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(54) **ELECTROLYSIS SYSTEM**

(57) An electrolysis apparatus is disclosed as including an electrolysis cell (10) accommodating therein electrolyte (70), a heating section (20) located around the electrolysis cell to heat the electrolysis cell, an electrode section (30) having an electrode unit (30a) immersed in the electrolyte and a power-conducting electrode portion (30b) supporting the electrode unit to apply the electrode unit with electric power, a lid body (45) defining a space region (40) in an area above the electrolysis cell, an exhaust section (50) located in the lid body to allow the space region to communicate with an outside for exhausting by-product gas, resulting from electrolysis of the electrolyte, from the space region to the outside, and an evaporation restraining member (60, 80, 80A, 80B, 90, 90A, 90B) floating on a liquid surface of the electrolyte so as to cover the liquid surface of the electrolyte for permitting by-product gas, resulting from electrolysis of the electrolyte, to escape to the space region while restraining the electrolyte from evaporating.

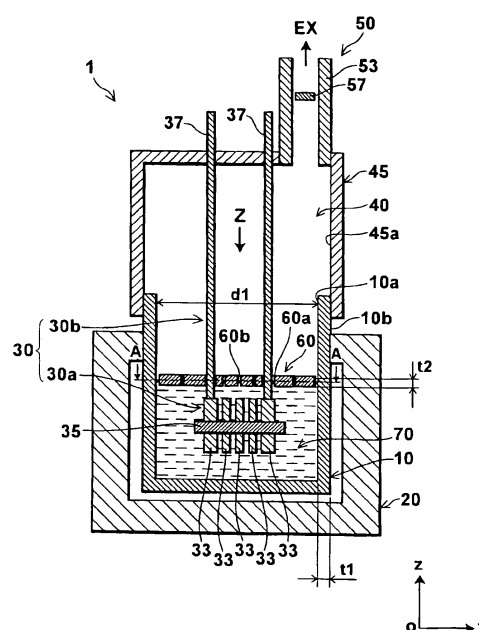


FIG.1

Description

ELECTROLYSIS APPARATUS

[TECHNICAL FIELD]

[0001] The present invention relates to an electrolysis apparatus and, more particularly, to an electrolysis apparatus having an evaporation restraining member.

[BACKGROUND ART]

[0002] In recent years, an electrolysis apparatus has been proposed for melting metal compound such as zinc chloride or the like to carry out electrolysis of the same for producing metal such as zinc or the like. With such an electrolysis apparatus, metal compound, filled in a crucible (electrolysis cell) made of graphite, is heated up to a temperature above a melting point of metal to obtain electrolyte. Then, applying electric current electrodes immersed in the resulting electrolyte enables electrolyte to be decomposed respectively into compound such as chloride and metal such as zinc.

[0003] With such an electrolysis apparatus, heating metal compound to a temperature beyond the melting point of metal results in the production of metal compound gas. If zinc chloride is heated to a temperature of, for instance, 400°C higher than a melting point of zinc by a value of approximately 50°C, then a part of zinc chloride is gasified from a liquid surface of melted zinc chloride and such gasified zinc chloride rises in the electrolysis apparatus to be cooled in an area above the liquid surface of electrolyte. This causes a large amount of electrolyte mist to be generated. Such electrolyte mist is adhered onto an inner wall of an exhaust pipe for exhausting by-product gas, thereby causing a possibility to occur with an issue of clogging the exhaust pipe.

[0004] Japanese Patent Application Laid-Open Publication 2005-200758 discloses an electrolysis cell structure body, comprised of an air space provided in an area above a liquid surface of electrolyte to cause by-product gas to convect, and a gas exhaust tube provided above such an air space. A temperature of the spacing at an upper area of the air space is set to be lower than a temperature of electrolyte to cause by-product gas and electrolyte mist to convect in the air space, causing electrolyte mist to drop into electrolyte to allow only by-product gas to be delivered to the exhaust pipe.

[DISCLOSURE OF INVENTION]

[Technical Problem]

[0005] However, upon studies conducted by the present inventors, with such a structure disclosed in Japanese Patent Application Laid-Open Publication 2005-200758, when heating electrolyte at a higher temperature, the amount of evaporated electrolyte increases.

es. In this case, there is a certain limitation in causing electrolyte mist to drop into electrolyte by causing by-product gas and electrolyte mist to convect in the air space.

[0006] Meanwhile, if the temperature for heating metal compound set at a lower level to lower the temperature of electrolyte, the amount of evaporated electrolyte can be reduced. However, the lower the temperature of electrolyte, the higher will be a voltage required for electrolysis and the greater will be liquid resistance of electrolyte with a resultant increase in electric power needed for electrolysis. Further, the low temperature results in an increase in viscosity of electrolyte and an electrolysis product is separated from electrode surfaces at slow speeds with a resultant difficulty of efficiently continuing electrolysis reaction. That is, there is a certain limitation in setting the temperature for heating metal compound to be lowered to maintain electrolyte at the lowered temperature.

[0007] The present invention has been completed with the above studies conducted by the present inventors in mind and has an object of the present invention to provide an electrolysis apparatus that can minimize the amount of evaporated electrolyte and prevent the occurrence of the clogging of an exhaust pipe without lowering a temperature of electrolyte.

[Technical Solution]

[0008] To solve the above issues, one aspect of the present invention provides an electrolysis apparatus comprising an electrolysis cell accommodating therein electrolyte, a heating section located around the electrolysis cell to heat the electrolysis cell, an electrode section having an electrode unit immersed in the electrolyte and a power-conducting electrode portion supporting the electrode unit to apply the electrode unit with electric power, a lid body defining a space region in an area above the electrolysis cell, an exhaust section located in the lid body to allow the space region to communicate with an outside for exhausting by-product gas, resulting from electrolysis of the electrolyte, from the space region to the outside, and an evaporation restraining member floating on a liquid surface of the electrolyte so as to cover the liquid surface of the electrolyte for permitting the by-product gas, resulting from electrolysis of the electrolyte, to escape to the space region while restraining the electrolyte from evaporating.

[Advantageous Effects]

[0009] With the electrolysis apparatus of one aspect of the present invention, the amount of evaporated electrolyte can be decreased and the clogging of an exhaust pipe can be avoided without lowering a temperature of electrolyte.

[BRIEF DESCRIPTION OF DRAWINGS]

[0010]

FIG. 1 is a cross-sectional view of an electrolysis apparatus of a first embodiment according to the present invention.

FIG. 2 is a view as viewed in a Z-direction of FIG. 1 and represents an enlarged top view of an evaporation restraining member used in the present embodiment.

FIG. 3 is an enlarged cross-sectional view taken on line A-A of FIG. 1.

FIG. 4 is a cross-sectional view of an electrolysis apparatus of a second embodiment according to the present invention.

FIG. 5 is a view as viewed in the Z-direction of FIG. 4 and represents an enlarged top view of an evaporation restraining member used in the present embodiment.

FIG. 6 is an enlarged cross-sectional view taken on line B-B of FIG. 4.

FIG. 7 corresponds to a positional relationship of FIG. 5 and represents an enlarged top view of an evaporation restraining member of a modified form of the present embodiment.

FIG. 8 corresponds to a positional relationship of FIG. 5 and represents an enlarged top view of an evaporation restraining member of another modified form of the present embodiment.

FIG. 9 is a cross-sectional view of an electrolysis apparatus of a third embodiment according to the present invention.

FIG. 10 is a view as viewed in the Z-direction of FIG. 9 and represents an enlarged top view of an evaporation restraining member used in the present embodiment.

