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(54) **Device for electrowinning rare metal using channeled cell and method thereof**

Vorrichtung zur Elektrogewinnung von seltenem Metall mit geriffelter Zelle und Verfahren dafür

Dispositif pour l'extraction électrolytique de métal rare utilisant une cellule cannelée et procédé associé

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Description

BACKGROUND OF THE INVENTION

1) Field of the invention

[0001] The present invention relates to a device for electrowinning metal and a method thereof. More particularly, the present invention relates to a device for rapidly electrowinning metal, such as Cu, Ag, Au or Pt, which is very thinly dissolved in a liquid by using a channeled cell and a method thereof.

2) Background of Related Art

[0002] First, rare metals subject to electrowinning in the present invention will be described.

[0003] The rare metals refer to metallic elements which are in very danger of early exhaustion and are unstable even in supply, have scarcity so that the reserve is not sufficient and omnipresence so that they are preponderant on specific areas. Currently, the rare metal has been used as a generic term referring to 35 kinds of elements such as Li, a rare earth element and In. The rare metals refer to metallic elements which have features of scarcity due to a tiny amount of deposits and localization because the rare metals are exclusively concentrated on specific regions, so the rare metals are subject to the danger of early exhaustion and are unstable even in supply. In Korea, the rare metal becomes a generic term to refer to 35 kinds of elements such as Li, a rare earth element and In.

[0004] The rare earth element, which is a generic term to refer to total 17 elements of scandium (Sc), yttrium (Y) and fifteen lanthanides, has been used as a core material in phosphor (TV, phosphor lamp), an abrasive (semiconductor, display) or a permanent magnet (electric vehicle, wind turbine).

[0005] As describe above, since the rare metal has the feature of scarcity and localization, China is a powerful nation in terms of reservation and production of the rare elements.

[0006] Specifically, since the physical and chemical properties of the rare earth elements are similar with each other, the rare earth elements could not be refined into the pure elements until the 1990's, so that they are rarely utilized. However, recently, as the technique of separating the rare earth elements has been developed, the utilization of the rare earth elements is abruptly increased from 1950.

[0007] Conventionally, schemes of separating and extracting a rare earth element include fractional crystallization, fractional precipitation, selective oxidation-reduction, ion exchange, solvent extraction, and extraction chromatography.

[0008] Hereinafter, an electrowinning scheme, which is an ion exchange scheme to separate europium (${}_{63}\text{Eu}$) from among various rare earth elements, will be described.

[0009] The europium is an element used for CRTs and three-wavelength fluorescent lamps as an activator of red phosphor in the form of high-purity oxide so that the demand of the europium has been increased.

[0010] However, in spite of the increasing of the demand, the content of the europium contained in a rare earth element mineral is less than 0.5% based on all rare earth elements. Thus, a process having several stages is required for high-purifying the europium.

[0011] Until the 1940's to 1950's, the intermediate concentrate containing 8 ~ 13% of europium has been obtained through a precipitation or ion exchange resin scheme. After the 1960's, the concentrate containing 75% of europium has been produced through solvent extraction. To obtain high-purified europium from the intermediate concentrate, the europium property, in which Eu^{3+} can be easily reduced into Eu^{2+} , is utilized.

[0012] In detail, the Eu^{2+} loses a property of trivalent rare earth element ion and represents a property of alkaline earth metal ion. Based on the above property difference, the europium may be easily separated from the rare earth elements.

[0013] The metallic reduction and electrowinning have been used to reduce Eu^{3+} . As describe above, in the present invention, the description of the metallic reduction will be omitted and the electrowinning of europium will be described.

[0014] First, as electrowinning, Hg-cathode electrowinning will be described with reference to FIG. 11 in which an Hg-cathode electrowinning device is depicted.

[0015] The Hg-cathode electrowinning, which is used first to refine europium through the electrowinning, uses Hg as a cathode and Pt as an anode in two electrolytic baths connected to each other through a salt bridge.

[0016] In detail, according to the electrowinning, the europium concentrate containing SO_4^{2-} ions is put in a cathode bath and sulfuric acid solution having the concentration of 1 mol/L is put in an anode bath. Then, if electrolyzed, EuSO_4 precipitate is formed by the europium in the cathode bath.

[0017] However, the Hg-cathode electrowinning can process only a small quantity and cause bad purity of europium, and in addition, may cause mercury contamination when europium oxide is produced, so the Hg-cathode electrowinning is not industrially used in recent years.

[0018] Next, as an electrowinning scheme, an ion-exchange membrane electrowinning scheme will be described with reference to FIG. 12 which schematically shows an ion-exchange membrane electrowinning device.

[0019] The ion-exchange membrane electrowinning scheme, which had been developed in 1980's, uses porous carbon electrodes installed in an electrolytic bath divided by an ion-exchange membrane.

[0020] According to the ion-exchange membrane electrowinning, europium is electrowinning while FeCl_2 solution is being input to the cathode bath at a predetermined speed in the state that concentrated europium (RECl_2 , specifically, Eu^{3+}) solution is put in the cathode bath.

[0021] In this case, the primarily reduced solution is secondarily reduced in an electrolytic bath having the same structure as that of the primary reduction, so that the europium reduction rate is increased to 99% or more. Then, the Eu^{2+} solution is transferred into a precipitation device.

[0022] In the precipitation device, the Eu^{2+} solution transferred from the electrolytic bath reacts with the mixing solution of ammonium sulfate of 2 mol/L and sulfuric acid of 1 mol/L to obtain EuSO_4 precipitate. Then, the europium is separated from the EuSO_4 precipitate. In this case, to restrain europium oxidation due to air contact, the EuSO_4 precipitate is preferably purged with nitrogen gas.

[0023] Next, porous carbon electrode electrowinning will be described with reference to FIG. 13 which schematically shows a porous carbon electrode electrowinning device.

[0024] In FIG. 13, reference numerals 1 and 3 denote outlets, reference numeral 2 denotes a gas exhaustion hole, reference number 4 denotes an inlet, reference number 5 denotes a glass reaction container, reference numeral 6 denotes a cathode, reference numeral 7 denotes an anode, and reference numeral 8 denotes porous graphite.

[0025] Similar to the ion-exchange membrane electrowinning, although the porous carbon electrode electrowinning using the porous carbon electrode electrowinning device depicted in FIG. 13 uses a porous carbon electrode, the porous carbon electrode has holes smaller than those of the ion-exchange membrane electrolytic electrode. In this case, the porosity is about 43%.

[0026] The porous carbon electrode electrowinning utilizes the principle that, when the solution containing europium-concentrated rare earth chloride and Br is input to the material inlet under a pressure, the europium reduction reaction occurs while the solution passes through the air gaps of the cathode and the oxidation reaction of Br occurs at the anode.

[0027] However, the porous carbon electrode electrowinning also has a low reduction rate so that the recovery rate is deteriorated. In addition, the product is contaminated by Br.

[0028] As described above, according to the conventional electrowinning schemes, there is adopted a scheme of increasing a reaction area, in which a stirrer such as a propeller is used or the reduction bath itself is rotated in order to increase the quantity of reaction and the reaction speed, or a scheme of increasing a reaction time, in which, as the ion-exchange membrane electrowinning described with reference to FIG. 12, the electrowinning solution obtained through a primary electrowinning is secondarily electrowinning, has been used.

[0029] There is a related art which is Korea Unexamined Patent Publication No. 10-1997-0006187 (published on February 19, 1997) entitled "a method of treating waste fluid using electrolytic oxidation and apparatus thereof".

[0030] US 5,989,407 A discloses an ozone generation and delivery system that lends itself to small scale applications and requires very low maintenance. The system includes an anode reservoir and a cathode phase separator each having a hydrophobic membrane to allow phase separation of produced gases from water.

[0031] WO 96/41038 A1 discloses an electrochemical cell for removing halides from a gas mixture comprising: a first cell housing and a second cell housing; a cathode associated with said first cell housing; an anode associated with said second cell housing; a porous ceramic membrane between said first cell housing and said second cell housing; and an electrolyte within said porous ceramic membrane which is molten at a temperature above about 150°C .

[0032] GB 2 372 626 A discloses a flow field plate for a fuel cell comprising at least one channel extending from a source of fluid to a drain for said fluid, in which the cross-sectional area of said channel at drain or source is less than 95% of the cross-sectional area at source or drain respectively.

[0033] EP 1 262 577 A1 discloses a kit of modular components for the manufacture of an electrochemical reactor of the so-called filter-press type.

[0034] GB 2 380 853 A discloses a fuel cell or electrolyser module, comprising: a) an electrically insulating housing comprising manifolds for operating fluids; b) a plurality of electrically conductive plates mounted in the housing with openings communicating to appropriate manifolds; and c) means to make operative sealing contact with an adjacent like module. The fuel cell may be of the proton exchange membrane type.

[0035] Further exemplary prior art devices and methods are known from US 5, 837, 122 A, US 4,707,239 A, WO 2004/079051 A1, and from US 6,607,655 B1.

SUMMARY OF THE INVENTION

[0036] Accordingly, the present invention has been made to solve the above problems, and an object of the present invention is to provide a device which is capable of greatly increasing a reaction quantity by increasing the contact area of an electrowinning solution, and at the same time, reducing the reaction time by increasing the reaction speed, without using a stirring unit or rotating an electrolytic bath, without using a porous electrode and without performing a process

of electrowinning several times, and a method thereof.

[0037] Specifically, another object of the present invention is to provide an electrowinning device capable of recovering a metal, such as Cu, Ag, Au or Pt, by metalizing a metallic ion of the metal included in a low-concentrated electrowinning solution, and a method thereof.

[0038] Still another object of the present invention is to solve a problem of contaminating a target metal which occurs in the related art.

[0039] The present invention suggests several objects without limitation to the above objects, and other objects, which are not described, can be clearly comprehended from the following description by those skilled in the art.

[0040] To achieve the above-described objects, according to an embodiment of the present invention, there is provided according to claim 1 a device for electrowinning metal using a channeled cell. The device comprises a cathode cell including a channel formed on a substrate having an inlet and an outlet; an anode cell including a channel formed on a substrate having an inlet and an outlet; and an ion-exchange membrane tightly interposed between the cathode and anode cells, wherein at least one bead for generating turbulent flow is formed on inner surfaces of the channels formed in the cathode and anode cells.

