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# (54) HIGH SPEED HORIZONTAL ELECTROFORMING APPARATUS FOR MANUFACTURING METAL FOIL AND METHOD FOR MANUFACTURING METAL FOIL

(57) The present invention relates to an apparatus and a method for manufacturing metal foil by electroforming. Provided is a horizontal electroforming apparatus comprising: base plate supply means for continuously supplying flexible and conductive base plates to be provided as cathode electrodes in one horizontal direction; a horizontal cell including a conductor roll which contacts a widthwise edge portion of the base plate to transfer the base plate and supply current to the base plate, anode electrodes arranged at one side of the base plate or spaced apart from each other at both respective sides of the base plate, an electrolyte supply device for supplying an electrolyte containing metal ion through a horizontal path formed by the base plates and the anode electrodes, and current supply devices arranged at one side or both sides of the base plate to supply current to the conductor roll and to the anode electrodes so as to enable electroseparation of the metal ion; and delaminating means for delaminating, from the base plate, metal foil electrodeposited at one side or both sides of the base plate.

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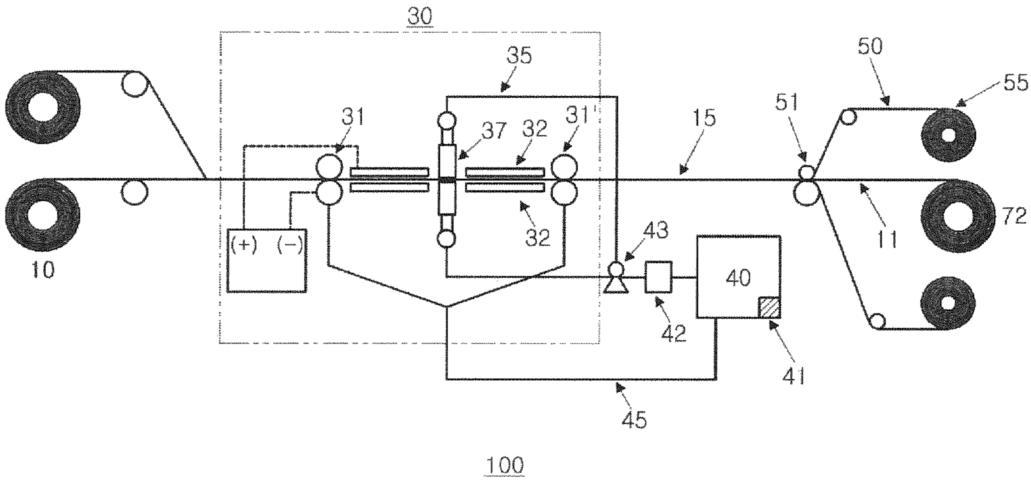



FIG. 1

## Description

[Technical Field]

**[0001]** The present disclosure relates to a method and apparatus for manufacturing metal foil at high speed, and particularly, to a method for continuously manufacturing metal foil by electroforming and an apparatus used in the method.

[Background Art]

**[0002]** In general, a rolling method and an electroforming method are both widely used methods for manufacturing metal foil. In the rolling method, metal slabs manufactured through iron making, steel making, and continuous casting are rolled into foil, and in the electroforming method, copper foil is manufactured using a drum cell.

**[0003]** In a most common process for manufacturing thin plates using a rolling method, slabs may be reheated and hot-rolled into metal plates having a thickness of several millimeters (mm), and such hot-rolled thin plates may be additionally cold-rolled into very thin foil having a thickness of 100 μm or less. US Patent No. 4948434 discloses such a method of manufacturing metal foil. In the disclosed method, cold rolling and annealing are performed repeatedly. Thus, the disclosed method has problems such as complex processes requiring large amounts of energy and time, difficulties in forming constant shapes, thickness deviations, non-uniform surface roughness, edge cracking, high manufacturing costs, and difficulties in manufacturing wide metal foil.

**[0004]** Recently, processes and apparatuses for manufacturing metal foil (copper foil) by an electroforming method have been researched. For example, Korean Patent Application Laid-open Nos. 1999-0064747 and 2004-0099972 disclose methods and apparatuses for manufacturing metal foil by electroforming. Metal foil can be manufactured through simple processes by using such methods.

**[0005]** In the patent documents, methods of manufacturing metal foil using a drum cell are disclosed. When metal foil is manufactured by an electroforming method using a drum cell, the surface of the drum cell is carefully treated and maintained to obtain a metal foil having a uniform thickness and surface roughness. Thus, processes may be suspended for checking or repairing the surface of the drum cell. In other words, the surface of the drum cell may not be continuously managed.