FIG. 11 is an enlarged cross-sectional view taken on line C-C of FIG. 10.

FIG. 12 corresponds to a positional relationship of FIG. 11 and represents an enlarged top view of an evaporation restraining member of a modified form of the present embodiment.

FIG. 13 corresponds to a positional relationship of FIG. 11 and represents an enlarged top view of an evaporation restraining member of another modified form of the present embodiment.

[BEST MODE FOR CARRYING OUT THE INVENTION]

[0011] Now, electrolysis apparatuses of various embodiments according to the present invention will be described below with reference to the accompanying drawings. Throughout the drawings, an x-axis, a y-axis and a z-axis represent a three-axis orthogonal coordinate system with the z-axis having a positive direction referred to as an upper direction and a negative direction referred to as a lower direction.

(First Embodiment)

[0012] First, the electrolysis apparatus of a first embodiment according to the present invention will be described below in detail.

[0013] FIG. 1 is a cross-sectional view of the electrolysis apparatus of the present embodiment. Further, FIG. 2 is an enlarged top view of FIG. 1, as viewed in the Z-direction that is parallel to the z-axis, for representing an evaporation restraining member forming part of the electrolysis apparatus of the present embodiment. FIG. 3 is an enlarged cross-sectional view taken on line A-A of FIG. 1.

[0014] As shown in FIG. 1, the electrolysis apparatus 1 of the present embodiment includes an electrolysis cell 10, a heating section 20, an electrode section 30, a lid body 45, an exhaust section 50 and an evaporation restraining member 60.

[0015] The electrolysis cell 10 is a cylindrical member, made of graphite, which is bottomed for internally accommodating electrolyte 70 composed of melted metal compound such as zinc chloride or the like. The electrolysis cell 10 has an inner surface 10a, coated with a glass-like carbon layer, with which electrolyte 70 is held in contact. The electrolysis cell 10 has, for instance, an inner diameter d1 of 400mm with a wall thickness t1 of 20 mm.

[0016] The heating section 20 is a bottomed cylindrical member located around the electrolysis cell 10 so as to surround the same. The heating section 20 has an upper end formed in an open end that is folded inward to be brought into contact with an outer wall 10b of the electrolysis cell 10 at an upper open end thereof to fixedly retain the electrolysis cell 10. Further, the electrolysis cell 10 has the open end protruding upward from a contact position with the heating section 20.

[0017] The heating section 20 heats and melts the metal compound accumulated in the electrolysis cell 10 to form electrolyte 70. Electrolyte 70 is maintained at a given temperature to reduce liquid resistance and when electrolyte 70 includes, for instance, zinc chloride, electrolyte 70 is maintained at a temperature of approximately 550°C.

[0018] The electrode section 30 supplies electric current to electrolyte 70 for making electrolysis of electrolyte 70. The electrode section 30 includes an electrode unit 30a entirely immersed in electrolyte 70, and a power-conducting electrode portion 30b.

[0019] The electrode unit 30a takes the form of a structure comprised of a plurality of plate-like graphite electrodes 33 unitarily juxtaposed by given distances on a ceramic base member 35 made of alumina to be fixedly retained in place. The electrode unit 30a is of a bipolar type formed in an electrode pair in which adjacent ones of the plurality of plural electrodes 33 have different polarities but may be of a unipolar type.

[0020] The power-conducting electrode portion 30b are a pair of columnar electrode bars each made of iron and each covered with a protector tube (not shown) made

of mullite. The pair of iron electrode bars 37 is connected to the electrodes 33 on both sides of the electrode unit 30a.

[0021] The lid body 45 includes a cylindrical member with an upper portion being closed and is located on the electrolysis cell 10 at an upper portion thereof. The lid body 45 has a lower end portion formed with an open end portion having an inner surface 45a kept in contact with the outer wall 10b protruding upward from a contact area held in contact with the heating portion 20 of the electrolysis cell 10. The lid body 45 and the outer wall 10b are hermetically sealed with each other by means of a seal member (not shown) such that the lid body 45 and the electrolysis cell 10 are formed in a unitary structure. This allows the electrolysis cell 10 to have an upper area formed with a space region 40 in a closed space. In addition, the lid body 45, closing an upper area of the space region 40, has a top surface portion formed with a pair of through-bores through which the pair of electrode bars 37 is inserted.

[0022] The exhaust section 50 includes an exhaust pipe 53 connected to the top surface portion, closing the upper area of the space region 40, of the lid body 45 at an area apart from the area in which the electrode bars 37 are inserted, and a filter 57 fitted in the exhaust pipe 53.

[0023] The exhaust pipe 53 is connected to an exhaust system (not shown) to allow by-product gas, generated during electrolysis of electrolyte 70, to be exhausted from the space region 40 to the outside through the exhaust system.

[0024] As shown in FIGS. 2 and 3 in detail, the evaporation restraining member 60 is placed on a liquid surface of electrolyte 70 in a floating state so as to cover a nearly greater part of the liquid surface of electrolyte 70. More particularly, the evaporation restraining member 60 is comprised of a circular plate-like member, having a pair of vertically extending first through-bore 60a, and a plurality of vertically extending second through-bores 60b.

[0025] The evaporation restraining member 60 is shaped in a plate-like configuration similar to a shape of the open end of the electrolysis cell 10 because of enabling the plate-like configuration to cover the greater portion of the liquid surface of electrolyte 70 and, hence, comprised of the circular plate-like member. However, the present invention is not limited to such a configuration and the evaporation restraining member 60 may take a variety of shapes depending on a structure, such as a rectangular shape, of the electrolysis cell 10 at the open end thereof.

[0026] Under a circumstance where electrolyte 70 is melted liquid of zinc chloride, further, the evaporation restraining member 60 may be preferably made of graphite on the standpoint of tolerance and specific gravity against electrolyte 70. By so doing, the evaporation restraining member 60 can be reliably placed on the liquid surface such that the evaporation restraining member 60 partly protrudes from the liquid surface of electrolyte 70 in a

floating state.

[0027] The pair of first through-bores 60a is formed in circular holes, penetrating upper and lower surfaces of the evaporation restraining member 60, through which the pair of electrode bars 37 is inserted. Each of the through-bores 60a has an opening diameter d2 that is greater than a diameter d4 of each electrode bar 37 involving the protector tube. The pair of electrode bars 37 is fixed to a support body (not shown) in an area above the evaporation restraining member 60 and connected to a D.C power supply (not shown).

[0028] The plurality of second through-bores 60b are formed in circular holes, penetrating the upper and lower surfaces of the evaporation restraining member 60 so as to allow a part of the liquid surface of electrolyte 70 to be exposed to the space region 40, which are formed in given distances in a cyclic pattern as to the x-y plane. As observed in the direction of the z-axis, the evaporation restraining member 60 is disposed so as to cover the electrode unit 30a immersed in electrolyte 70. Thus, the plurality of second through-bores 60b of the evaporation restraining member 60 are necessarily disposed in a region involving a projection geometry, projected onto the evaporation restraining member 60, of the electrode unit 30a which is immersed in electrolyte 70.

[0029] Each of the first through-bores 60a has an opening diameter d2 of, for instance, 60mm and each of the second through-bores 60b has an opening diameter of, for instance, 20mm. Further, each of the electrode bars 37, involving the protector tube, has a diameter d4 of 50mm. In addition, the evaporation restraining member 60 has an outer diameter of, for instance, 90mm with a thickness t2 of 5mm.