[0041] Preferably, the cathode and anode cells are formed of graphite.

[0042] Preferably, the channels formed in the cathode and anode cells match with each other at both sides of the ion-exchange membrane.

[0043] A sectional shape of the channel may be one of a rectangular shape, a U-shape, and a V-shape.

[0044] Preferably, an electrowinning solution input to the inlet may flow at Reynolds number of 2000 or more.

[0045] Preferably, according to an embodiment of the present invention, a solution containing Cu, Ag, Au or Pt ion is input to the inlet formed in the cathode cell, and an ion containing solution, which pair-reacts with the solution containing Cu, Ag, Au or Pt ion, is input to the inlet formed in the anode cell.

[0046] The pair reaction represents a reaction that may cause the most suitable reaction of precipitating Cu, Ag, Au or Pt from the solution of containing Cu, Ag, Au or Pt ion.

[0047] Preferably, according to an embodiment of the present invention, the at least one bead for generating turbulent flow is installed per a unit length of the channel.

[0048] To achieve the above-described objects, according to another embodiment of the present invention, there is provided according to claim 8 a method of electrowinning metal using a channeled cell. The method includes preparing a substrate for a cathode cell and a substrate for an anode cell; forming channels in the substrates; fixing the substrates having the channels to both sides of an ion-exchange membrane by tightly attaching the substrates to the both sides of the ion-exchange membrane; and electrowinning the metal after inputting an electrowinning solution through an inlet formed in the substrate, wherein at least one bead for generating turbulent flow is formed on an inner surface of the channel formed in the cathode and anode cells.

[0049] Preferably, the substrates are formed of graphite.

[0050] In addition, preferably, an electrowinning solution input to the inlet flows at Reynolds number of 2000 or more.

[0051] The details of other embodiments are described in the detailed description and shown in the accompanying drawings.

[0052] The advantages, the features, and schemes of achieving the advantages and features of the present invention will be apparently comprehended by those skilled in the art based on the embodiments, which are detailed later in detail, together with accompanying drawings. The present invention is not limited to the following embodiments but includes various applications and modifications. The embodiments will make the disclosure of the present invention complete, and allow those skilled in the art to completely comprehend the scope of the present invention. The present invention is only defined within the scope of accompanying claims.

[0053] The same reference numerals denote the same elements throughout the specification, and sizes, positions, and coupling relationships of the elements may be exaggerated for clarity.

[0054] According to an embodiment of the present invention, a reaction quantity of electrolytic reduction and a reaction speed may be greatly increased by using a simple constructed device, without using a stirring unit or rotating an electrolytic bath, and without using a porous electrode or performing an electrowinning process several times.

BRIEF DESCRIPTION OF DRAWINGS

[0055]

FIG. 1 is a schematic perspective view showing a channeled cell constituting a device for electrowinning metal according to an embodiment of the present invention.

FIG. 2 is a schematic plan view showing a channeled cell constituting a device for electrowinning metal according to an embodiment of the present invention.

FIG. 3 is a schematic sectional view showing a channeled cell constituting a device for electrowinning metal according

to an embodiment of the present invention.

FIG. 4 is a schematic sectional view showing a device for electrowinning metal according to an embodiment of the present invention.

FIG. 5 is a view showing a simulation of a fluid flow difference according to Reynolds number in a channel of a device for electrowinning metal according to an embodiment of the present invention, where (a) is a view showing a case that the Reynolds number is 69.44 and (b) is a view showing a case that the Reynolds number is 6944.

FIG. 6 is a graph showing variations of Reynolds number and a recovery rate in a device for electrowinning metal according to an embodiment of the present invention.

FIG. 7 is a graph showing a quantity of electric charge (which is a value substituted into applied quantity of electric charge/theoretical quantity of electric charge) and a recovery rate in a device for electrowinning metal according to an embodiment of the present invention.

FIG. 8 is a graph showing variations of sulfuric acid concentration of a solution containing Cu^{2+} and a recovery rate in a device for electrowinning metal according to an embodiment of the present invention.

FIG. 9 is a graph showing a variation of a recovery rate according to a type of a metal electrowinned through a device for electrowinning metal according to an embodiment of the present invention.

FIG. 10 is a flowchart schematically illustrating a method of electrowinning metal according to an embodiment of the present invention.

FIG. 11 is a schematic view showing an Hg-cathode electrolytic reduction device according to the related art.

FIG. 12 is schematic view showing an ion-exchange membrane electrolytic reduction device according to the related art.

FIG. 13 is a schematic view showing a porous carbon electrolytic reduction device according to the related art.

DETAILED DESCRIPTION OF THE INVENTION

[0056] Hereinafter embodiments of the present invention will be described in detail with reference to accompanying drawings.

[0057] FIG. 1 is a schematic perspective view showing a channeled cell constituting a device for electrowinning metal according to an embodiment of the present invention.

[0058] Referring to FIG. 1, a channeled cell 100 constituting a device for electrowinning metal according to an embodiment of the present invention may include a substrate 120, a channel 160 including an inlet 130 through which an electrowinning solution is input and an outlet 140 through which an electrowinning completed solution is discharged, and a turbulent flow generating bead 180 formed at a part of the channel 160.

[0059] As shown in FIG. 1, although only one channeled cell 100 constituting a cathode or anode of the device for electrowinning europium is depicted in FIG. 1, it should be understood that two channeled cells 100 are required for the cathode and anode. This will be described below with reference to FIG. 4.

[0060] As shown in FIG. 1, although the channel 160 of the channeled cell 100 may have an arc shape, if required, the channel 160 may have a shape formed by alternating a U-shape and an inverted-U shape. That is, the channel 160 may include a bent portion having a curved shape.

[0061] Only, since the channel 160 depicted in FIG. 1 has the by-effect that the fluidity of the electrowinning solution, that is, the Reynolds number is increased at the portion bent at a right angle, it is preferable to allow the channel 160 to have the arc shape.

[0062] Preferably, the channeled cell 100 or the substrate 120 is formed of graphite.

[0063] The reason of forming the channeled cell 100 or the substrate 120 of graphite is because the graphite is not corroded by acid, does not react with the europium obtained through the electrowinning, has excellent workability, and is a low price material.

[0064] As described above, it is preferable in the device for electrowinning europium to form the channeled cell 100 and the substrate 120 in the same shape.

[0065] As will be described below with reference to FIG. 4, the channeled cell 100 and the substrate 120 are preferably arranged to be matched with each other.

[0066] Further, as shown in FIG. 1, at least one turbulent flow generating bead 180 is preferably formed in the channel 160 provided on the substrate 120 per a unit length.

[0067] The unit length will be described below with reference to FIG. 2. Further, the preferable turbulent flow generating bead 180 will be described with reference to FIG. 3.

[0068] FIG. 2 is a plan view showing a channeled cell constituting a device for electrowinning europium according to an embodiment of the present invention.

[0069] It may be understood that the channeled cell 200 constituting the device for electrowinning europium depicted in FIG. 2 substantially has the same configuration as that depicted in FIG. 1. Thus, in the description of FIG. 2, the same elements will be assigned with the same reference numerals, and the repetition in the description of the same elements

having the same reference numerals will be omitted in order to avoid redundancy.

[0070] As shown in FIG. 2, it may be known that the turbulent flow generating bead 180 is formed at a central portion of the channeled cell 200 with respect to a horizontal width.

[0071] In this case, it should be understood that the unit length represents the length from left to right of each channel 160 shown in FIG. 2.

[0072] As shown in FIG. 2, although the channel 160 may be formed from left to right in a single unit 160, the channel 160 may be formed in two columns separated from each other in the channel cell 200 like a double-arc shape.

[0073] If the unit length of the channel 160 having the arc shape is equal to '1', the unit length of the channel 160 having the arc shape may be equal to '1/2'.

[0074] In this case, it is preferable to understand the unit length as a substituted unit length.

[0075] Thus, when at least one turbulent flow generating bead 180 is formed every the unit length in a case of the arc shape, at least one turbulent flow generating bead 180 may be formed every the unit length in a case of the double-arc shape. When the number of turbulent flow generating beads 180 having the double arc shape is compared with that of turbulent flow generating beads 180 having the arc shape, the number of turbulent flow generating beads 180 having the double-arc shape may be two times more than the number of turbulent flow generating beads 180 having the arc shape.

[0076] FIG. 3 is a schematic sectional view showing a channeled cell constituting a device for electrowinning europium according to an embodiment of the present invention.

[0077] In the channeled cell 300 constituting the device for electrowinning europium according to an embodiment of the present invention, a sectional shape of the turbulent flow generating bead 180 formed on the inner surface of the channel 160 may be known from FIG. 3.

[0078] As shown in FIG. 3, the turbulent flow generating bead 180 substantially has a cross-sectional surface of a trapezoid shape, but the sectional shape of the turbulent flow generating bead 180 is not limited thereto.

[0079] For example, the turbulent flow generating bead 180 may have a cross-section surface of a hexagonal pillar, a water drop shape or a semicircular shape.

[0080] In short, preferably, the turbulent flow generating bead 180 protrudes from the inner surface of the channel 160 at a suitable height.

[0081] To the contrary, the turbulent flow generating bead 180 may be formed by allowing the inner surface of the channel 160 to be concaved.

[0082] That is, according to an embodiment of the present invention, the bead 180 may be formed on the inner surface of the channel 160 in a concave-convex shape.

[0083] The bead 180 may be alternately formed on the inner surface of the channel 160

[0084] It should be known that the bead 180 may have any shapes if the bead 180 can cause turbulent flow on the inner surface of the channel 160.

[0085] As described above, the turbulent flow generating bead 180 may protrude from the inner surface of the channel 160. In this case, a height of the turbulent flow generating bead 180 may have preferably a half of the height of the channel 160, or more preferably, two thirds of the height of the channel 160.

[0086] Even when the bead 180 is formed by allowing the inner surface of the channel 160 to be concaved, the height of the bead 180 is preferably determined in accordance with the above description.