**[0006]** Moreover, the rate of metal foil production by electroforming is affected by the surface area of a drum cell dipped into an electrolyte. That is, the rate of production is limited by the size of the drum cell. However, if a large drum cell is used, manufacturing costs are increased, and it may be difficult to replace the large drum cell. In addition, although the rate of production can be increased by increasing the velocity of an electrolyte at a gap between an anode and a cathode, it is difficult to increase the velocity of the electrolyte because the velocity of the electrolyte is gradually decreased due to a curved gap between the anode and the cathode.

[Disclosure]

[Technical Problem]

**[0007]** An aspect of the present disclosure may include a method and apparatus for manufacturing metal foil with high productivity by an electroforming method using a horizontal cell.

**[0008]** An aspect of the present disclosure may also provide an electroforming method and apparatus for manufacturing metal foil with high productivity and at low cost by supplying an electrolyte at high speed to form electro-deposition layers on upper and lower sides of a base sheet.

**[0009]** An aspect of the present disclosure may also provide an electroforming method and apparatus for manufacturing metal foil through a continuous process using any metal usable for electro-deposition.

**[0010]** As aspect of the present disclosure may also provide an apparatus for manufacturing metal foil having a uniform composition, surface texture, and thickness, by forming a uniform current density between an anode and a cathode.

**[0011]** An aspect of the present disclosure may also provide a horizontal electroforming apparatus configured to improve productivity by stabilizing a flow field of an electrolyte supplied at high speed and preventing vortexes.

[Technical Solution]

**[0012]** According to an aspect of the present disclosure, a horizontal electroforming apparatus may include: a base sheet supply device configured to continuously supply a flexible and conductive base sheet functioning as a cathode in one direction; a horizontal cell including conduct rolls configured to apply a current to the base sheet whale making contact with lateral edges of the base sheet and moving the base sheet, anodes spaced apart from one or both sides of the base sheet, an electrolyte supply device configured to supply an electrolyte containing metal ions to a horizontal passage formed by the base sheet and the anodes, and a current supply device configured to supply a current to the conduct rolls and the anodes to cause electro-precipitation of the metal ions on one or both sides of the base sheet; and a stripping device configured to strip metal foil electro-deposited on one or both sides of the base sheet from the base sheet.

**[0013]** The electrolyte supply device includes an electrolyte supply nozzle configured to supply an electrolyte to one or both sides of the base sheet in the same direction as a moving direction of the base sheet, a direction opposite to the moving direction of the base sheet, or both directions.

**[0014]** A plurality of horizontal cells may be provided, and the plurality of horizontal cells may be arranged linearly, in a moving direction of the base sheet.

**[0015]** The horizontal electroforming apparatus may further include a heat treatment device configured to perform a heat treatment such as induction heating, atmosphere heating, or direct heating on the metals foil electrodeposited on the base.

**[0016]** The stripping device may include a plurality of rollers capable of causing a difference in shear force between the base sheet and the metal foil.

**[0017]** An edge mask may be disposed in the horizontal cell to prevent electro-precipitation of metal ions on the lateral edges of the base sheet.

**[0018]** Each of the anodes may have a thickness decreasing from a center to edges thereof in a width direction of the base sheet.

**[0019]** Each of the anodes may be divided into a plurality of sub electrodes in a width direction of the base sheet, and the sub electrodes may have different sizes. In addition, different currents may be supplied to the sub electrodes.

**[0020]** Each of the anodes may be divided into a plurality of sub electrodes in a moving direction of the base sheet, and the sub electrodes may have different sizes. In addition, different currents may be supplied to the sub electrodes.

**[0021]** The electrolyte supply nozzle may be inclined or curved to supply an electrolyte in a electrolyte-flow direction. In this case, at least an end portion of the electrolyte supply pipe is separable to supply an electrolyte in forward and backward directions relative to the moving direction of the base sheet. The end portion may have a sectional shape similar to the shape of a de Laval nozzle.

**[0022]** According to another aspect of the present disclosure, a method for manufacturing metal foil may include: supplying an electrolyte containing metal ions to a surface of a flexible and conductive base sheet which functions as a cathode and is horizontally fed in one direction; forming an electro-deposition layer on one or both sides of the base sheet through electro-precipitation of the metal ions of the electrolyte on one or both sides of the base sheet, the electro-precipitation of the metal ions being caused by the base sheet and anodes spaced apart from one or both the sides of the base sheet; and stripping the electro-deposition layer from the base sheet as metal foil.