[0030] Here, electrolyte mist is present in the space region 40 at a rate varying in proportion to the amount of evaporated electrolyte 70. In addition, the amount of evaporated electrolyte 70 varies in proportion to a surface area of a liquid phase relative to a gas phase when the liquid phase and the gas phase are held in contact with each other, i.e. in proportion to a surface area in which the liquid surface of electrolyte 70 is held in direct contact with the space region 40.

[0031] Therefore, the evaporation restraining member 60 is placed on the liquid surface of electrolyte 70 so as to cover the greater part of the liquid surface of electrolyte 70 in the floating state with a part of the liquid surface of electrolyte 70 being exposed to the space region 40 via the second through-bores 60b. With such a structure being adopted, even if a temperature of electrolyte 70 reaches high temperatures, the amount of evaporated electrolyte 70 can be reduced while appropriately permitting by-product gas, generated upon electrolysis of electrolyte 70, to escape to the space region 40.

[0032] Further, the evaporation restraining member 60 is placed on the liquid surface of electrolyte 70 in the floating state. Even if the liquid surface moves upward or downward depending on an increment or decrement of electrolyte 70, the evaporation restraining member 60

can cover the liquid surface of electrolyte 70 following the movement thereof. This allows the liquid surface to have a minimized exposed surface area, reliably decreasing the amount of evaporated electrolyte 70.

[0033] With the structure of the present embodiment, therefore, applying the evaporation restraining member 60 reliably enables a reduction in the amount of evaporated electrolyte 70 while realizing electrolysis reaction with high efficiency at high temperatures.

[0034] Further, the liquid surface of electrolyte 70 is appropriately exposed to the space region 40 via the second through-bores 60b. This allows by-product gas, generated following electrolysis of electrolyte 70, to escape through the second through-bores 60b to the space region 40, reliably enabling the suppression of a situation under which by-product gas undesirably remain in a lower area of the evaporation restraining member 60.

[0035] At the same time, a reduction occurs in the amount of evaporated electrolyte 70 while achieving a reduction in a heat discharge rate of electrolyte 70. This results in an increase in a heat retention effect of electrolyte 70 to enable the heat section 20 to have improved heating efficiency.

[0036] Further, the reduction occurs in the amount of evaporated electrolyte 70 and the rate of generating electrolyte mist is decreased. This allows the filter 57 to be less subjected to the occurrence of electrolyte mist adhered thereto to minimize a risk of clogging. This enables by-product gas such as, for instance, chlorine gas, generated in electrolysis of electrolyte 70 to be efficiently exhausted from the space region 40, resulting in improvement in safety of the electrolysis apparatus.

[0037] Incidentally, in case that the power-conducting electrode portion 30b is not provided to extend above the electrode unit 30a but provided to extend laterally to or beneath the electrode unit 30a, of course, it is not needed that the pair of first through-bores 60a is formed in the evaporation restraining member 60, and such a situation is applicable to the following embodiments.

(Second Embodiment)

[0038] Next, an electrolysis apparatus of a second embodiment according to the present invention will be described below in detail with reference to the accompanying drawings.

[0039] FIG. 4 is a cross-sectional view of the electrolysis apparatus of the present embodiment. Further, FIG. 5 is an enlarged top view of FIG. 4, as viewed in the Z-direction that is parallel to the z-axis, for representing an evaporation restraining member used in the present embodiment. Furthermore, FIG. 6 is an enlarged cross-sectional view taken on line B-B of FIG. 4.

[0040] The electrolysis apparatus 2 of the present embodiment mainly differs from the first embodiment in that the evaporation restraining member 60 is replaced by an evaporation restraining member 80 with other structures being identical to each other. Therefore, the present em-

bodiment will be described below with a focus on such a differing point and like or corresponding component parts bear like reference numerals to suitably simplify the description or to omit such a description.

[0041] As shown in FIGS. 4 to 6, more particularly, the evaporation restraining member 80 is a circular plate-like member placed on the liquid surface of electrolyte 70 in a floating state so as to cover a nearly greater part of the liquid surface of electrolyte 70. The evaporation restraining member 80 has the same structure as that of the evaporation restraining member 60 of the first embodiment and includes a pair of first through-bores 80a inserting the electrode bars 37 of the electrode section 30, and a plurality of second through-bores 80b but differs from the evaporation restraining member 60 of the first embodiment in respect of a detailed structure of the second through-bores 80b. Also, the pair of first through-bores 80a of the evaporation restraining member 80 has the same structure as the pair of first through-bores 60a of the evaporation restraining member 60 of the first embodiment.

[0042] That is, the plurality of second through-bores 80b is provided in a limited way in an inward area surrounded with a circle 85, having a diameter composed of a distance between respective center axes of the pair of first through-bores 80a and 80a (i.e. between respective center axes of the pair of electrode bars 37 and 37), which passes across respective center points of the pair of first through-bores 80a and 80a as to the x-y plane. In other words, the plurality of second through-bores 80b is provided in a limited region involving a projection geometry, projected onto the evaporation restraining member 80, of the electrode unit 30a which is immersed in electrolyte 70.

[0043] Therefore, the evaporation restraining member 80 has a structure having the plurality of second through-bores 80b provided in the limited way only at the region corresponding to an upper area of the electrode unit 30a immersed in electrolyte 70. Meanwhile, a remnant area, in which none of such through-bores 80b is provided in the evaporation restraining member 80, realizes a structure for reliably covering the liquid surface of electrolyte 70.

[0044] With the structure of the present embodiment, accordingly, the evaporation restraining member 80 is capable of minimizing an exposed area of the liquid surface of electrolyte 70 to reliably decrease the amount of evaporated electrolyte 70 while enabling by-product gas, generated upon electrolysis initiated at the electrode unit 30a, to be directly exhausted to the space region 40 at high efficiency in an area immediately above the electrode unit 30a. This reliably prevents by-product gas from accumulating at a lower area of the evaporation restraining member 80.

[0045] Further, a reduction in the amount of evaporated electrolyte 70 results in a decrease in a heat radiation effect of electrolyte 70. As a result, electrolyte 70 can have an increased heat retention effect with resultant im-

provement in heating efficiency of the heating section 20.

[0046] With the evaporation restraining member 80 of the present embodiment, the pair of first through-bores 80a are provided for inserting the pair of electrode bars 37, respectively, and, in addition thereto, the second through-bores are provided in the evaporation restraining member 80 to allow the liquid surface of electrolyte 70 to be exposed in the limited region involving the projection geometry, projected onto the evaporation restraining member 80, of the electrode unit 30a immersed in electrolyte 70. Thus, the evaporation restraining member 80 may be conceivably applied in various modified forms as typically described below in detail.

[0047] FIG. 7 shows a positional relationship corresponding to that of FIG. 5 and represents an enlarged top view of an evaporation restraining member of a modified form of the present embodiment.

[0048] As shown in FIG. 7, in particular, the evaporation restraining member 80A of the modified form has a single second through-bore 80Ab having a contour continuous with that of a pair of first through-bores 80Aa through which the pair of electrode bars 37 are inserted, respectively, with the pair of first through-bores 80Aa and the second through-bore 80Ab providing a single through-bore in a continuous contour as a whole.

[0049] More particularly, in addition to that the second through-bore 80Ab has an opening configuration which is formed in a limited region involving a projection geometry, projected onto the evaporation restraining member 80A, of the electrode unit 30a immersed in electrolyte 70, the second through-bore 80Ab has an opening configuration which corresponds to the projection geometry of the electrode unit 30a, i.e. which matches the projection geometry of the electrode unit 30a.