[0087] A width or length of the turbulent flow generating bead 180 may be equal to that of the channel 160. However, the width of the turbulent flow generating bead 180, that is, the width, which is widened to the left and right in a direction of the unit length based on the width, is not limited to the width of the channel 160, but even when the width of the turbulent flow generating bead 180 is not smaller than that of the channel 160, if the by-effect of turbulent flow generation, that is, stirring is obtained, the turbulent flow generating bead 180 may have any widths.

[0088] The inlet 130 is depicted at a low end of FIG. 3. The reason is because it is assumed that the electrowinning solution is input from the rear surface of the substrate 120 when an ion-exchange membrane 420 (see FIG. 4) is finally interposed in the substrate 120.

[0089] Thus, it should be known that the shape of the inlet 130 may be changed into another suitable shape.

[0090] Three turbulent flow generating beads 180 are depicted in FIG. 3. As described above, this means that three turbulent flow generating beads 180 are formed per the unit length of the channel.

[0091] That is, the turbulent flow generating bead 180 formed at one place in the channel 160 having the unit length has the arc shape as shown in FIG. 2. However, in FIG. 3, the turbulent flow generating beads 180 are formed at three places per the unit length of the channel.

[0092] FIG. 4 is a schematic sectional view showing a device for electrowinning europium according to an embodiment of the present invention.

[0093] It may be known from FIG. 4 that right and left substrates 120-1 and 120-2 are tightly coupled to each other in the device 400 for electrowinning europium according to an embodiment of the present invention in the state that the ion exchange membrane 420 is interposed between the right and left substrates 120-1 and 120-2.

[0094] It is preferably understood that the right and left substrates 120-1 and 120-2 serve as a cathode cell and an

anode cell. In the following description, the cathode cell may be referred to as a cathode or a substrate and the anode cell may be referred to as an anode or a substrate. However, it should be noted that they represent the same objects.

[0095] It is the most preferable that the right and left substrates 120-1 and 120-2, which serves as the anode and cathode cells, are formed of graphite.

[0096] The reason that the right and left substrates 120-1 and 120-2, all are formed of graphite has been described above.

[0097] It may be known from FIG. 4 that the cross-sectional shape of the channel 160 is rectangular. However, as described above, the sectional shape of the channel 160 may not be limited to the rectangular shape.

[0098] Meanwhile, it is preferable that the right and left substrates 120-1 and 120-2 have the same shape as described above.

[0099] All of the channels 160 formed in the right and left substrates 120-1 and 120-2 are arranged to match with each other.

[0100] In this case, the matched arrangement of both channels 160 means that the openings of both channels 160, which are formed in the right and left substrates 120-1 and 120-2 and face each other about the ion-exchange membrane 420, match with each other.

[0101] That is, when three channels 160 are formed in the right substrate 120-1, three channels 160 are formed in the left substrate 120-2. In addition, the right and left substrates 120-1 and 120-2 are arranged such that the openings of the channels 160 of one side are matched with the openings of the channels 160 of the opposite side.

[0102] Next, the chemical reaction of Cu ion (Cu^{2+}) in FIG. 4 will be described.

[0103] The arrow ㊟ of FIG. 4, which is depicted to describe one example of the rare metal electrowinning according to the present invention, represents that a solution containing Cu^{2+} is input into the cathode cell as an electrowinning solution. For example, the input of the electrowinning solution is preferably performed through the inlet 130 of FIG. 1.

[0104] It is preferable to add sulfuric acid (H_2SO_4) to the solution containing Cu^{2+} . The electrolytic reduction reaction of the electrowinning solution is accelerated by the sulfuric acid. Hereinafter, the existence of the sulfuric acid will be described with reference to FIG. 8.

[0105] Preferably, as soon as the Cu^{2+} -containing solution is input in the direction of arrow (a), for example, a Fe^{2+} -containing solution, which can cause a pair reaction, is input in the direction of arrow ㊟.

[0106] In this case, the pair reaction represents the most suitable reaction that can precipitate Cu from the Cu^{2+} -containing solution. In the present invention, the Fe^{2+} containing solution is used for the pair reaction.

[0107] While the Fe^{2+} -containing solution is flowing from the arrow ㊟ to the arrow (d), the Fe^{2+} -containing solution makes the pair reaction with the Cu^{2+} -containing solution.

[0108] As the result, the Fe^{2+} -containing solution is oxidized into the Fe^{3+} containing solution. In this case, while the Fe^{2+} is oxidized into Fe^{3+} , an electron (e^-) generated from the left substrate 120-2 flows into the right substrate 120-1 electrically connected thereto through a current flow (not shown), so that Cu is precipitated from the Cu^{2+} in the electrowinning, solution input in the direction of arrow ㊟.

[0109] When the input solution containing Cu^{2+} flows through the channel 160 in the cathode cell, the Cu^{2+} obtains an electron, so that the Cu is precipitated, as denoted as the reference numeral 440 in the drawings.

[0110] Although Cu precipitations 440 are depicted in the drawings as the precipitations 440 are formed on a right side wall of the channel 160, it should be noted that the precipitations 440 are formed on all of the three surfaces of the channel 160. The detailed mechanism of simultaneously forming the precipitations 440 on all of the three surfaces of the channel 160 will be described with reference to FIG. 5.

[0111] Only, it is preferable to understand that the reason that the precipitations 440 are produced from all of the three surfaces of the channel 160 is because the electrowinning solution flows at Reynolds number of 2000 or more so that a turbulent flow is generated.

[0112] For reference, it should be noted that the Cu^{2+} -containing solution as the electrowinning solution flows in the direction perpendicular to the ground, that is, in the y-axis direction perpendicular to the ground when it is assumed that the ground is an x-axis.

[0113] The Cu^{3+} -drained solution remaining after being precipitated into Cu may be discharged through the outlet 140 denoted as arrow ㊟ in FIG. 4

[0114] In FIG. 4, while the Cu^{2+} -containing solution is flowing from the arrow ㊟ to the arrow (b), most Cu^{2+} is precipitated into Cu. This is because current flows through the ion-exchange membrane 420 formed between the right and left substrates 120-1 and 120-2 and the current assists the precipitation of most Cu^{2+} into Cu while the Cu^{2+} -containing solution is flowing.

[0115] In this case, the sulfuric acid (H_2SO_4) dissociates into SO_4^{2-} ions, so that the precipitation of Cu^{2+} into Cu is accelerated by the SO_4^{2-} ions.

[0116] It has been already described above that the oxidation of Fe^{2+} to Fe^{3+} as the pair reaction occurs on the left substrate 120-2 while the precipitation of Cu^{2+} into Cu occurs on the right substrate 120-1.

[0117] FIG. 5 is a view showing a simulation of a fluid flow difference according to Reynolds number in a channel of

a device for electrowinning metal according to an embodiment of the present invention, where (a) is a view showing a case that the Reynolds number is 69.44 and (b) is a view showing a case that the Reynolds number is 6944.

[0118] In more detail, (a) of FIG. 5 is a view showing the case that the Reynolds number of 69.44 and the flow rate of 10cc/hr, and (b) of FIG. 5 is a view showing the case of the Reynolds number of 6944 and the flow rate of 1000 cc/hr.

[0119] Specifically, (a) and (b) of FIG. 5 are views showing the mass-transfer phenomenon according to each of the Reynolds (Re) numbers as velocity vectors colored according to velocity magnitudes when the electrowinning solution is provided into the channel 160.

[0120] It may be known from (a) of FIG. 5 that, when the Re number is low, most of the mass migrations occur at the central portion of the channel 160, that is, only a portion colored with yellow. Specifically, the mass migration occurs only in the y-axis direction and rarely occurs in the x-z axis direction.

[0121] To the contrary, It may be known from (b) of FIG. 5 that, when the Re number is high, the mass migration actively occur in the x-z axis directions. The above phenomenon may occur because the electrowinning solution input through the inlet 130 forms swirl and the swirl continuously flows in the y-axis direction.

[0122] It is known in the art that the swirl actually occurs in a turbulent flow state and the swirl phenomenon due to the turbulent flow is effectively generated at the Re number 200.

[0123] Hereinafter, 'Re number' will be described in brief.

[0124] The Reynolds number is a term of the hydrodynamic field that is defined as the ratio of "an inertia force" to "a viscous force". In detail, the Re number is defined as the simple formula of (liquid density * flow velocity * vertical height)/liquid viscosity.

[0125] The Re number is utilized as one of the most important non-dimensional numbers in hydrodynamics and specifically, hydrokinetics. It has been known that, when the Re numbers are similar with each other, two types of fluid flows represent flows that are similar to each other in hydrodynamics.

[0126] When the Re number is low, a laminar flow dominated by a viscous force, which is calm and has a constant fluid flow, is generated. To the contrary, When the Re number is high, a turbulent flow dominated by an inertial force, which includes a vortex and has extreme perturbations, is generated.

[0127] Meanwhile, the Re number is named after Osborne Reynolds (1842-1912).

[0128] As described above, it should be understood that the case of the Re number of 2000 or more is noted in the present invention.

[0129] When the Re number is 2000 or more, it may be expected that since a flowing material, for example, an electrowinning solution makes contact with the electrode surface, and in more detail, makes contact with x and y axes, the probability that the flowing material makes contact with the electrode surface is increased, so that the reaction efficiency is proportionally increased.

[0130] To the contrary, when the Re number is less than 2000, it may be expected that although the flowing material, for example, an electrowinning solution makes contact with the electrode surface, the probability that the flowing material makes contact with the electrode surface is decreased, so that the reaction efficiency is proportionally decreased.

[0131] Hereinafter, various examples of the device for electrowinning metal according to the embodiment of the present invention will be described.

[0132] In this case, the Cu^{2+} -containing solution has been controlled to have the Cu concentration of 1000ppm and the H_2SO_4 concentration of 0.01 -2 M.

[0133] In addition, a rectangular shape has been applied as the sectional shape of the channel.

[0134] The cross sectional areas of the channel have been set into 0.2, cm^2 and the total length of the channel has been fixed at 200 cm.