**[0023]** One or both sides of the base sheet may be coated with oxide films.

**[0024]** The stripped metal foil may be heat-treated at 300°C to 600°C.

**[0025]** The electrolyte may be supplied to a horizontal passage formed between the base sheet and the anodes in the same direction as a moving direction of the base sheet and a direction opposite to the moving direction of the base sheet.

**[0026]** Different electrolytes may be supplied to both the sides of the base sheet.

**[0027]** Prior to the stripping of the electro-deposition layer, the method may further include: secondarily supplying an electrolyte; and secondarily forming an electro-deposition layer. Different electrolytes may be supplied in the supplying of the electrolyte and the secondary supplying of the electrolyte. The metal foil may be formed to have a multi-layer structure.

[Advantageous Effects]

**[0028]** According to an embodiment of the present disclosure, metal foil may be manufactured at a high rate.

**[0029]** According to another embodiment of the present disclosure, metal foil having improved surface roughness on both sides thereof, a uniform composition, and a uniform thickness may be manufacturing at a high rate.

**[0030]** According to another embodiment of the present disclosure, the thickness of metal foil may be controlled through a continuous process, or metal foil having a multi-layer structure may be manufacturing through a continuous process.

**[0031]** According to another embodiment of the present disclosure, different types of metal foil may be simultaneously manufactured.

**[0032]** According to another embodiment of the present disclosure, although an electrolyte is supplied to a base sheet at high speed, vibration of the base sheet may be structurally suppressed to allow the electrolyte to form a uniform flow field and thus to induce stable electro-precipitation. Therefore, high-quality metal foil having a uniform composition, surface, and thickness may be manufactured.

**[0033]** According to another embodiment of the present disclosure, an electro-precipitation region may be increased, and thus metal foil may be manufactured with high productivity.

**[0034]** By using the horizontal electroforming apparatus according to an embodiment of the present disclosure, metal foil having a uniform composition, surface texture, and thickness in a width direction thereof may be manufacturing at a high rate.

**[0035]** Furthermore, since the horizontal electroforming apparatus is configured to structurally prevent nonuniform current density in a width direction, high-quality metal foil may be manufactured with improved productivity.

**[0036]** Furthermore, according to an embodiment of the present disclosure, current density may be controlled in the moving direction of a base sheet to form an entirely uniform electro-deposition layer.

[Description of Drawings]

**[0037]**

FIG. 1 is a schematic view illustrating an apparatus for manufacturing metal foil according to an embodiment of the present disclosure.

FIG. 2 is a schematic view illustrating the apparatus for manufacturing metal foil according to another embodiment of the present disclosure.

FIG. 3 is a view illustrating anodes each divided in the width direction of a base sheet and having a thickness decreasing from the center to lateral edges thereof, according to an embodiment of the present disclosure.

FIG. 4 is a schematic view illustrating anodes divided in a moving direction of a base sheet according to an embodiment of the present disclosure.

FIG. 5 is a schematic view illustrating a horizontal cell including inclined electrolyte supply nozzles according to an embodiment of the present disclosure.

FIG. 6 is a schematic view illustrating a horizontal cell including curved electrolyte supply nozzles according to an embodiment of the present disclosure.

FIG. 7 is a cross-sectional view illustrating a de Laval nozzle formed on an end of an electrolyte supply pipe according to another embodiment of the present disclosure.

FIG. 8 is a view illustrating a horizontal electroforming apparatus in which a plurality of horizontal cells are arranged linearly, according to another embodiment of the present disclosure.

FIG. 9 is a graph showing a current density curve of a horizontal electroforming apparatus including a horizontal cell in which anodes each having a thickness decreasing from the center to lateral edges thereof as shown in FIG. 3 are disposed, and a current density curve of a drum type electroforming apparatus including a drum cell of the related art.

FIGS. 10A to 10C are schematic views illustrating distal end structures of electrolyte supply nozzles used in Example 2, FIG. 10A illustrating an right-angled nozzle, FIGS. 10B and 10C illustrating curved nozzles according to embodiments of the present disclosure.

FIGS. 11A to 11C are views illustrating streamlines of flow fields of an electrolyte supplied under a laminar flow condition through the electrolyte supply nozzles shown in FIGS. 10A to 10C.

FIGS. 12A to 12C are views illustrating streamlines of flow fields of an electrolyte supplied under a turbulent flow condition through the electrolyte supply pipes shown in FIGS. 10A to 10C.