[0050] With such a structure of the modified form, accordingly, only an upper region corresponding to the electrode unit 30a immersed in electrolyte 70 is exposed to the space region 40 in a limited way. This allows electrolyte 70 to have the liquid surface exposed in a limited small surface area with a reliable reduction in the amount of evaporated electrolyte 70 while enabling by-product gas, resulting from electrolysis initiated at the electrode unit 30a, to be directly exhausted to the space region 40 with increased efficiency. This prevents by-product gas in a further reliable manner from accumulating in an area beneath the evaporation restraining member 80A.

[0051] FIG. 8 shows a positional relationship corresponding to that of FIG. 5 and represents an enlarged top view of an evaporation restraining member of another modified form of the present embodiment.

[0052] With an evaporation restraining member 80B of another modified form shown in FIG. 8, in particular, four second through-bores 80Bb are juxtaposed in an area sandwiched between a pair of first through-bores 80Ba. In addition, the pair of first through-bores 80Ba have the same structures as those of the pair of through-bores 60a of the evaporation restraining member 60 of the first embodiment.

[0053] More particularly, in addition to that the four second through-bores 80Bb have opening configurations formed in limited regions involving a projection geometry, projected onto the evaporation restraining member 80A, of the electrode unit 30a immersed in electrolyte 70, the four second through-bores 80Bb have opening configurations respectively corresponding to four gap portions each of which is defined as a gap portion between an adjacent pair of five electrodes 33 of the electrode unit 30a. That is, the second through-bores 80Bb have opening configurations matching the projected shapes of the gap portions of the five electrodes 33, respectively.

[0054] With such a structure of another modified form, accordingly, only an upper region corresponding to the four gap portions of the five electrodes 33 of the electrode unit 30a immersed in electrolyte 70 are exposed to the space region 40. This enables by-product gas, resulting from electrolysis initiated at the electrode unit 30a, to be directly exhausted to the space region 40 with increased efficiency. This further reliably prevents by-product gas from accumulating in an area beneath the evaporation restraining member 80B while permitting the liquid surface of electrolyte 70 to have a further minimized exposed surface area to reliably decrease the amount of evaporated electrolyte 70.

(Third Embodiment)

[0055] Next, an electrolysis apparatus of a third embodiment according to the present invention will be described below in detail with reference to the accompanying drawings.

[0056] FIG. 9 is a cross-sectional view of the electrolysis apparatus of the present embodiment. FIG. 10 is an enlarged top view of FIG. 9, as viewed in the Z-direction that is parallel to the z-axis, for representing an evaporation restraining member used in the present embodiment. FIG. 11 is an enlarged cross-sectional view taken on line C-C of FIG. 10.

[0057] The electrolysis apparatus 3 of the present embodiment mainly differs from the second embodiment in that the evaporation restraining member 80 of the second embodiment is replaced by an evaporation restraining member 90 with other structures being identical to each other. Therefore, the present embodiment will be described below with a focus on such a differing point and like or corresponding component parts bear like reference numerals to suitably simplify the description or to omit such a description.

[0058] As shown in FIGS. 9 to 11, more particularly, the plurality of second through-bores 80b of the evaporation restraining member 80 of the second embodiment represent simplified circular holes whereas a plurality of second through-bores 90b of the evaporation restraining member 90 include through-holes each formed in a top-sliced cone-shaped inner circumferential surface 90w. In addition, a pair of first through-bores 90a of the evaporation restraining member 90 have the same structure

as the pair of first through-bores 60a of the evaporation restraining member 60 of the first embodiment and the pair of first through-bores 80a of the evaporation restraining member 80 of the second embodiment.

[0059] That is, the plurality of second through-bores 90b include the through-holes each having the top-sliced cone-shaped inner circumferential surface 90w with an opening diameter d6, placed on the evaporation restraining member 90 at a bottom wall thereof facing electrolyte 90, which is greater than an opening diameter d5 placed on the evaporation restraining member 90 at a top wall thereof facing the space region 40. With each of the second through-bores 90b, for instance, the opening diameter d6, placed at the bottom wall facing electrolyte 90, is 20mm and the opening diameter d5, placed at the top wall facing the space region 40, is 15mm.

[0060] With such a structure of the present embodiment, accordingly, by-product gas, resulting from electrolysis, can smoothly escape through the second through-bores 90b to prevent by-product from accumulating in an area beneath the evaporation restraining member 90, while reliably minimizing an exposed surface area of the liquid surface of electrolyte 70 to enable a reduction in the amount of evaporated electrolyte 70.

[0061] The evaporation restraining member 90 of the present embodiment is intended to provide a structure in which by-product gas, resulting from electrolysis, is enabled to smoothly escape through the second through-bores 90b and a variety of modifications are conceivably provided as typically described below.

[0062] FIG. 12 corresponds to the positional relationship shown in FIG. 11 and is an enlarged cross-sectional view of an evaporation restraining member of a modified form of the present embodiment.

[0063] As shown in FIG. 12, more particularly, with an evaporation restraining member 90A of the present modification, each of a plurality of second through-bores 90Ab has an inner wall 90w1, formed in a top-sliced cone-shaped circumferential wall with a diameter increasing downward from a top wall facing the space region 40, and an inner wall 90w2 formed in a top-sliced cone-shaped circumferential wall with a diameter decreasing upward from a bottom wall facing electrolyte 70.

[0064] That is, the inner walls 90w1 and 90w2 of each of the plurality of second through-bores 90Ab are formed in a surface structure in which both of adjacent top-sliced cone-shaped inner walls are connected to each other via a stepped portion formed in a planar wall portion. When complicated work is needed for performing processing of the inner wall formed in a continuous top-sliced cone-shaped inner wall, the evaporation restraining member 90A can be processed at the top and bottom walls in a separate fashion, providing a further simplified processing capability.

[0065] With the structure of the present embodiment, therefore, simply performing the processing results in the formation of the second through-bores 90Ab that enables by-product gas, resulting from electrolysis, to smoothly

escape. Such by-product gas can be exhausted to the space region 40 at further increased efficiency. This reliably prevent by-product gas from accumulating in an area beneath the evaporation restraining member 90A while minimizing an exposed surface area of the liquid surface of electrolyte 70, thereby reliably enabling a reduction in the amount of evaporated electrolyte 70.

[0066] FIG. 13 corresponds to the positional relationship shown in FIG. 11 and represents an enlarged cross-sectional view of an evaporation restraining member of another modified form of the present embodiment.

[0067] As shown in FIG. 13, more particularly, with an evaporation restraining member 90B of the present modification, each of a plurality of second through-bores 90Bb has an inner wall 90w3 formed with a circumferential surface with a diameter continuously and decreasing upward in a decrescent way from a bottom wall facing electrolyte 70.

[0068] That is, the inner wall 90w3 of each of the plurality of second through-bores 90Bb has a structure having a curved surface that smoothly varies from an area facing electrolyte 70 to another area facing the space region 40. This allows by-product gas, resulting from electrolysis, to smoothly escape upward without unnecessarily disturbing a flow of by-product gas resulting from electrolysis such that by-product gas can be guided to the space region 40.

[0069] With the structure of the present embodiment, therefore, by-product gas resulting from electrolysis can smoothly escape through the second through-bores 90Bb, thereby enabling by-product gas resulting from electrolysis to be exhausted to the space region 40 at further increased efficiency. This reliably prevent by-product gas from accumulating in an area beneath the evaporation restraining member 90B while minimizing an exposed surface area of the liquid surface of electrolyte 70, thereby reliably enabling a reduction in the amount of evaporated electrolyte 70.

[0070] Further, the inner wall structure of the various second through-bores 90b, 90Ab and 90Bb, formed in the evaporation restraining members 90, 90A and 90B, respectively, may be applied to parts of such through-bores and remaining through-bores may take simplified circular holes.