[0135] The theoretical quantity of electric charge required for electrowinning Cu by reducing Cu^{2+} ions to 100% may be calculated according to Faraday law. It has been set in the present invention to apply 90%, 100%, 150% and 200 % of the theoretical quantity of electric charge.

[0136] Meanwhile, based on various kinds of basic conditions described above, the experiments have been performed under following various different conditions: ① Re number (see FIG. 6), ② Quantity of electric charge (see FIG. 7), ③ sulfuric acid concentration (see FIG. 8), ④ another rare metals except for Cu (see FIG. 9). Hereinafter, the recovery rates (%) under the above various kinds of electrolytic condition will be described.

[0137] First, the recovery rate according to the Re number will be described.

[0138] FIG. 6 is a graph showing variations of Reynolds number and a recovery rate in a device for electrowinning metal according to an embodiment of the present invention.

- Hereinafter, all recovery rates are obtained by measuring the quantity of a rare metal in the solution remaining after the electrowinning using the ICP-AES (Inductively Coupled Plasma - Atomic Emission Spectrometer).

[0139] In FIG. 6, various kinds of variable control conditions are the same as those in following Table 1.

[Table 1]

Sulfuric acid concentration (M)	Cross-sectional area of channel (cm ²)	Channel length (cm)	Cu concentration (ppm)	Applied quantity of electric charge (%)
1	0.2	100	1000	110

[0140] According to the experimental result of the Cu electrowinning performed based on the variable conditions in Table 1, the recovery rate (%) exceeds about 60% at the Re number less than 2,000, that is, about the Re number of 1,500. However, it is known that the recovery rate (%) reaches at 95% at the Re number of 2,000 or more so that the recovery rate actually approaches to 100%.

[0141] Meanwhile, even though the Re number reaches at 3,000, there is no difference in the recovery rate. Thus, it is understood that the Re number of at least 2,000 according to an embodiment of the present invention is preferable.

[0142] Next, the recovery rate according to the quantity of electric charge will be described.

[0143] FIG. 7 is a graph showing a quantity of electric charge (which is a value substituted into applied quantity of electric charge/theoretical quantity of electric charge) and a recovery rate in a device for electrowinning metal according to an embodiment of the present invention.

[0144] In FIG. 7, various kinds of variable control conditions are the same as those in following Table 2.

[Table 2]

Sulfuric acid concentration (M)	Cross-sectional area of channel (cm ²)	Channel length (cm)	Cu concentration (ppm)	Re number
1	0.2	100	1000	2082

[0145] According to the experimental result of the Cu electrowinning performed based on the variable conditions in Table 2, as shown in FIG. 7, when the ratio of the substituted value of the quantity of applied electric charge into the theoretical quantity of electric charge, that is, before the quantity of electric charge reaches at 90%, the recovery rate (%) is equal to or less than 95%. However, when the quantity of electric charge is 110% or more, the recovery rates (%) are 95% or more in all cases. Thus, when the quantity of supplied electric charge is over 110%, the quantity of electric charge has no correlation with the recovery rate (%).

[0146] Next, the recovery rate according to the sulfuric acid concentration will be described.

[0147] FIG. 8 is a graph showing variations of sulfuric acid concentration of a solution containing Cu²⁺ and a recovery rate in a device for electrowinning metal according to an embodiment of the present invention.

[0148] In FIG. 8, various kinds of variable control conditions are the same as those in following Table 3.

[Table 3]

Applied quantity of electric charge (%)	Cross-sectional area of channel (cm ²)	Channel length (cm)	Cu concentration (ppm)	Re number
110	0.2	100	1000	2082

[0149] According to the experimental result of the Cu electrowinning performed based on the variable conditions in Table 3, as shown in FIG. 8, the correlation between the sulfuric acid concentration and the recovery rate (%) is weak.

[0150] Thus, although there is no need to specify the sulfuric acid concentration (mole) of the Cu²⁺-containing solution, the sulfuric acid concentration preferably is '1' M. It is preferably determined that the limit of the sulfuric acid concentration is '2' M.

[0151] Finally, the recovery rates of Au, Pt and Ag except for Cu will be discussed.

[0152] FIG. 9 is a graph showing a variation of a recovery rate according to a type of a metal electrowinned through a device for electrowinning metal according to an embodiment of the present invention.

[0153] In FIG. 8, various kinds of variable control conditions are the same as those in following Table 4.

[Table 4]

Applied quantity of electric charge (%)	Cross-sectional area of channel (cm ²)	Channel length (cm)	Concentration (ppm)	Re number
110	0.2	100	500	2082

[0154] According to the experimental results of the electrowinning of a metal-ion solution including Au, Pt and Ag performed based on the variable conditions in Table 4, as shown in FIG. 9, the recovery rate of Au is almost 95%, the recovery rate of Pt is almost 90%, and the recovery rate of Ag is 96% or more.

[0155] Thus, the electrowinning device according to the embodiment is enabled to be applied for electrowinning various rare metal as well as Cu.

[0156] Hereinafter, a method of electrowinning metal according to an embodiment of the present invention will be described

[0157] FIG. 10 is a flowchart schematically illustrating a method of electrowinning metal according to an embodiment of the present invention.

[0158] Referring to FIG. 10, a method of electrowinning metal according to an embodiment of the present includes a step S10 of preparing substrates, a step S20 of forming channels in the substrates, a step S30 of attaching the substrates to both side surfaces of an ion-exchange membrane, and a step S40 of performing electrowinning after inputting an electrowinning solution.

Step of preparing substrate

[0159] As described with reference to FIG. 1, in the step S10 of preparing substrates, the substrates 120 which are formed of graphite are prepared.

[0160] In this case, as described above, two substrates 120-1 and 120-2 for a cathode and an anode are prepared.

Step of forming channel in substrate

[0161] As described with reference to FIGS. 1 to 3, in the step S20 of forming channels in the substrates, the channels 160 having a particular shape are formed in the substrates 120-1 and 120-2.

[0162] In this case, although the description of the various kinds of conditions about the channel 160 will be omitted since the various kinds of conditions about the channel 160 has been described above, it should be noted that at least one turbulent flow generating bead 180 must be formed in the channels every a unit length.

Step of attaching substrates to both side surfaces of ion-exchange membrane

[0163] In the step S30 of attaching the substrates to both side surfaces of the ion-exchange membrane, the substrate 120-1 and 120-2 for a cathode and an anode are attached to both side surfaces of the ion exchange membrane 420 (see FIG. 4).

[0164] In this case, it may be understood that the ion exchange membrane 420 may be a negative-ion exchange membrane or to the contrary, a positive-ion exchange membrane according to the electric property of the solution input to the substrate 120-1 or 120-2.

[0165] In the present invention, the negative-ion exchange membrane has been used as the ion exchange membrane 420 because a Cu²⁺-containing solution has been used as the electrowinning solution.

[0166] However in case of an element which exists in a negative-ion state at normal times like Pt or Au, it may be understood that the ion exchange membrane 420 must be the positive-ion exchange membrane.

Step of performing electrowinning after inputting electrowinning solution

[0167] Finally, in the step S40 of performing electrowinning after inputting an electrowinning solution, as described above, the Cu²⁺-containing solution is input through the inlet 130 and then, the electrowinning is performed.

[0168] In this case, as shown in FIG. 5, the Cu²⁺-containing solution flows at the Re number of 2,000 by the turbulent flow generating bead 180 formed in the substrate 120-1, so that the Cu is reduced in on the three surfaces of the channel 160, so that the Cu is precipitated as the Cu precipitations 440.

[0169] Although the Re number of 2,000 or more is achieved by inputting the Cu²⁺-containing solution into the inlet 130 at a high rate, it should be noted that the Re number of 2,000 or more may be achieved through the turbulent flow generating bead 180.

[0170] Since the graphite rarely react with Cu, the Cu precipitations 440 precipitated and attached to the three surfaces of the substrate 120-1 can be easily separated from the substrate 120-1 after the substrate 120-1 has been removed from the ion exchange membrane 420 (FIG. 4) .

[0171] Although the present invention has been described by making reference to the embodiments and accompanying drawings, it should be understood that the present invention is not limited to the embodiments but includes all modifications, equivalents and alternatives. Accordingly, those skilled in the art should understand the spirit and scope of the present invention as defined in the following claims. In addition, those skilled in the art should understand that the equivalents and the modifications belong to the scope of the present invention.

Claims

1. A device for electrowinning metal using a channeled cell (100, 200, 300, 400), the device comprising:

a cathode cell including a channel (160) formed on a substrate (120) having an inlet (130) and an outlet (140); an anode cell including a channel (160) formed on a substrate (120) having an inlet (130) and an outlet (140); and an ion-exchange membrane (420) tightly interposed between the cathode and anode cells,

characterized in that at least one bead (180) for generating turbulent flow is formed on inner surfaces of the channels (160) formed in the cathode and anode cells.

2. The device of claim 1, wherein the cathode and anode cells are formed of graphite.

3. The device of claim 1, wherein the channels (160) formed in the cathode and anode cells match with each other at both sides of the ion-exchange membrane (420).

4. The device of claim 1, wherein a sectional shape of the channel (160) is one of a rectangular shape, a U-shape, and a V-shape.

5. The device of claim 1, wherein an electrowinning solution input to the inlet (130) flows at Reynolds number of 2000 or more.

6. The device of claim 5, wherein the electrowinning solution containing Cu, Ag, Au or Pt ion is input to the inlet (130) formed in the cathode cell, and an ion containing solution, which pair-reacts with the electrowinning solution containing Cu, Ag, Au or Pt ion, is input to the inlet (130) formed in the anode cell.

7. The device of claim 1, wherein the at least one bead (180) for generating turbulent flow is installed per a unit length of the channel (160).

8. A method of electrowinning metal using a channeled cell (100, 200, 300, 400), the method being **characterized by** the steps of:

preparing a substrate (120) for a cathode cell and a substrate (120) for an anode cell; forming channels (160) in the substrates (120); fixing the substrates (120) having the channels (160) to both sides of an ion-exchange membrane (420) by tightly attaching the substrates (120) to the both sides of the ion-exchange membrane (420); and electrowinning the metal after inputting an electrowinning solution through an inlet (130) formed in the substrate (120),

wherein at least one bead (180) for generating turbulent flow is formed on an inner surface of the channel (160) formed in the substrate (120).