[Best Mode]

**[0038]** Embodiments of the present disclosure provide a horizontal cell electroforming apparatus and a method for manufacturing metal foil by electro-depositing a metal on a base sheet fed horizontally in the electroforming apparatus. The embodiments of the present disclosure will now be described in detail with reference to the accompanying drawings. The disclosure may, however, be exemplified in many different forms and should not be construed as being limited to the specific embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. In the drawings, the shapes and dimensions of elements may be exaggerated for clarity.

**[0039]** A horizontal electroforming apparatus 100 will now be described with reference to FIG. 1 and 2 according to an aspect of the present disclosure. FIGS. 1 and 2 are schematic views illustrating the horizontal electroforming apparatus 100 according to embodiments of the present disclosure.

**[0040]** In the embodiments of the present disclosure, the horizontal electroforming apparatus 100 includes a base sheet supply device 10, a horizontal cell 30 (also referred to as an electroforming cell 30), an electrolyte supply device, and a metal foil stripping device.

**[0041]** The base sheet supply device 10 supplies a base sheet 11 to the inside of the electroforming cell 30. Base sheets 11 having a predetermined size may be fed on after another, or a base sheet 11 may be continuously fed. In a non-limiting example, a base sheet 11 wound in the form of a coil may be continuously fed into the horizontal cell 30. After the base sheet 11 is fed, another coiled base sheet 11 may be continuously fed.

**[0042]** In this case, the rear edge of the base sheet 11 may be bonded to the front edge of the next base sheet 11 by a method such as welding so as to continuously supply the base sheets 11 to the inside of the horizontal cell 30. The edges of the base sheets 11 may be shaped into predetermined patterns for easily joining the edges.

**[0043]** Furthermore, a base sheet 11 having a uniform surface roughness may be used because the surface roughness of the base sheet 11 will be transferred (copied) to electro-deposition layers to be formed on the base sheet 11. A base sheet 11 having a uniform surface roughness may be obtained by polishing. Therefore, a polishing machine may be used to obtain base sheets 11 having proper surface roughness. If a base sheet 11 is polished to a desired degree of surface roughness as described above, the degree of surface roughness may be transferred from the base sheet 11 to metal foil 50 during an electroforming process, and thus the metal foil 50 may have an equivalent degree of surface roughness.

**[0044]** The surface roughness of a base sheet 11 may be adjusted by any method, such as chemical, mechanical, or chemical and mechanical polishing methods known in the related art. For example, mechanical polishing, chemical polishing such as etching, or chemical mechanical polishing (CMP) may be used.

**[0045]** When metal foil 50 is manufactured by an electroforming method, the quality of the metal foil 50 may be significantly affected by the surface roughness thereof. For example, electro-deposition layers (metal foil 50) deposited, on a base sheet 11 may have surface roughness transferred from the base sheet 11, and thus a short circuit occurring in a defective portion (roughness defect) of the metal foil 50 may damage the surface of the base sheet 11 and thus may cause non-uniform electro-deposition and surface defects. The surface roughness of a base sheet 11 may be adjusted according to the use of metal foil 50 to be formed. For example, if metal foil 50 for substrates of display devices are formed, a base sheet 11 polished to a surface roughness of 4 nm or less may be used, and if metal foil 50 for substrates of solar cells, a base sheet 11 polished to a surface roughness of 40 nm or less may be used.

**[0046]** When a base sheet 11 is polished as described above, materials such as abrasives, polishing liquids, or removed particles may remain on the base sheet 11, and thus a cleaning process may be necessary. To this end, the horizontal electroforming apparatus 100 of the embodiments of the present disclosure may include a pre-cleaning device. The surfaces of the base sheet 11 may be cleaned with an acid solution such as a diluted hydrochloric acid solution or a diluted sulfuric acid solution, and water.

**[0047]** In addition, a drying device (not shown) may be used to dry the base sheet 11 after cleaning. The base sheet 11 may be dried by blowing compressed air or high-temperature gas onto the base sheet 11, or heating the base sheets 11.

**[0048]** In the embodiments of the present disclosure, when metal foil 50 is formed by electroforming, any base sheet 11 may be used as long as the base sheet 11 is flexible and conductive. For example, a base sheet 11 formed of stainless steel or titanium may be used.

**[0049]** In the embodiments of the present disclosure, during a manufacturing process, if metal foil 50 is electro-deposited on a base sheet 11 and strongly adhered thereto, it may be difficult to separate the metal foil 50 from the base sheet 11. Therefore, oxide films may be previously formed on the base sheet 11. Then, electro-deposition layers (metal foil 50) formed on the base sheet 11 may easily separated because oxide films formed on the base sheet 11 may lower the adhesion between the metal foil 50 and the base sheets 11.

