide layer **211**, and anchor portions **216**.

[0118] The base member **210** is formed into a plate shape. The base member **210** may have a flat plate shape or a curved plate shape. Although there is no particular limitation on the thickness of the base member **210**, the thickness thereof may be 0.5 to 4.0 mm, for example.

[0119] The base member **210** is constituted by an alloy material containing Cr (chromium). An Fe—Cr-based alloy steel (stainless steel etc.), a Ni—Cr-based alloy steel, or the like may be used as such a metal material. Although there is no particular limitation on the Cr content in the base member **210**, the Cr content may be 4 to 30 mass %.

[0120] The base member **210** may contain Ti (titanium) and Al (aluminum). Although there is no particular limitation on the Ti content in the base member **210**, the Ti content may be 0.01 to 1.0 at. %. Although there is no particular limitation on the Al content in the base member **210**, the Al content may be 0.01 to 0.4 at. %. The base member **210** may contain Ti as TiO_2 (titania), and Al as Al_2O_3 (alumina).

[0121] The base member **210** has a surface **210***a* and a plurality of recesses **210***b*. The surface **210***a* is an outer surface of the base member **210**. The base member **210** is bonded to the chromium oxide layer **211** on the surface **210***a*. Although the surface **210***a* is formed into a substantially planar shape in FIG. **5**, the surface **210***a* may be provided with minute recesses and protrusions, or may be curved or bent entirely or partially.

[0122] The recesses **210***b* are formed in the surface **210***a*. The recesses **210***b* extend from the surface **210***a* toward an inner portion of the base member **210**. Anchor portions **216**, which will be described later, are embedded in the recesses **210***b*.

[0123] Although there is no particular limitation on the number of recesses **210***b*, the recesses **210***b* are preferably widely distributed in the surface **210***a*. Also, although there is no particular limitation on the intervals between recesses **210***b*, it is particularly preferable that the recesses **210***b* are disposed at equal intervals. Accordingly, the anchor effect resulting from the anchor portions **216** can be evenly exerted on the entire chromium oxide layer **211**, thus particularly inhibiting separation of the chromium oxide layer **211** from the base member **210**.

[0124] The cross-sectional shapes of the recesses **210***b* are curved or bent entirely or partially. The cross-sectional shape of a recess **210***b* is not a linear shape, but a shape in which at least a portion thereof is warped. The deepest portion of the recess **210***b* may have an acute angle, an obtuse angle, or a round shape. FIG. **5** shows, as an example, a wedge-shaped recess **210***b* that is curved entirely (the right side in FIG. **5**), and a wedge-shaped recess **210***b* having a curved lower half (the left side in FIG. **5**).

[0125] The chromium oxide layer **211** is formed on the surface **210***a* of the base member **210**. The chromium oxide layer **211** covers at least a portion of the surface **210***a* of the base member **210**. The chromium oxide layer **211** is connected to the anchor portions **216**. The chromium oxide layer **211** is formed covering the anchor portions **216**. Although there is no particular limitation on the thickness of the chromium oxide layer **211**, the thickness thereof may be 0.5 μm to 10 μm.

[0126] The anchor portion **216** is an example of the "separation inhibition portion" for inhibiting separation of the chromium oxide layer **211** from the base member **210**. The anchor portions **216** are disposed in the recesses **210***b* of the base member **210**. The anchor portions **216** are connected to the chromium oxide layer **211** near opening portions of the recesses **210***b*.

[0127] In a cross-section of the base member **210** in the thickness direction, an average actual length of the plurality of anchor portions **216** is longer than an average straight line length of the plurality of anchor portions **216**. This means that at least one of the anchor portions **216** is warped due to at least one of the anchor portions **216** being curved or bent entirely or partially. Thus, the anchor effect of the anchor portions **216** on the base member **210** can be increased, thus inhibiting separation of the chromium oxide layer **211** from the base member **210**. Thus, it is possible to inhibit vaporization of chromium from the base member **210** to the outside, and thus to inhibit the electrodes of the electrochemical cells from deteriorating through chromium poisoning. Also, if the alloy member **400** is used as a current collector member for collecting electrical current from the electrochemical cells, it is possible to inhibit a reduction in the electrical current path between the base member **210** and the chromium oxide layer **211**, and thus to inhibit an increase in the electric resistance of the alloy member **400**.

[0128] The average actual length of the plurality of anchor portions **216** refers to the average value of actual lengths L**1** of the anchor portions **216**. As shown in FIG. **5**, the actual length L**1** refers to the length of a line segment obtained by connecting midpoints of a portion of an anchor portion **216** embedded in a recess **210***b* in a surface direction perpendicular to the thickness direction. The actual length L**1** indicates the total length of the anchor portion **216** in the direction in which the anchor portion **216** extends.