9. The method of claim 8, wherein the substrates (120) are formed of graphite.

10. The method of claim 8, wherein an electrowinning solution input to the inlet (130) flows at Reynolds number of 2000 or more.

Patentansprüche

1. Vorrichtung zur Elektrogewinnung von Metall mit einer mit einem Kanal versehenen Zelle (100, 200, 300, 400), wobei die Vorrichtung umfasst:

eine Kathodenzone, die einen auf einem Substrat (120) ausgebildeten Kanal (160) mit einem Einlass (130) und einem Auslass (140) aufweist;
 eine Anodenzone, die einen auf einem Substrat (120) ausgebildeten Kanal (160) mit einem Einlass (130) und einem Auslass (140) aufweist;
 eine Ionenaustauschmembran (420), die dicht zwischen der Kathoden- und der Anodenzone angeordnet ist,

dadurch gekennzeichnet, dass wenigstens eine Wulst (180) zum Erzeugen einer turbulenten Strömung auf Innenflächen der Kanäle (160) ausgebildet ist, die in der Kathoden- und der Anodenzone ausgebildet sind.

2. Vorrichtung nach Anspruch 1, wobei die Kathoden- und die Anodenzone aus Graphit ausgebildet sind.
3. Vorrichtung nach Anspruch 1, wobei die Kanäle (160), die in der Kathoden- und der Anodenzone ausgebildet sind, an beiden Seiten der Ionenaustauschmembran (420) miteinander übereinstimmen.
4. Vorrichtung nach Anspruch 1, wobei eine Querschnittsform des Kanals (160) eine rechteckige Form, eine U-Form und/oder eine V-Form ist.
5. Vorrichtung nach Anspruch 1, wobei eine Elektrogewinnungslösung, die in den Einlass (130) eingespeist wird, mit einer Reynolds-Zahl von 2000 oder mehr strömt.
6. Vorrichtung nach Anspruch 5, wobei die Elektrogewinnungslösung, die Cu-, Ag-, Au- oder Pt-Ionen enthält, in den Einlass (130) eingespeist wird, der in der Kathodenzone ausgebildet ist, und eine ionenhaltige Lösung, welche mit der Elektrogewinnungslösung, die Cu-, Ag-, Au- oder Pt-Ionen enthält, eine Paar-Reaktion eingeht, in den Einlass (130) eingespeist wird, der in der Anodenzone ausgebildet ist.
7. Vorrichtung nach Anspruch 1, wobei die wenigstens eine Wulst (180) zum Erzeugen einer turbulenten Strömung jeweils einmal pro Einheitslängenabschnitt des Kanals (160) angebracht ist.
8. Verfahren zur Elektrogewinnung von Metall mit einer mit einem Kanal versehenen Zelle (100, 200, 300, 400), wobei das Verfahren durch die folgenden Schritte gekennzeichnet ist:
 Herstellen eines Substrats (120) für eine Kathodenzone und eines Substrats (120) für eine Anodenzone;
 Ausbilden von Kanälen (160) in den Substraten (120);
 Befestigen der Substrate (120), welche die Kanäle (160) aufweisen, auf beiden Seiten einer Ionenaustauschmembran (420), indem die Substrate (120) dicht an den beiden Seiten der Ionenaustauschmembran (420) angebracht werden; und
 Durchführen einer Elektrogewinnung des Metalls nach dem Einspeisen einer Elektrogewinnungslösung durch einen Einlass (130), der in dem Substrat (120) ausgebildet ist,
 wobei wenigstens eine Wulst (180) zum Erzeugen einer turbulenten Strömung auf einer Innenfläche des Kanals (160) ausgebildet ist, der in dem Substrat (120) ausgebildet ist.
9. Verfahren nach Anspruch 8, wobei die Substrate (120) aus Graphit ausgebildet sind.
10. Verfahren nach Anspruch 8, wobei eine Elektrogewinnungslösung, die in den Einlass (130) eingespeist wird, mit einer Reynolds-Zahl von 2000 oder mehr strömt.

Revendications

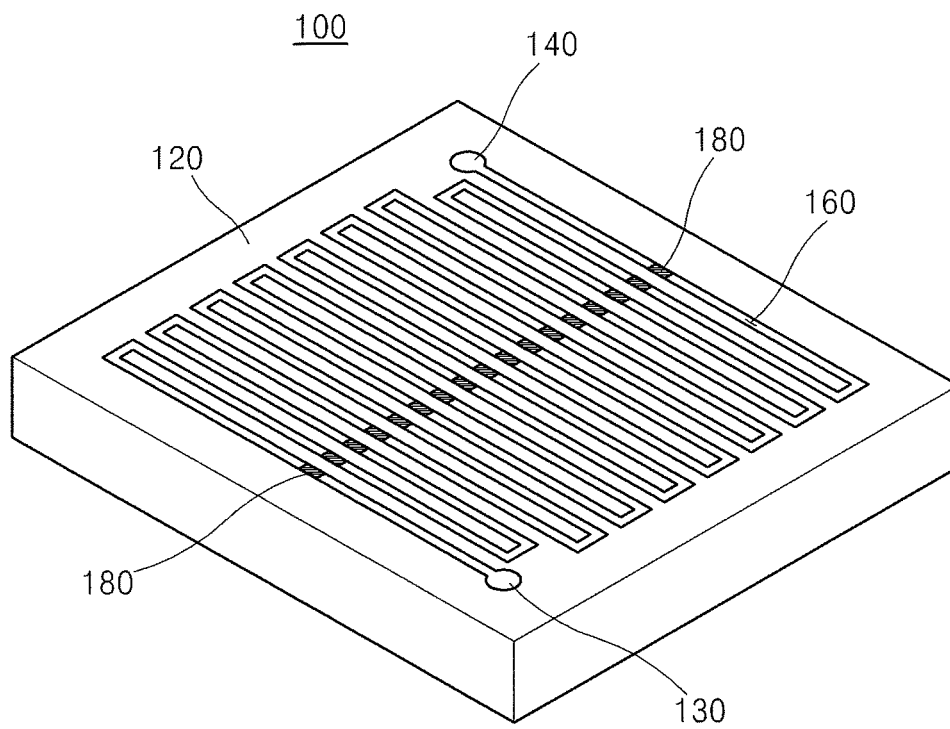
1. Dispositif pour l'extraction par voie électrolytique d'un métal, utilisant une cellule cannelée (100, 200, 300, 400), le dispositif comprenant :

une cellule de cathode comprenant un canal (160) formé sur un substrat (120) ayant une entrée (130) et une sortie (140) ;
 une cellule d'anode comprenant un canal (160) formé sur un substrat (120) ayant une entrée (130) et une sortie (140) ; et
 une membrane échangeuse d'ions (420) interposée étroitement entre les cellules de cathode et d'anode,

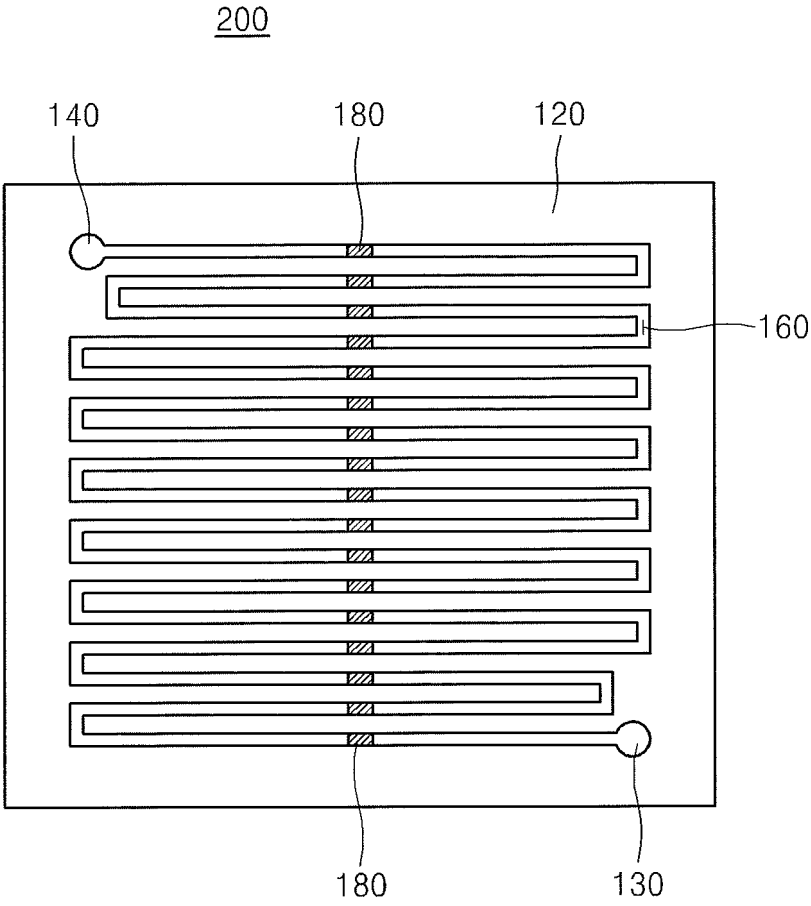
caractérisé en ce qu'au moins un bourrelet (180) pour générer un écoulement turbulent est formé sur les surfaces intérieures des canaux (160) formés sur les cellules de cathode et d'anode.