**[0050]** In the horizontal electroforming apparatus 100 of the embodiments of the present disclosure, the horizontal cell 30 is separated from the base sheet supply device 10 and used to electro-deposit a metal on a base sheet 11.

**[0051]** In the embodiments of the present disclosure, a base sheet 11 is continuously fed into the electroforming cell 30 (horizontal cell 30) in a fixed direction. Herein, the 'electroforming cell 30 (horizontal cell 30)' may be defined as a unit cell in which an electrolyte is supplied to a base sheet 11 so as to electro-deposit metal layers on the base sheet 11 by an electro-precipitation reaction between metal ions and the base sheet 11. In addition, the expression 'fixed direction' is used herein to refer to that the moving direction of base sheets 11 fed into the electroforming cell 30 is not changed at least until the base sheets 11 depart from the electroforming cell 30. That is, in the present disclosure, the moving direction of a base sheet 11 is expressed as a horizontal direction or horizontal, and for this reason, the electroforming cell 30, into which a base sheet 11 is fed in the horizontal direction to cause metal deposition thereon by an electro-precipitation reaction of metal ions of an electrolyte, may be referred to as a horizontal cell.

**[0052]** In a drum type electroforming apparatus of the related art, an electrolyte is contaminated by residues remaining after a drum is polished to obtain a desired degree of surface roughness. However, since the horizontal cell 30 is separated from the base sheet supply device 10 in the embodiments of the present disclosure, this problem may be prevented. Furthermore, in a drum type electroforming apparatus of the related art, if it is necessary to replace a base sheet, a drum is replaced together with the base sheet, and thus manufacturing costs are increased. However, according to the embodiments of the present disclosure, a base sheet 11 can only be replaced, and thus manufacturing costs can be reduced.

**[0053]** The horizontal cell 30 includes: conduct rolls 31 and 31' configured to convey a base sheet 11 and connect cathodes to a power source; anodes 32 spaced a constant distance from one or both sides of the base sheet 11; a current supply device 33, configured to supply a current (negative (-) charge) to the conduct rolls 31 and 31' and a current (positive (+) charge) to the anodes 32; and an electrolyte supply device containing an electrolyte for causing an electrolyte reaction.

**[0054]** The conduct rolls 31 and 31' function as conveying units to move a base sheet 11 into the horizontal cell 30 and out of the horizontal cell 30, and function as connectors connecting the base sheet 11 functioning as a cathode to the current supply device 33 so as to cause an electrolyte reaction between the anodes 32 and the base sheet 11 and thus to induce precipitation of metal ions on the base sheet 11. The conduct rolls 31 and 31' may make contact with lateral edge portions of a base sheet 11 to move the base sheet 11 into the horizontal cell 30 and out of the horizontal cell 30.

**[0055]** In the embodiments of the present disclosure, since a flexible and conductive base sheet 11 is used, the base sheet 11 may be subject to deflection due to the weight thereof. In this case, the distances between the base sheet 11 and the anodes 32 may be varied, and thus current density may not be uniform. As a result, metal foil 50 having a uniform thickness may not be produced. The conduct rolls 31 disposed at an entrance side and the conduct rolls 31' disposed at an exit side may be rotated at different speeds so as to prevent deflection of a base sheet 11. That is, if the exit conduct rolls 31' are rotated faster than the entrance conduct rolls 31, deflection of a base sheet 11 caused by the weight of the conduct rolls 31 may be prevented.

**[0056]** The anodes 32 are spaced a constant distance apart from a base sheet 11 passing through the horizontal cell 30. Thus, flow passages for an electrolyte are formed between the anodes 32 and the base sheet 11.

**[0057]** An electrolyte may be uniformly supplied to a base sheet 11 in the width direction of the base sheet 11 for uniform current density and production of metal foil 50 having a uniform thickness. However, when an electrolyte is supplied to a base sheet 11 through electrolyte supply pipes 35, the electrolyte may be concentrated on lateral edge portions of the base sheet 11 to cause a non-uniform current density in the width direction of the base sheet 11. In this case, defective metal foil 50 having a non-uniform thickness in the width direction may be produced. Therefore, a method or device may be necessary to form a uniform current density in the width direction of a base sheet 11. For example, edge masks may be used to prevent a locally high current density and thus the formation of electro-deposition layers having a non-uniform thickness.