[0071] Furthermore, the inner wall structure of the various second through-bores 90b, 90Ab and 90Bb, formed in the evaporation restraining members 90, 90A and 90B, respectively, may be applied to parts of or a whole of the second through-bores 80b of the evaporation restraining member 80 of the second embodiment, parts of or a whole of the second through-bores 80Ab of the evaporation restraining member 80A or parts of or a whole of the second through-bores 80Bb of the evaporation restraining member 80B.

[0072] Hereunder, test examples complying the various embodiments described above will be described below in detail.

(Example 1)

[0073] First, in an example 1, electrolysis of electrolyte was conducted using the electrolysis apparatus 1 of the first embodiment under a condition mentioned below.

[0074] The electrolysis cell 10, having an inner diameter d1 of 400mm with a wall thickness t1 of 20mm, was fixedly placed inside the heating section 20. Thereafter, zinc chloride was poured as a metal compound into the electrolysis cell 10, in which zinc chloride was heated up to a temperature of 550°C to be melted to adequately decrease liquid resistance of poured zinc chloride, thereby forming electrolyte 70.

[0075] Subsequently, the electrode unit 30a, supported with the electrode bars 37 each made of iron and including the protector tube with a diameter d4 of 50mm, was immersed in electrolyte 70. Then, the electrode bars 37 were inserted through the first through-bores 60a of the evaporation restraining member 60, made of graphite and having an outer diameter d5 of 390mm with a wall thickness t2 of 5mm, which had the first through-bores 60a each with an opening diameter d2 of 60mm and the second through-bores 60b each with an opening diameter d3 of 20mm. The evaporation restraining member 60 was dropped onto the liquid surface of electrolyte 70, on which the evaporation restraining member 60 is placed in a floating condition.

[0076] The lid body 45, having the exhaust section 50 connected to the exhaust system, has the open end whose inner wall 45a is unitarily fixed to the outer wall 10b of the open end of the electrolysis cell 10 via the seal member, thereby defining the space region 40.

[0077] By using the electrolysis apparatus 1 of the structure set forth above, the electrode unit 30a is supplied with electric current with current density of 0.5Acm², thereby conducting electrolysis of electrolyte 70 continuously for 8 hours.

[0078] During such electrolysis, an inside of the lid body 45 through an observation window (not shown) located on the lid body 45 was observed, thereby confirming the presence of or absence of the occurrence of electrolyte mist under a visual observation method. Further, after electrolysis has been completed, a comparison was made between weights of the filter 57 made of carbon felt on stages before and after electrolysis to check the amount of evaporated electrolyte 70, i.e. the amount of generated electrolyte mist, upon which evaluation was made in terms of a resulting increment.

(Example 2)

[0079] Next, in an example 2, electrolysis of electrolyte was conducted using the electrolysis apparatus 2 of the second embodiment under the same condition as that of the example 1. During electrolysis, the presence of or absence of the occurrence of electrolyte mist was similarly confirmed under the visual observation method. In addition, after electrolysis, a comparison was similarly

made between weights of the filter 57 on stages before and after electrolysis. Also, the structures of various modifications of the second embodiment were not adopted.

5 (Example 3)

[0080] Subsequently, in an example 3, electrolysis of electrolyte was conducted using the electrolysis apparatus 3 of the third embodiment under the same condition as that of the example 1. During electrolysis, the presence of or absence of the occurrence of electrolyte mist was similarly confirmed under the visual observation method. In addition, each through-bore 90b had an opening diameter d6 of 20mm at the end facing electrolyte 70 and an opening diameter d5 of 15mm at the other end facing the space region 40. Moreover, the structures of various modifications of the third embodiment were not adopted.

20 (Comparative Example)

[0081] For a comparative example, electrolysis was conducted under the same structure and the condition as those of the apparatus used in the example 1 except that the evaporation restraining member 60 is not provided. During electrolysis, the presence of or absence of the occurrence of electrolyte mist was similarly confirmed under the visual observation method. After electrolysis, a comparison was similarly made between weights of the filter 57 made of carbon felt on stages before and after electrolysis.

[0082] With the examples 1 to 3, during electrolysis continuously conducted for 8 hours, observing the inside of the lid body 45 through the observation window (not shown) provided on the lid body 45 allowed the inside of the lid body 45 to be viewed well.

[0083] With the comparative example, on the contrary, the lid body 45 was internally filled with white-colored mist of zinc chloride under a status in which no inside could be viewed. Such a result enabled an evaluation to be made that with the examples 1 to 3, the amount of electrolyte mist can be further effectively reduced than that obtained in the comparative example.

[0084] Further, with the examples 1 to 3, the increment in weight of the filter 57 on a stage after electrolysis continuously conducted for 8 hours decreased to 1/15 of the increment in weight of the filter 57 in the comparative example. Among the examples 1 to 3 in comparison, the increment in weight of the filter 57 on a stage of electrolysis in the example 3 marked the smallest value. As a result, the examples 1 to 3 can be evaluated to have further favorable effects of efficiently minimizing the occurrence of electrolyte mist than that obtained in the comparative example.

[0085] With the present invention, further, it is of course to be appreciated that a kind, an arrangement and the number of pieces of component members are not limited to those of the embodiments set forth above and modi-

fications may be made without departing from the scope of the invention upon suitably substituting those component elements by those which provide equivalent operations and effects.

INDUSTRIAL APPLICABILITY

[0086] As set forth above, the present invention provides an electrolysis apparatus, available to minimize the amount of evaporated electrolyte while preventing the occurrence of the clogging of an exhaust pipe without causing a reduction in temperature of electrolyte, which has a general-purpose and universal characteristic based on which the present invention is expected to be applied to a variety of electrolysis apparatuses.

Claims

1. An electrolysis apparatus comprising:

an electrolysis cell accommodating therein electrolyte;
a heating section located around the electrolysis cell to heat the electrolysis cell;
an electrode section having an electrode unit immersed in the electrolyte and a power-conducting electrode portion supporting the electrode unit to apply the electrode unit with electric power;
a lid body defining a space region in an area above the electrolysis cell;
an exhaust section located in the lid body to allow the space region to communicate with an outside for exhausting by-product gas, resulting from electrolysis of the electrolyte, from the space region to the outside; and
an evaporation restraining member floating on a liquid surface of the electrolyte so as to cover the liquid surface of the electrolyte for permitting by-product gas, resulting from electrolysis of the electrolyte, to escape to the space region while restraining the electrolyte from evaporating.

2. The electrolysis apparatus according to claim 1, wherein:

the evaporation restraining member has a through-bore through which the electrolyte is exposed to the space region so as to cause the by-product gas, resulting from electrolysis of the electrolyte, to escape to the space region.

3. The electrolysis apparatus according to claim 2, wherein:

the through-bore is formed in the evaporation restraining member at a region involving a pro-

jection geometry of the electrode unit projected on the evaporation restraining member.

4. The electrolysis apparatus according to claim 3, wherein:

the through-bore has an opening shape corresponding to the electrode unit.

5. The electrolysis apparatus according to claim 4, wherein:

the through-bore has an opening shape corresponding to a gap portion between electrodes of the electrode unit.

6. The electrolysis apparatus according to claim 2, wherein:

the through-bore has an opening diameter that decreases from a side facing the electrolyte to the other side facing the space region.

7. The electrolysis apparatus according to claim 6, wherein:

the through-bore has an opening diameter that decreases from a side facing the electrolyte to the other side facing the space region via a stepped portion.

8. The electrolysis apparatus according to claim 6, wherein:

the through-bore has an opening diameter that progressively decreases from a side facing the electrolyte to the other side facing the space region.