2. Dispositif selon la revendication 1, dans lequel les cellules de cathode et d'anode sont formées de graphite.
3. Dispositif selon la revendication 1, dans lequel les canaux (160) formés dans les cellules de cathode et d'anode correspondent entre eux au niveau des deux côtés de la membrane échangeuse d'ions (420).
4. Dispositif selon la revendication 1, dans lequel la forme en coupe du canal (160) est l'une parmi une forme rectangulaire, une forme de U, et une forme de V.
5. Dispositif selon la revendication 1, dans lequel la solution d'extraction par voie électrolytique introduite dans l'entrée (130) s'écoule avec un nombre de Reynolds de 2000 ou plus.
6. Dispositif selon la revendication 5, dans lequel
 la solution d'extraction par voie électrolytique contenant des ions Cu, Ag, Au ou Pt est introduite dans l'entrée (130) formée dans la cellule de cathode, et
 une solution contenant des ions, réagissant par paire avec la solution d'extraction par voie électrolytique contenant des ions Cu, Ag, Au ou Pt, est introduite dans l'entrée (130) formée dans la cellule d'anode.
7. Dispositif selon la revendication 1, dans lequel l'au moins un bourrelet (180) pour générer un écoulement turbulent est installé pour chaque unité de longueur du canal (160).
8. Procédé pour l'extraction par voie électrolytique d'un métal, utilisant une cellule cannelée (100, 200, 300, 400), le procédé étant **caractérisé par** les étapes de :
- préparation d'un substrat (120) pour une cellule de cathode et d'un substrat (120) pour une cellule d'anode ;
 formation de canaux (160) dans les substrats (120) ;
 fixation des substrats (120) ayant les canaux (160) aux deux côtés d'une membrane échangeuse d'ions (420) par attachement serré des substrats (120) aux deux côtés de la membrane échangeuse d'ions (420) ; et
 extraction par voie électrolytique du métal après introduction d'une solution d'extraction par voie électrolytique par une entrée (130) formée dans le substrat (120),
- dans lequel au moins un bourrelet (180) pour générer un écoulement turbulent est formé sur une surface intérieure du canal (160) formé dans le substrat (120).
9. Procédé selon la revendication 8, dans lequel les substrats (120) sont formés de graphite.
10. Procédé selon la revendication 8, dans lequel une solution d'extraction par voie électrolytique introduite dans l'entrée (130) s'écoule avec un nombre de Reynolds de 2000 ou plus.

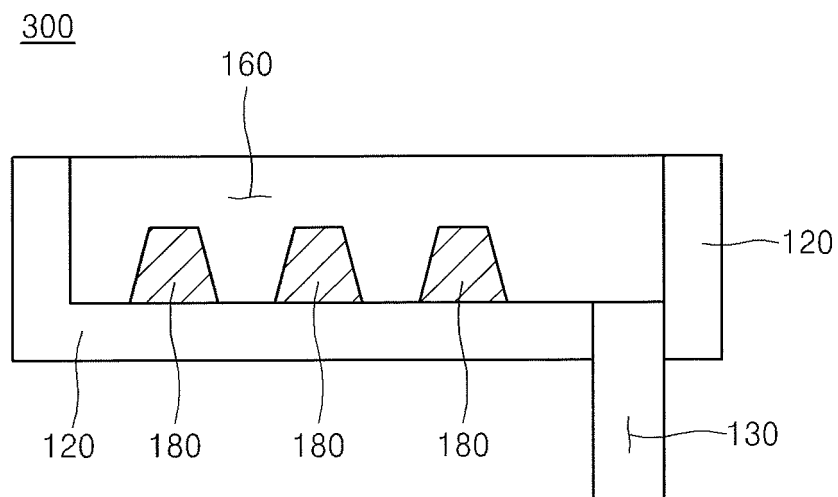
[Fig. 1]



[Fig. 2]



[Fig. 3]



[Fig. 4]

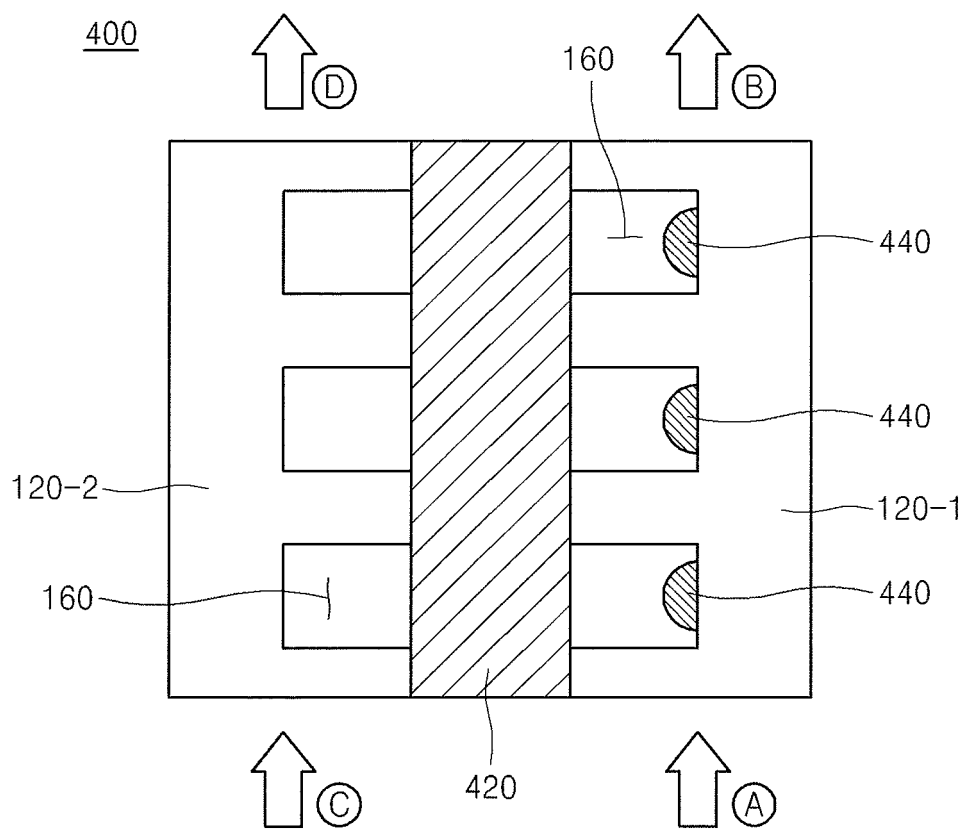
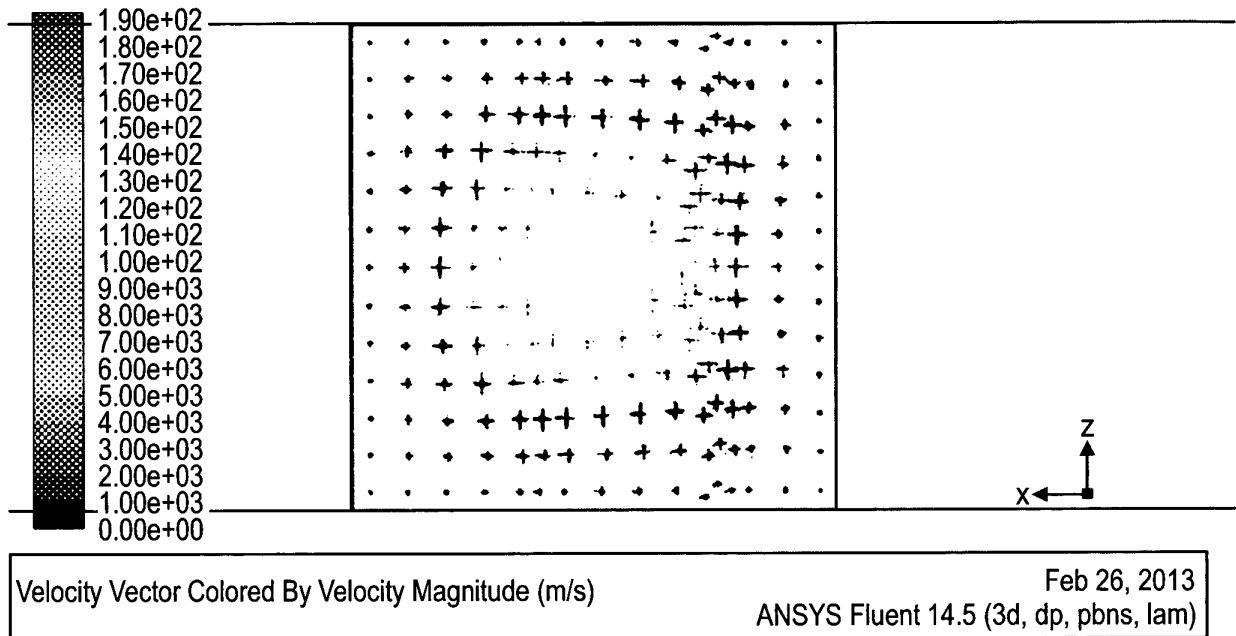
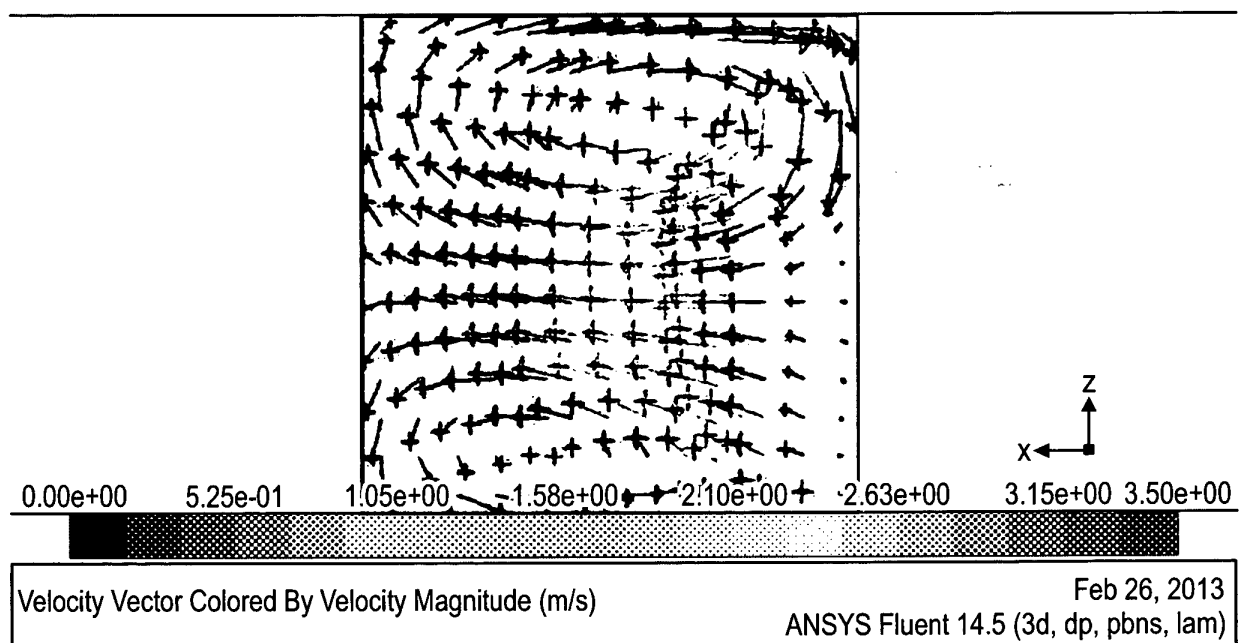