**[0058]** In addition, the thickness of each of the anodes 32 may be reduced from the center to lateral edges thereof. In this case, the gaps between the anodes 32 and a base sheet 11 functioning as a cathode may be increased in directions toward lateral edges, and thus a locally high current density caused by the concentration of an electrolyte may be offset by the outwardly decreasing thicknesses of the anodes 32. In this way, electro-deposition on a base sheet 11 may be controlled.

**[0059]** For example, as shown in FIG. 3, the anodes 32 may have thicknesses continuously decreasing in a curved shape in directions from the center to the lateral edges of a base sheet 11 (in this case, the anodes may be referred as curved anodes 32a). The curved anodes 32a may not have a constant curvature. The curved anodes 32a having thicknesses varying in the width direction of a base sheet 11 may prevent a localized high current density at edge portions of the base sheet 11 caused by an electrolyte concentrating on the edge portions, and thus the speed and composition of metal precipitation may be uniform between the curved anodes 32a and the base sheet 11 functioning as a cathode. Therefore, metal foil 50 may not have surface defects caused by a non-uniform current density in a width direction.

**[0060]** Although current density can be uniformly maintained using the curved anodes 32a thicker at the centers than the edges thereof, each of the anodes 32 may be divided into plurality of sub electrodes in the width direction thereof as shown in FIG. 3 for more uniform current density (in this case, the anodes 32a may be referred to as width-division anodes 32a). The sub electrodes of the width-division anodes 32a may have the same width or different widths. In addition, some of the sub electrodes of the width-division anodes 32a may have different sizes, and the other of the parts may have the same size. Referring to FIG. 2, the anodes 32a are curved and divided in the width directions thereof. However, the embodiments of the present disclosure are not limited thereto. For example, anodes only curved or anodes only divided may be used.

**[0061]** Since currents to the sub electrodes of the width-division anodes 32a can be individually controlled, current density uniformity may be maintained more precisely. That is, if currents from the current supply device 33 to the sub electrodes of the width-division anodes 32a are individually controlled according to a desired amount of electro-deposition in the width direction, the amount of a metal electro-deposited on a base sheet 11 may be uniformly controlled in the width direction, and thus metal foil 50 having a uniform thickness may be obtained.

**[0062]** Furthermore, in the embodiments of the present disclosure, the anodes 32 may be divided into sub electrodes in the moving direction of a base sheet 11 (in this case, the anodes 32 may be referred as front-to-back division anodes 32b). For example, the width-division anodes 32a may also be divided in the moving direction of a base sheet 11. Like the width-division anodes 32a, the sub electrodes of the front-to-back division anodes 32b may have different sizes, and currents to the sub electrodes of the front-to-back division anodes 32b may be individually controlled.

**[0063]** When a base sheet 11 is fed in the horizontal cell 30, initial electro-deposition of a metal may function as electro-deposition nuclei for the next electro-deposition, and thus electro-deposition may occur continuously and stably. Furthermore, although an electrolyte is supplied at high speed, electro-deposition layers may not be striped or separated.

**[0064]** The rate of electro-deposition is affected by the flow rate of an electrolyte, the feeding speed of a base sheet 11, and the relative velocities thereof. In the embodiments of the present disclosure, an electrolyte may be supplied in the same direction as the moving direction of a base sheet 11, the opposite direction to the moving direction of the base sheet 11, or both directions. For example, in a region in which an electrolyte is supplied in the opposite direction to the moving direction of a base sheet 11, the rate of electro-deposition may be low because the electrolyte and the base sheet 11 make contact with each other for a relatively short period of time. In this case, anodes 32 divided into sub electrodes in the moving direction of the base sheet 11 may be used to increase the rate of electro-deposition by applying different currents to the sub electrodes of the anodes 32.

**[0065]** Furthermore, in a region in which an electrolyte is supplied in the same direction as the moving direction of a base sheet 11, the rate of electro-deposition may be high because the electrolyte and the base sheet 11 make contact with each other for a relatively long period of time. However, the rate of electro-deposition may be gradually reduced because the concentration of metal ions of the electrolyte may be gradually reduced. In this case, like in the former case, anodes 32 divided into sub electrodes in the moving direction of the base sheet 11 may be used to increase the rate of electro-deposition by applying different currents to the sub electrodes of the anodes 32.

**[0066]** In addition, the anodes 32 may have thicknesses decreasing in directions from the centers to the lateral edges thereof and may be divided into sub electrodes in the width and length directions thereof. In this case, the current densities of regions corresponding to the sub electrodes of the anodes 32 may be individually controlled, and thus metal foil 50 having a more uniform thickness may be obtained.