[0129] The average actual length of the anchor portions **216** can be obtained by arithmetically averaging the actual lengths L**1** of twenty anchor portions **216** that are selected at random from an image obtained by enlarging a cross-section of the base member **210** at a magnification of 1,000 to 20,000 times using a FE-SEM (Field Emission Scanning Electron Microscope). Note that, if twenty anchor portions **216** cannot be observed in one cross-section, twenty anchor portions **216** need only to be selected from a plurality of cross-sections. However, an anchor portion **216** having an actual length L**1** of less than 0.1 μm is excluded when the average actual length of the anchor portions **216** is calculated because such an anchor portion **216** has a slight anchor effect, and makes little contribution to the effect of inhibiting separation of the chromium oxide layer **211**.

[0130] The average straight line length of the plurality of anchor portions **216** refers to the average value of straight line lengths L**2** of the anchor portions **216**. As shown in FIG. **5**, the straight line length L**2** refers to the length of a straight line connecting the start point and the end point of a line segment that defines the actual length L**1**. The straight line length L**2** indicates the shortest distance between both ends of the anchor portion **216**.

[0131] The average straight line length of the plurality of anchor portions **216** can be obtained by arithmetically averaging the straight line lengths L**2** of the twenty anchor portions **216** selected in order to obtain the above-described average actual length.

[0132] Note that, although the actual length L**1** is substantially the same as the straight line length L**2** if the anchor portion **216** is entirely linearly formed, the actual length L**1** is longer than the straight line length L**2** if at least a portion thereof is warped as the anchor portion **216** according to this embodiment. As shown in FIG. **5**, the anchor portions **216** may have different actual lengths L**1** and different straight line lengths L**2**, or may have the same actual length L**1** and the same straight line length L**2**.

[0133] Although there is no particular limitation on the average actual length, the average actual length may be 0.5 μm to 600 μm inclusive, for example. Although there is no particular limitation on the average straight line length, the average straight line length may be 0.4 μm to 550 μm inclusive, for example.

[0134] Although there is no particular limitation on the average vertical length of the anchor portions **216** in a cross-section of the base member **210** along the thickness direction, the average vertical length thereof may be 0.4 μm to 500 μm inclusive, for example. The average vertical length refers to the average value of vertical lengths L**3** of the anchor portions **216**. As shown in FIG. **5**, the vertical length L**3** refers to the total length of the anchor portion **216** in the thickness direction that is perpendicular to the surface **210***a* of the base member **210**. As shown in FIG. **5**, the anchor portions **216** may have different vertical lengths L**3**, or may have the same vertical length L**3**.

[0135] Also, it is preferable that the average bonding width of the plurality of anchor portions **216** and the chromium oxide layer **211** is 0.1 μm or more in a cross-section of the base member **210** along the thickness direction. Accordingly, the bonding strength between the anchor portions **216** and the chromium oxide layer **211** is increased, thus inhibiting the anchor portions **216** from breaking away from the chromium oxide layer **211**. As a result, it is possible to further inhibit separation of the chromium oxide layer **211** from the base member **210**.

[0136] The average bonding width of the plurality of anchor portions **216** refers to the average value of bonding widths W**5** of the anchor portions **216**. The bonding width W**5** refers to the total length of a tangent line between the anchor portion **216** and the chromium oxide layer **211** in a cross-section of the base member **210** along the thickness direction. The tangent line between the anchor portion **216** and the chromium oxide layer **211** may be a straight line, a curved line, a wavy line, or the like.

[0137] The average bonding width of the plurality of anchor portions **216** can be obtained by arithmetically averaging bonding widths W**5** of the twenty anchor portions **216** selected in order to obtain the above-described average vertical length.

[0138] Note that there is no particular limitation on the upper limit of the bonding width W**5**, and the upper limit thereof may be 100 μm or less, for example.

[0139] Although there is no particular limitation on the ratio of the average bonding width to the average actual length, the ratio thereof is preferably 0.5 or less. Accordingly, the anchor portions **216** can protrude sharply, thus further increasing the anchoring force of the anchor portions **216** to the base member **210**.

[0140] The anchor portions **216** are constituted by a ceramic material. Although examples of the ceramic material constituting the anchor portions **216** include Cr_2O_3 (chromium oxide), Al_2O_3 (alumina), TiO_2 (titania), CaO (calcium oxide), SiO_2 (silica), MnO (manganese oxide), and $MnCr_2O_4$ (manganese chromium spinel), the examples thereof are not limited thereto.

[0141] Oxides of an element whose equilibrium oxygen pressure is lower than that of Cr (chromium) (referred to as a "low-equilibrium oxygen pressure element" hereinafter) are suitable as the ceramic material constituting the anchor portions **216**. Because the low-equilibrium oxygen pressure element is an element that has a greater affinity for oxygen than Cr and is more likely to be oxidized, it is possible to inhibit oxidation of the base member **210** that surrounds the anchor portions **216** as a result of the anchor portions **216** preferentially taking oxygen that permeates the chromium oxide layer **211**. This makes it possible to maintain the forms of the anchor portions **216**, and thus to obtain the anchor effect resulting from the anchor portions **216** for a long period of time. As a result, it is possible to inhibit separation of the chromium oxide layer **211** from the base member **210**.

[0142] Although examples of the low-equilibrium oxygen pressure element include Al (aluminum), Ti (titanium), Ca (calcium), Si (silicon), and Mn (manganese) and examples of oxides thereof include Al_2O_3, TiO_2, CaO, SiO_2, MnO, and $MnCr_2O_4$, examples thereof are not limited thereto.