Fig. 5

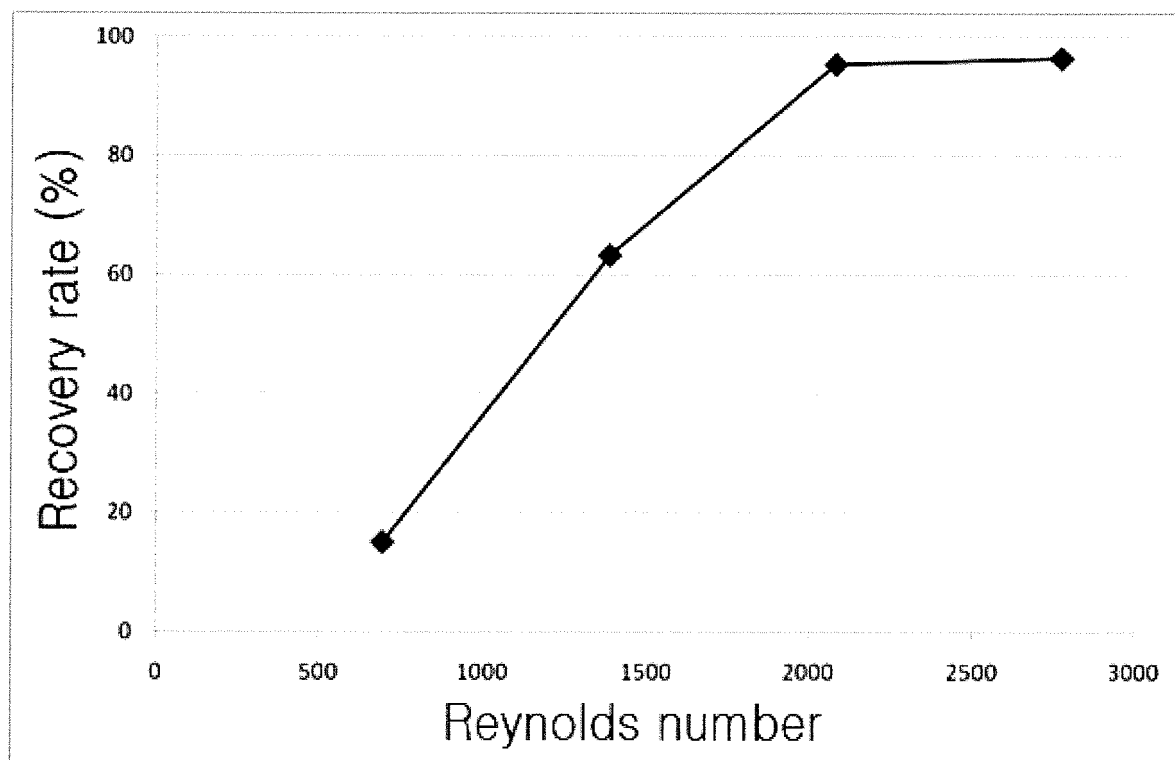


(a)

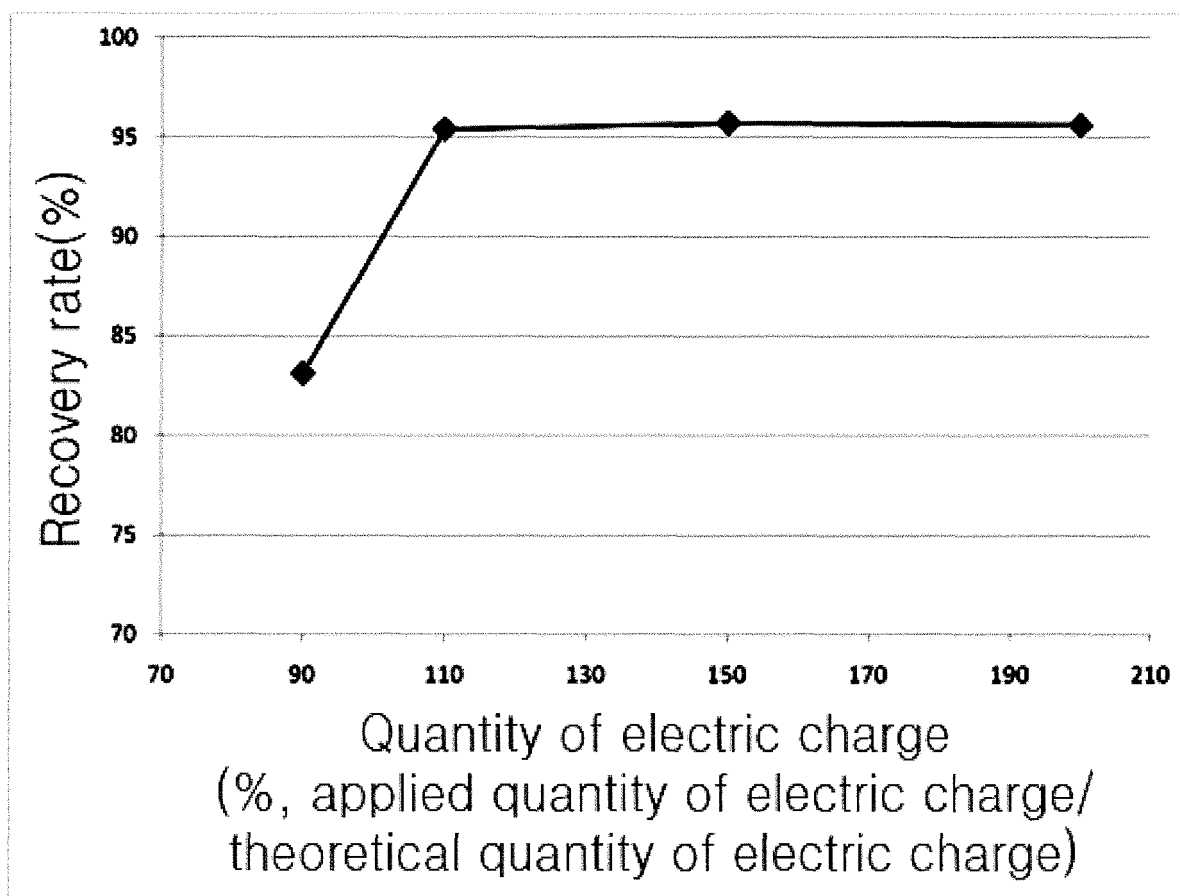


(b)

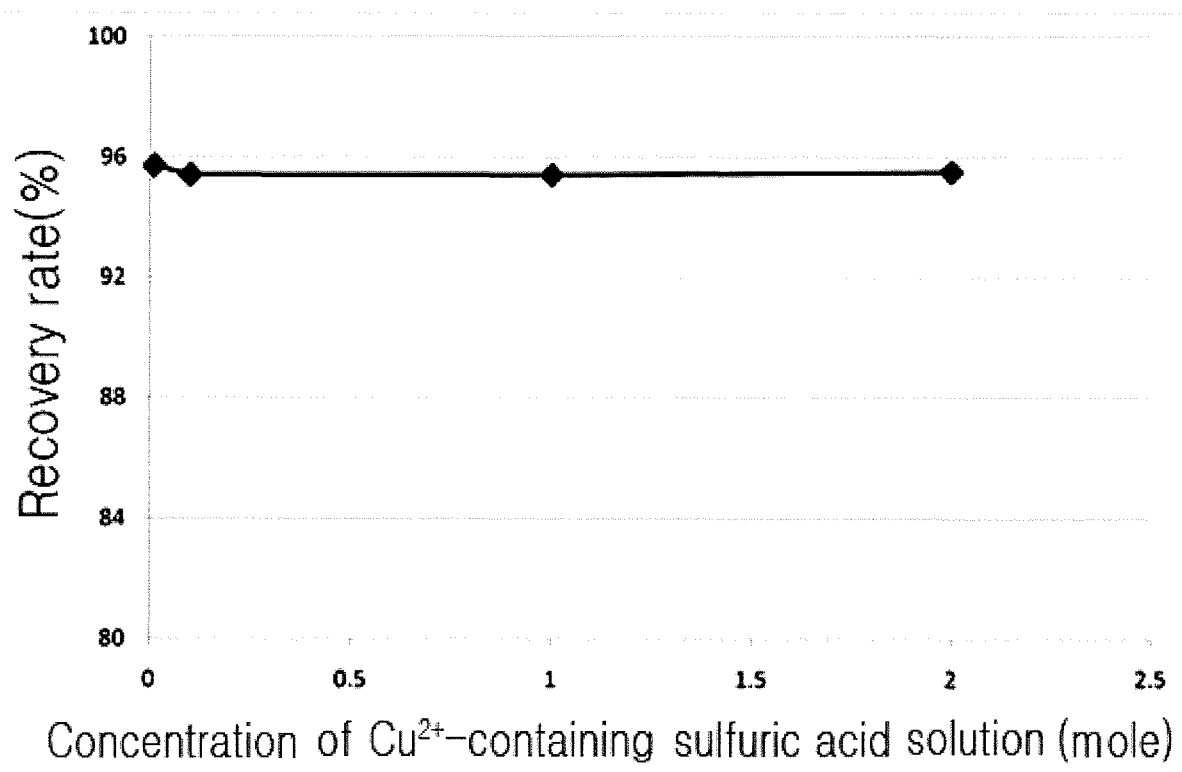
[Fig. 6]