9. The electrolysis apparatus according to claim 1, wherein:

the evaporation restraining member has a through-bore through which the power-conducting electrode portion extends.

10. The electrolysis apparatus according to claim 1, wherein:

the electrolyte is zinc chloride and the evaporation restraining member is made of graphite.

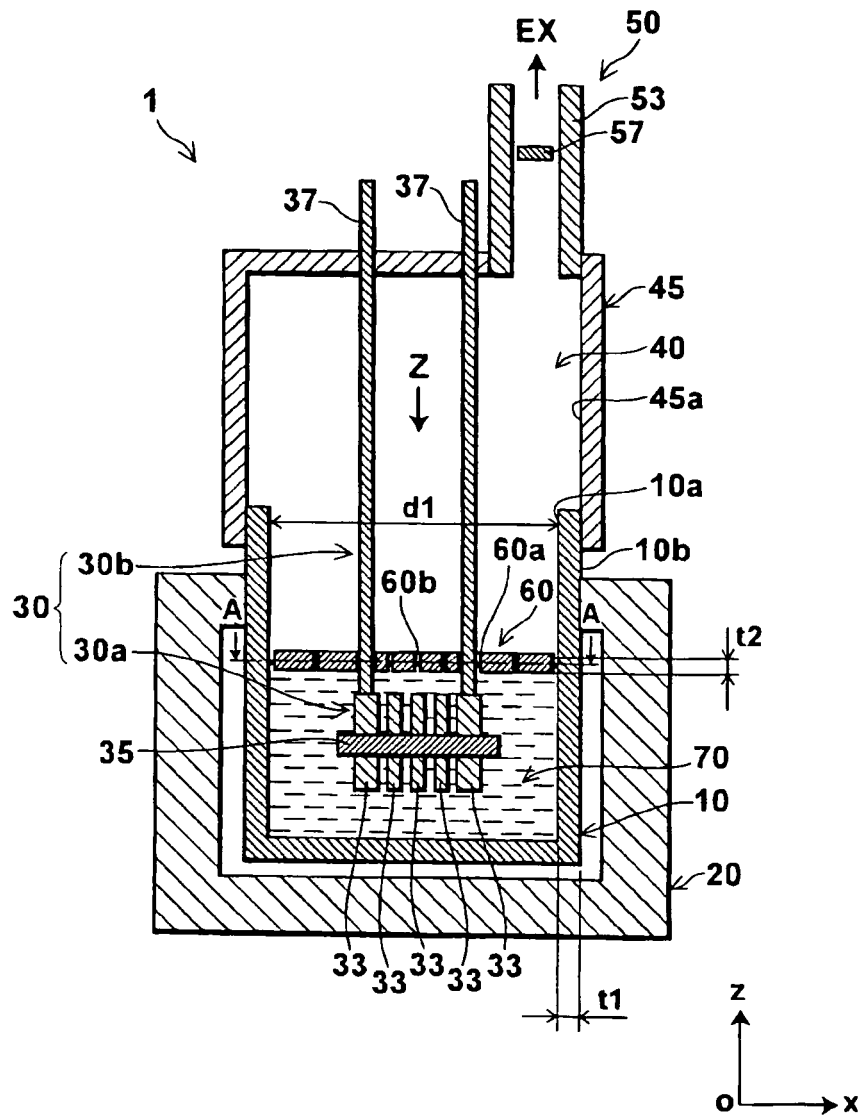


FIG.1

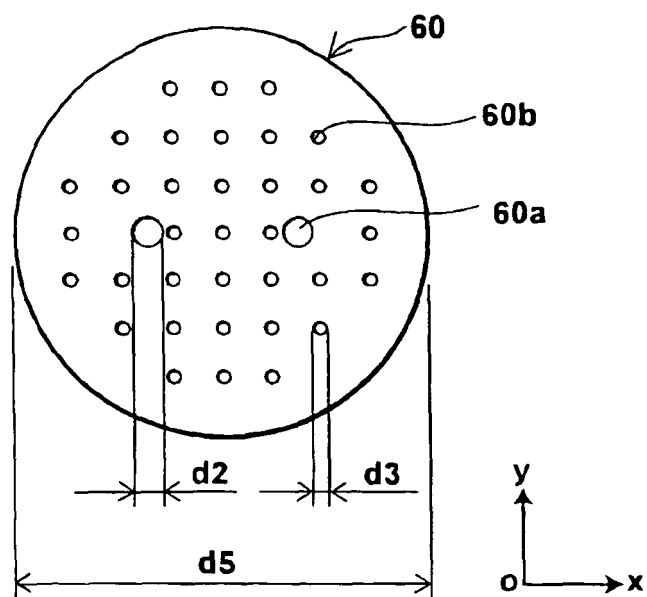


FIG. 2

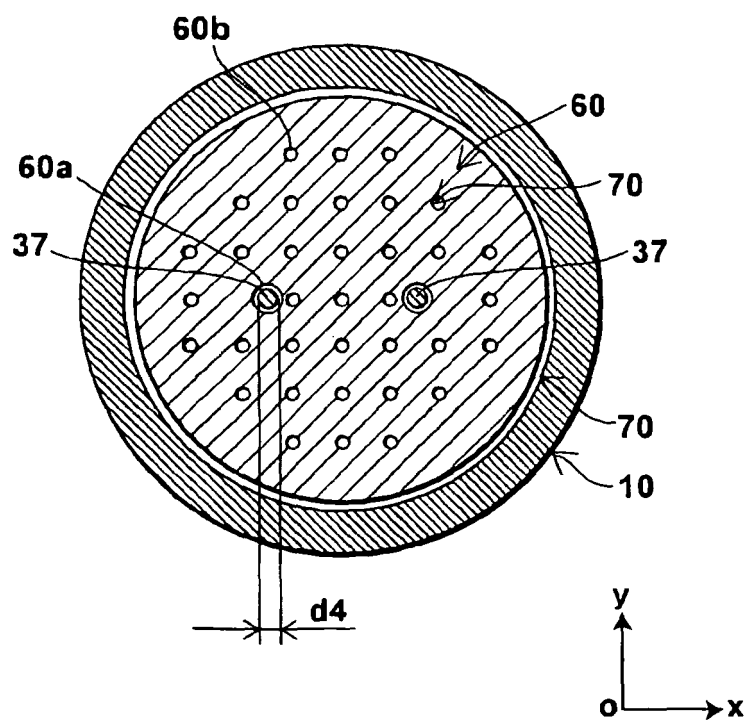


FIG. 3

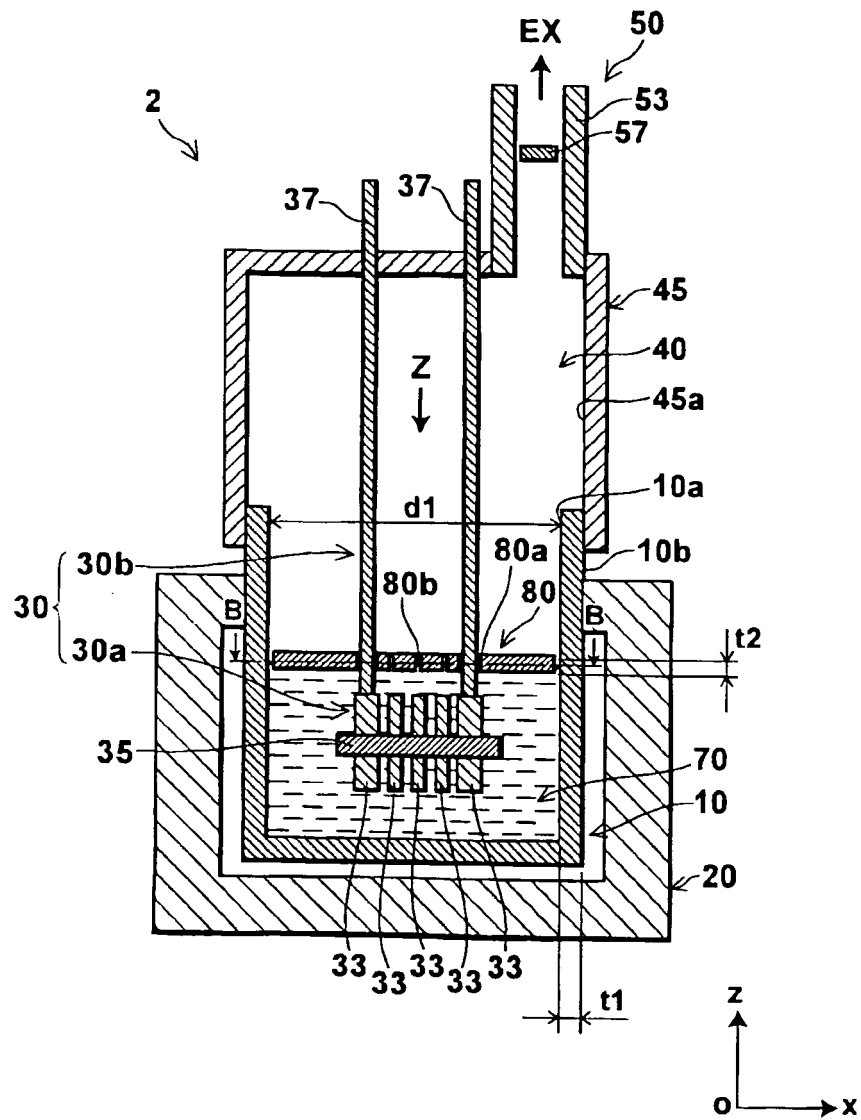


FIG.4

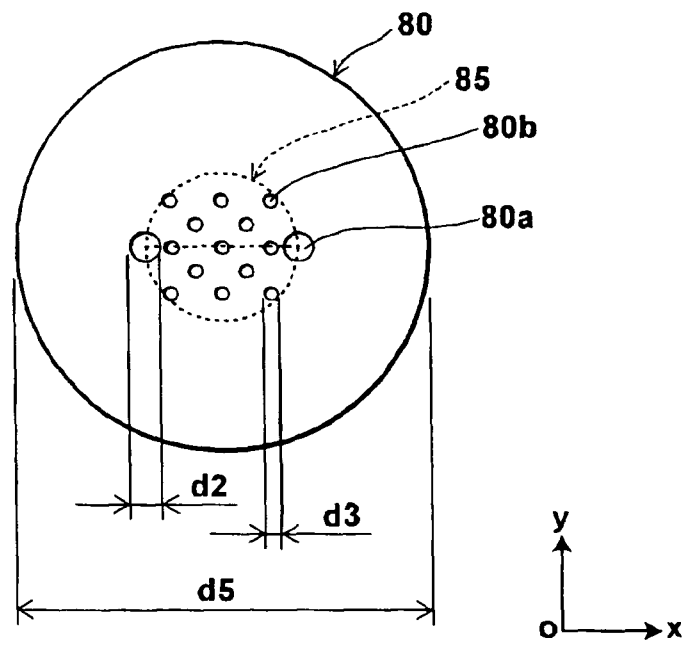


FIG. 5

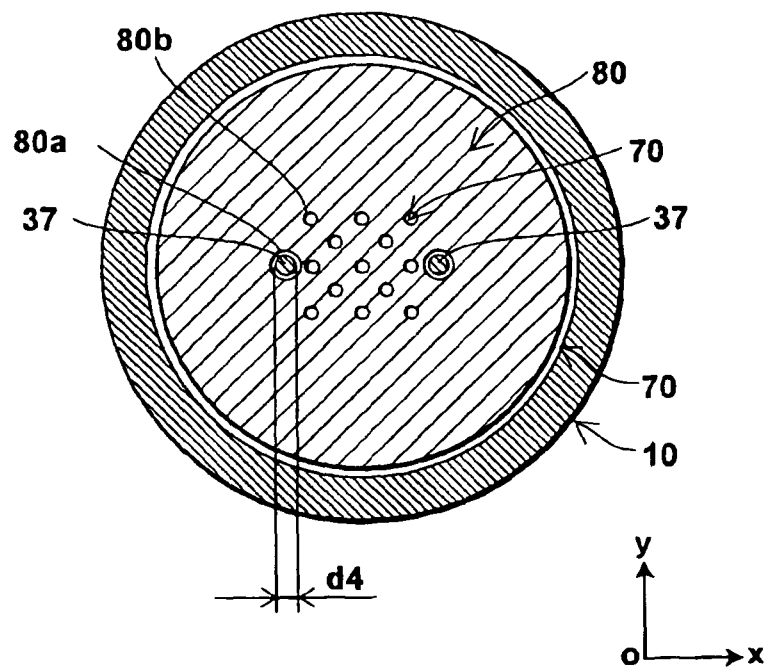


FIG. 6

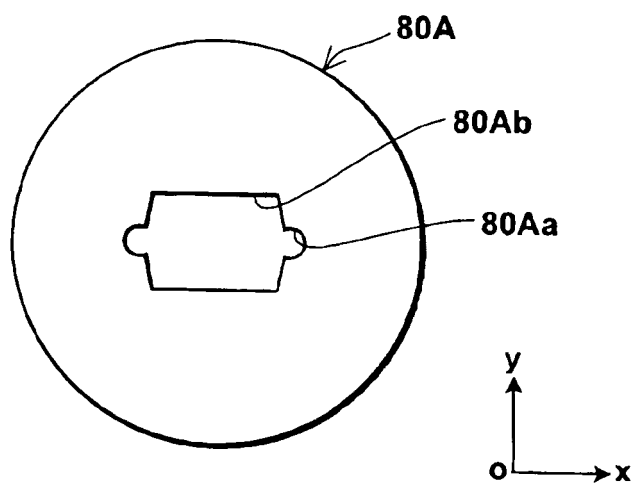


FIG. 7