**[0067]** As described above, when an electrolyte reaction occurs between an electrolyte and a base sheet 11 functioning as a cathode, metal ions included in the electrolyte are electro-deposited on the base sheet 11 (electro-precipitation of metal ions). Therefore, if the electrolyte is supplied at high speed, more metal ions may be electro-deposited on the base sheet 11 at a high electro-deposition rate.

**[0068]** In a drum cell type electroforming apparatus of the related art, an electrolyte flows in a curved flow passage because a base sheet is curved according to the curvature of a drum cell, and thus the velocity of the electrolyte is gradually decreased to lower the rate of electro-deposition. Thus, metal foil 50 manufactured using the drum type electroforming apparatus may have a non-uniform thickness.

**[0069]** However, according to the embodiments of the present disclosure, since the horizontal cell 30 is used, an electrolyte may flow in a horizontal flow passage, and thus the electrolyte may be supplied at a high flow rate without a decrease in velocity. Therefore, the rate of electro-deposition of metal ions may be increased. An electrolyte may be supplied at a maximum velocity of 5,000 in Reynolds number, and the velocity of the electrolyte may be increased or decreased relatively to the feeding speed of a base sheet 11. In addition, according to the state of electro-deposition, the electrolyte may be supplied within a laminar-flow velocity range (in which streamlines of the electrolyte are straight without turbulence), and after electro-deposition is stabilized, the electrolyte may be rapidly supplied within a turbulent-flow velocity range (in which streamlines of the electrolyte fluctuate to the left and right).

**[0070]** If the velocity of an electrolyte is high at an initial stage of electro-deposition, an electro-deposition layer may be stripped from a base sheet 11 to cause an electro-deposition fail, and thus after the electro-deposition layer is grown to a thickness of several micrometers and thus can securely adhere to the base sheet 11 owing to stress accumulated therein, the velocity of the electrolyte may be increased to form a high-velocity flow field. However, when forming a high-velocity flow field, the velocity of the electrolyte may be controlled not to increase to a level cancelling out the surface tension between the electro-deposition layer and the base sheet 11. That is, if the velocity of the electrolyte is increased to a certain level, the shearing stress between a flow field formed by the electrolyte and the electro-deposition layer becomes greater than the surface tension between the electro-deposition layer and the base sheet 11, and thus the electro-deposition layer may be stripped.

**[0071]** The current supply device 33 is used to supply a negative (-) current to the conduct rolls 31 and 31' and a positive (+) current to the anodes 32. The current supply device 33 is not limited to a particular type. For example, a general type of current supply device may be used as the current supply device 33. Thus, a detailed description of the current supply device 33 will not be given.

**[0072]** An electrolyte may be supplied to a side of a base sheet 11 fed into the horizontal cell 30 to form metal foil 50 on the side of the base sheet 11 by causing precipitation of a metal, or may be supplied to both sides of the base sheet 11 to form metal foil 50 on both sides of the base sheet 11 by causing precipitation of a metal and thus to increase the production rate of the metal foil 50.

**[0073]** As described above, when a base sheet 11 is fed in the horizontal cell 30, an electrolyte is supplied to one or both sides of the base sheet 11 through electrolyte supply nozzles 37, and the electrolyte flows in horizontal flow passages formed between the base sheet 11 and the anodes 32. Then, metal ions are deposited on the base sheet 11 by an electro-precipitation reaction caused by the anodes 32 and the base sheet 11 functioning as cathodes, and thus an electro-deposition layer is formed on one or both sides of the base sheet 11 by the deposited metal ions.

**[0074]** For this, the electrolyte supply device may include an electrolyte tank 40 containing an electrolyte and the electrolyte supply nozzles 37 through which the electrolyte is supplied to a base sheet 11. The electrolyte contained in the electrolyte tank 40 may be supplied to a base sheet 11 fed into the horizontal cell 30 through the electrolyte supply pipes 35 and the electrolyte supply nozzles 37. The electrolyte supply nozzles 37 may supply an electrolyte to one or both sides of a base sheet 11.

**[0075]** In the accompanying drawings, an electrolyte is supplied to both sides of a base sheet 11 from the electrolyte tank 40. However, different electrolytes may be supplied to both sides of a base sheet 11 to electro-deposit different metals on the both sides of the base sheet 11 and thus to produce two kinds of metal foil 50.