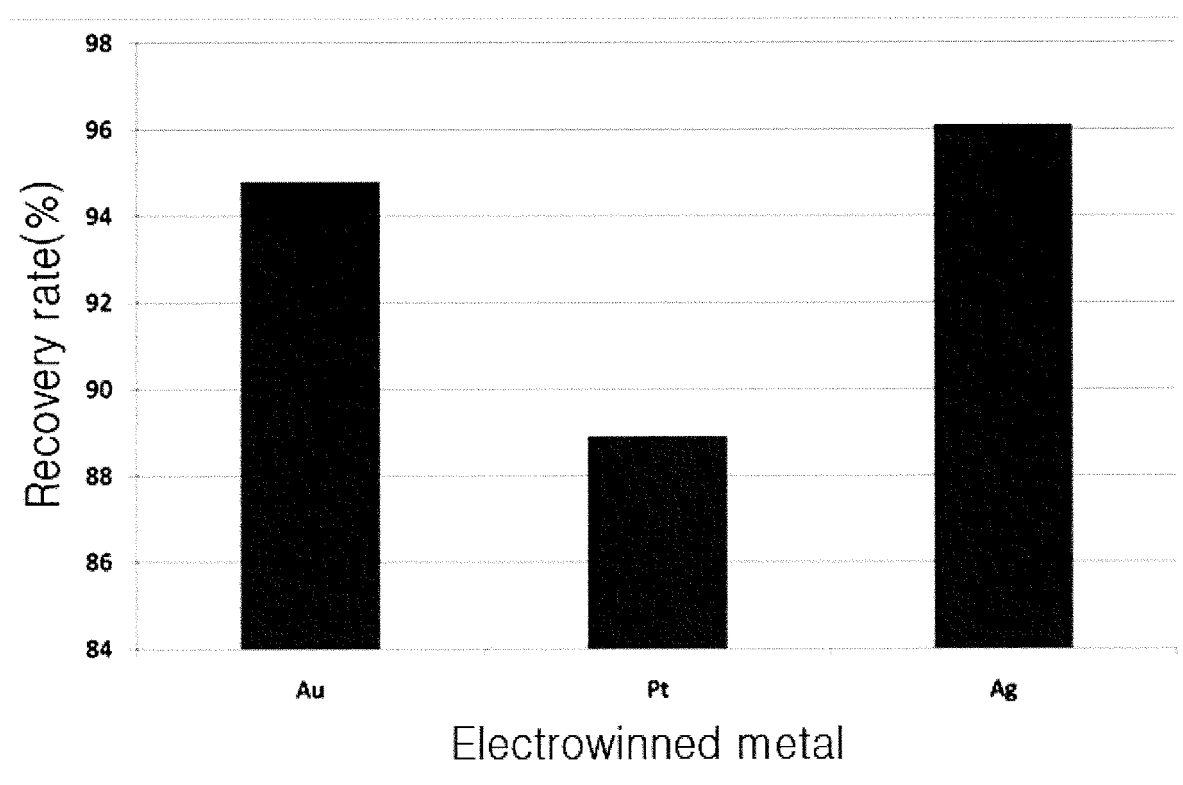
[Fig. 7]



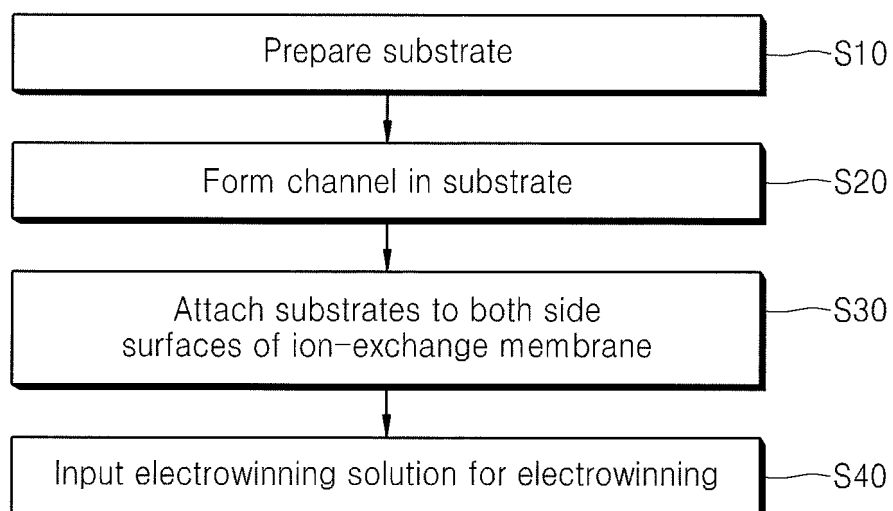
[Fig. 8]



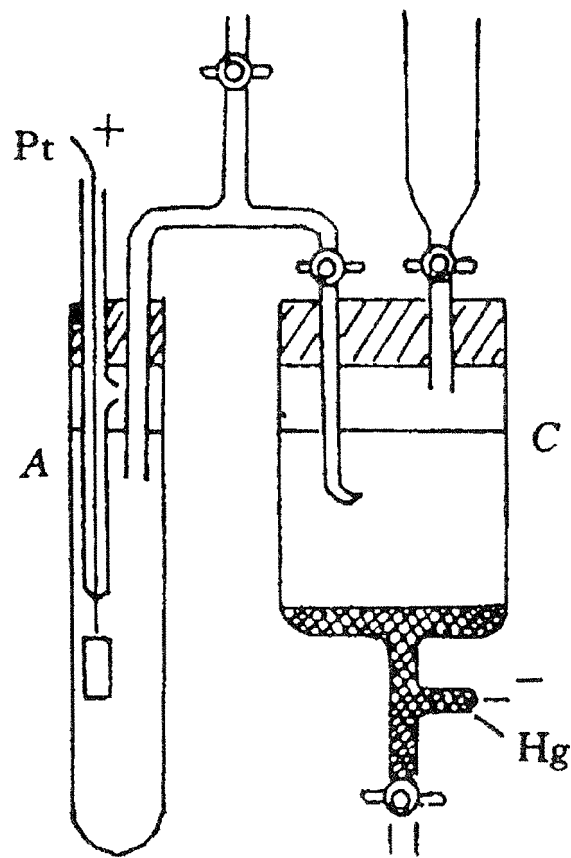
[Fig. 9]



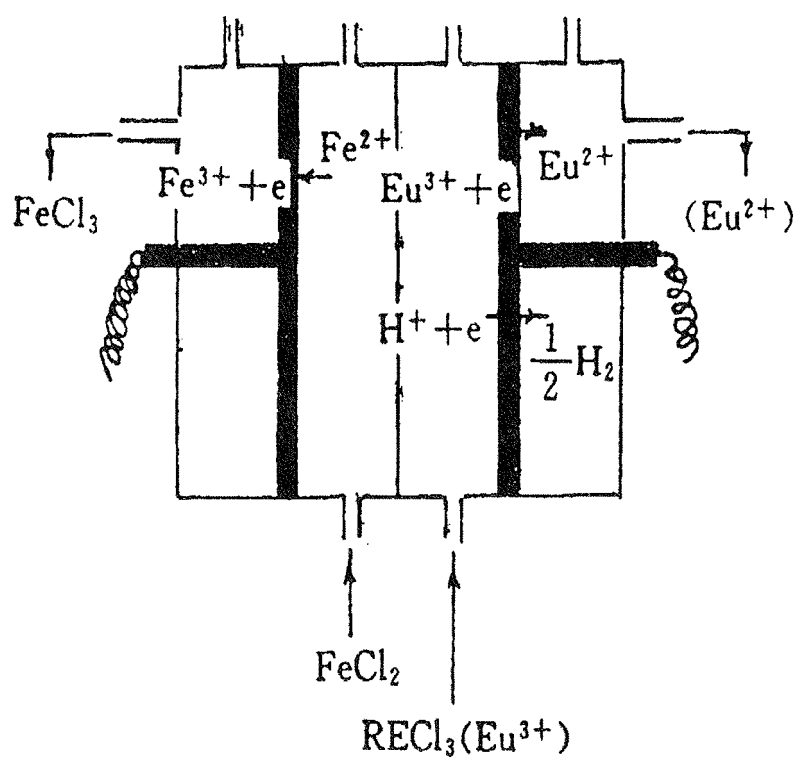
[Fig. 10]



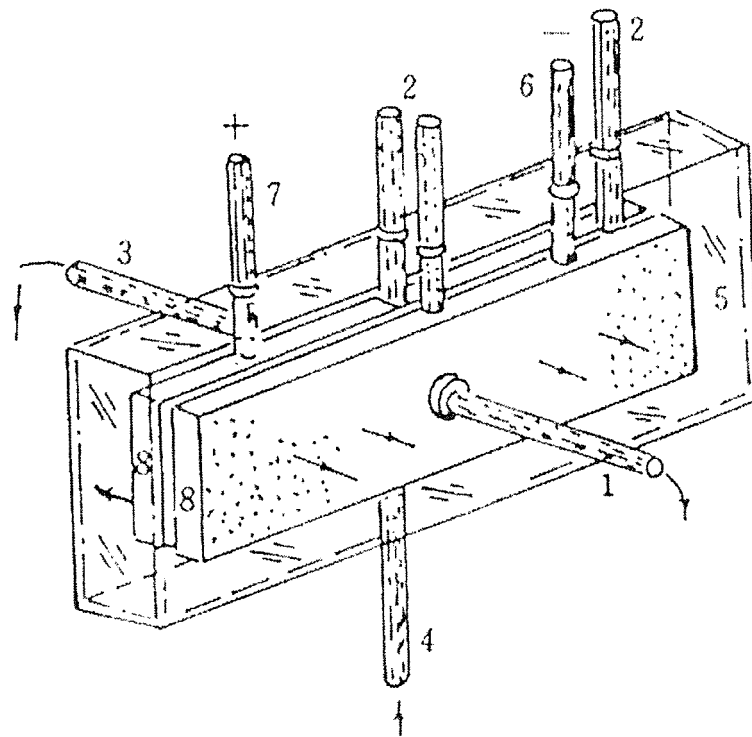
[Fig. 11]



[Fig. 12]



[Fig. 13]



REFERENCES CITED IN THE DESCRIPTION

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