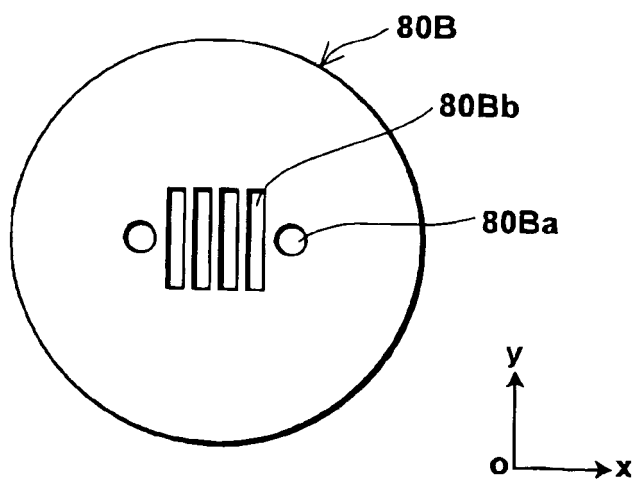


FIG. 8

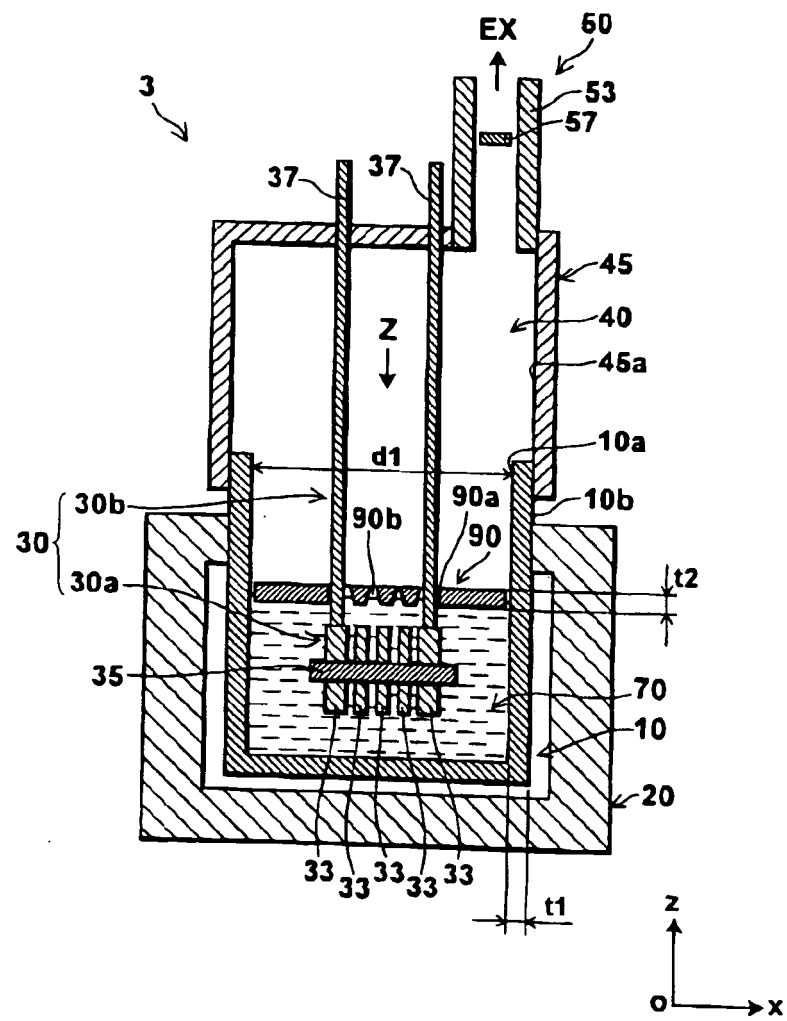


FIG.9

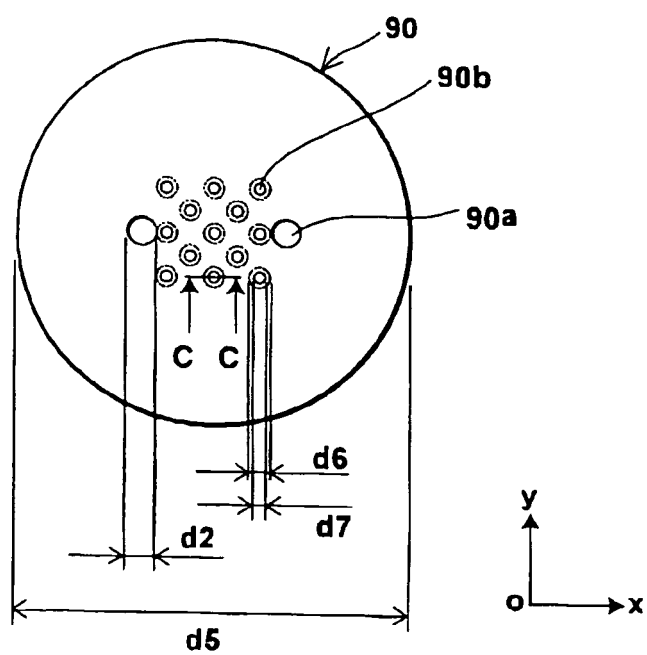


FIG. 10

FIG.11

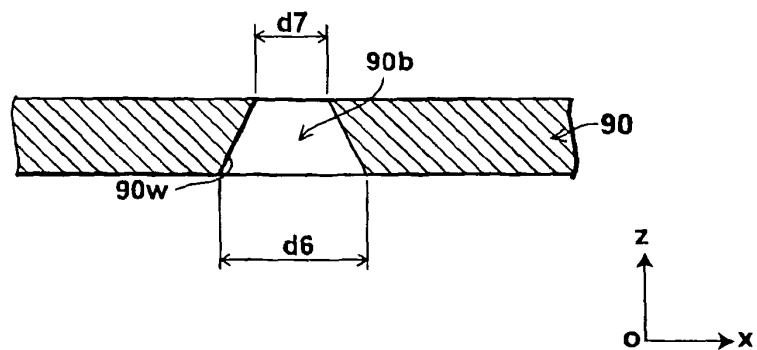


FIG.12

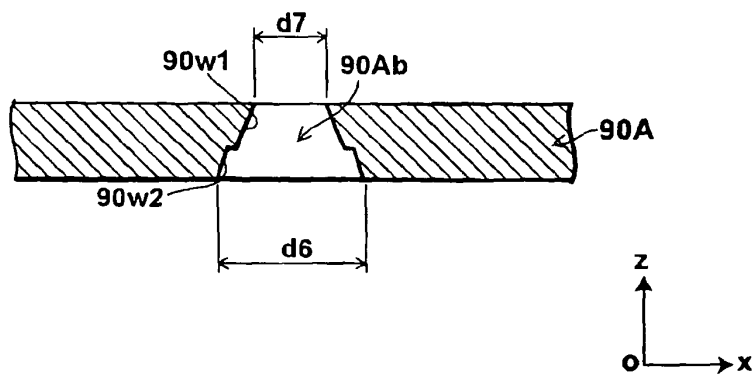
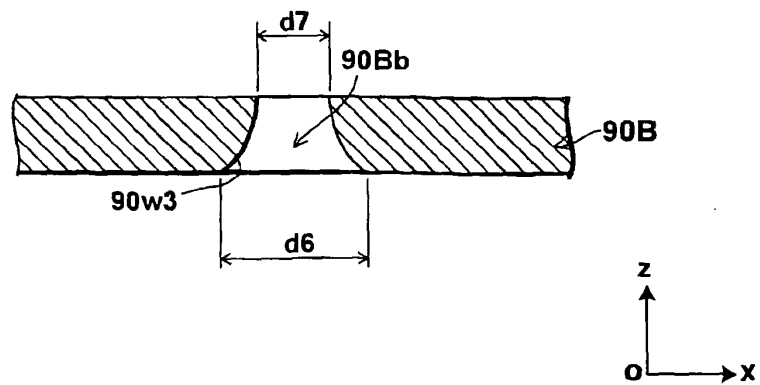


FIG.13



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/003048

A. CLASSIFICATION OF SUBJECT MATTER

C25C7/06(2006.01) i, C25C3/08(2006.01) i, C25C3/22(2006.01) i, C25C3/34(2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C25C7/06, C25C3/08, C25C3/22, C25C3/34

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2008

Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2001-052909 A (Shibafu Engineering Co., Ltd.), 23 February, 2001 (23.02.01), Par. Nos. [0014], [0021], [0044] to [0046], [0051], [0052]; Fig. 4 (Family: none)	1-10

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

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"&" document member of the same patent family

Date of the actual completion of the international search
05 November, 2008 (05.11.08)Date of mailing of the international search report
18 November, 2008 (18.11.08)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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Form PCT/ISA/210 (second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2005200758 A [0004] [0005]