[0143] The anchor portion **216** may contain only one type of oxide of a low-equilibrium oxygen pressure element, or may contain two or more types thereof. The anchor portion **216** may be constituted by Al_2O_3, a mixture of Al_2O_3 and TiO_2, or a mixture of TiO_2, MnO, and $MnCr_2O_4$, for example.

[0144] It is preferable that the average content of the low-equilibrium oxygen pressure elements in the plurality of anchor portions **216** is 0.05 or more in terms of a cation ratio when a molar ratio of the elements to the sum of all constituent elements excluding oxygen is defined as the cation ratio. This makes it possible to further inhibit oxidation of the base member **210** that surrounds the anchor portions **216**, and thus to obtain the anchor effect resulting from the anchor portions **216** for a long period of time.

[0145] There is no particular limitation on the upper limit of the average content of the low-equilibrium oxygen pressure elements in the plurality of anchor portions **216**, and a larger upper limit is more preferable.

[0146] The average content of the low-equilibrium oxygen pressure elements in the plurality of anchor portions **216** can be obtained using the following method. First, with each of the twenty anchor portions **216** selected in order to obtain the above-described average vertical length, the contents of low-equilibrium oxygen pressure elements are measured in terms of the cation ratios at ten points at which the actual length L**1** is divided into eleven portions. Then, with regard to each anchor portion **216**, the maximum value is selected from the contents measured at the ten points. Then, the average content of the low-equilibrium oxygen pressure elements is obtained by arithmetically averaging the twenty maximum values selected for the twenty anchor portions **216**.

[0147] The anchor portion **216** is preferably in contact with at least a portion of the inner surface of the recess **210***b*. It is particularly preferable that the recess **210***b* is entirely filled with the anchor portion **216**, and the anchor portion **216** is in contact with substantially the entire inner surface of the recess **210***b*.

[0148] Although there is no particular limitation on the number of anchor portions **216**, ten or more anchor portions **216** are preferably observed in a 10 mm length of the surface **210***a* in the observation of a cross-section of the base member **210**, and twenty or more anchor portions **216** are more preferably observed in a 10 mm length thereof. Accordingly, the anchor effect resulting from the anchor portions **216** can be evenly exerted in a wide range, thus particularly inhibiting separation of the chromium oxide layer **211** from the base member **210**.

[0149] Method for Manufacturing Alloy Member **900**

[0150] A method for manufacturing an alloy member **400** will be described.

[0151] First, a plurality of recesses **210***b* are formed in the surface **210***a* of the base member **210**. It is possible to efficiently form the recesses **210***b* using shot peening, sand blasting, or wet blasting, for example. At this time, the depth and the width of the recesses **210***b* are adjusted by adjusting the particle size of a polishing agent. Accordingly, it is possible to adjust the average actual length, the average straight line length, the average vertical length, and the average bonding width of the plurality of anchor portions **216** to be formed later. Also, the recesses **210***b* are curved or bent entirely or partially by leveling the surface thereof using a roller after the recesses **210***b* are formed. This makes it possible to warp at least some of the anchor portions **216** to be formed later.

[0152] Then, by applying, onto the surface **210***a* of the base member **210**, a paste for an anchor portion obtained by adding ethyl cellulose and terpineol to oxides of the low-equilibrium oxygen pressure elements, the recesses **210***b* are filled with the paste for an anchor portion.

[0153] Then, the paste for an anchor portion applied onto the surface **210***a* of the base member **210** is removed using a squeegee, for example.

[0154] Then, as a result of performing heat treatment (800° C. to 900° C., 1 to 20 hours) on the base member **210** in an atmosphere, the paste for an anchor portion with which the recesses **210***b* are filled is solidified to form the anchor portions **216**, and the chromium oxide layer **211** for covering the anchor portions **216** is formed.

OTHER EMBODIMENTS

[0155] Although embodiments of the present invention have been described above, the present invention is not limited thereto, and various modifications can be made without departing from the gist of the present invention.

[0156] Although the base member **210** includes the recesses **210***b* and the chromium oxide layer **211** includes the embedded portions **211***b* in the above-described first embodiment, the chromium oxide layer **211** may include the recesses **210***b* and the base member **210** may include the embedded portions **211***b*, for example. It is possible to effectively inhibit separation of the chromium oxide layer **211** even in this case.

What is claimed is:

1. An alloy member configured to be used in an electrochemical cell stack, the alloy member comprising:

a base member constituted by an alloy material containing chromium;

a chromium oxide layer covering at least a portion of a surface of the base member;

a pore formed in an interface region of the base member that is located 30 μm or less from an interface between the chromium oxide layer and the base member, the pore configured to inhibit separation of the chromium oxide layer from the base member; and

an extending portion extending from the pore into the base member,

the extending portion containing an oxide of an element whose equilibrium oxygen pressure is lower than equilibrium oxygen pressure of a major element of the base member.

2. The alloy member according to claim **1**, comprising

a metal oxide disposed on an inner surface of the pore.

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