**[0076]** An electrolyte may be supplied at high speed through the electrolyte supply nozzles 37 to horizontal flow passages formed between a base sheet 11 and the anodes 32. In this case, the electrolyte may flow in the same direction as the moving direction of the base sheet 11 or the opposite direction to the moving direction of the base sheet 11. In addition, the electrolyte may flow from the electrolyte supply nozzles 37 in the same direction (forward direction) as the moving direction of the base sheet 11 and the opposite direction (backward direction) to the moving direction of the base sheet 11.

**[0077]** If the electrolyte flows in both the forward and backward directions with respect to the moving direction of the base sheet 11, electro-deposition may occur substantially twice. That is, the electrolyte supplied in the backward direction may make contact with the base sheet 11 for a relative short period of time due to a high velocity relative to that of the base sheet 11 to result in primary electro-deposition (a relatively small amount of electro-deposition), and the electrolyte supplied in the forward direction may make contact with the base sheet 11 for a relatively long period of time to result in secondary electro-deposition (a relatively large amount of electro-deposition as compare with that of the primary electro-deposition).

**[0078]** In the embodiments of the present disclosure, the electrolyte supply pipes 35 may include an electrolyte supply pipe through which an electrolyte is supplied in the same direction (forward direction) as the moving direction of a base sheet 11 and an electrolyte supply pipe through which the electrolyte is supplied in the backward direction. Therefore, since an electrolyte is supplied through he electrolyte supply pipes 35 in the forward and backward directions with reference to the moving direction of a base sheet 11, a non-uniform flow field may be formed by the electrolyte. The non-uniform flow field may reduce non-uniform electro-deposition on the base sheet 11, and thus, metal foil 50 having a more uniform thickness may be formed.

**[0079]** To this end, for example, the electrolyte supply pipes 35 may include inclined electrolyte supply nozzles 37a as shown in FIG. 5. The inclined electrolyte supply nozzles 37a may be inclined from the ends of the electrolyte supply pipes 35 in the forward and backward directions with reference to the moving direction of a base sheet 11. In another example shown in FIG. 6, the electrolyte supply pipes 35 may include curved electrolyte supply nozzles 37b. The curved electrolyte supply nozzles 37b may be curved to the forward and backward directions with respect to the moving direction of a base sheet 11 so as to supply an electrolyte between a base sheet 11 and the anodes 32. In this case, an electrolyte may be stably supplied to the flow passages formed between a base sheet 11 and the anodes 32 through the curved electrolyte supply nozzles 37b formed on ends of the electrolyte supply pipes 35, and thus the formation of a non-uniform flow field may be suppressed.

**[0080]** If the flow field of an electrolyte is stabilized, a vortex of the electrolyte may not be generated on the base sheet 11, and thus the electrolyte may make uniform contact with a large area of the base sheet 11. As a result, the rate of electro-precipitation or electro-deposition may be increased. Therefore, metal foil 50 having a uniform composition, surface, and thickness may be produced. If an electrolyte is supplied to both sides (upper and lower sides) of a base sheet 11, the base sheet 11 may be vibrated due to a pressure difference between upward and downward streams of the electrolyte, thereby resulting in non-uniform electro-deposition. However, this problem may be lowered by horizontally supplying an electrolyte through the curved electrolyte supply nozzles 37b.

**[0081]** As described above, the flow field of an electrolyte may be stabilized by using the curved electrolyte supply nozzles 37b according to the embodiment of the present disclosure, and this was experimentally confirmed as explained in examples below.

**[0082]** In another embodiment of the present disclosure, the electrolyte supply pipes 35 may include dispensers 38 on ends thereof. An electrolyte may be supplied from the electrolyte supply pipes 35 to a base sheet 11 through the dispensers 38 uniformly in the width direction of the base sheet 11. When an electrolyte is supplied from the electrolyte supply pipes 35 to flow passages formed between a base sheet 11 and the anodes 32, the flow rate of the electrolyte may be varied in directions from the center to the lateral edges of the base sheet 11, and thus the velocity of the electrolyte may be varied in the directions. In this case, current density may be varied in the directions from the center to the lateral edges of the base sheet 11, and thus an electro-deposition layer may not be uniformly formed. However, if the dispensers 38 are used, an electrolyte may be uniformly supplied to a base sheet 11 throughout the entire area of the base sheet 11.

**[0083]** As shown in FIG. 7, the dispensers 38 may be shaped like a de Laval nozzle. In this case, an electrolyte may be supplied from the electrolyte supply pipes 35 to a base sheet 11 through the dispensers 38 uniformly in the width direction of the base sheet 11 without reducing the flow field of the electrolyte.

**[0084]** As described in the previous embodiments of the present disclosure, the curved electrolyte supply nozzles 37b may be formed on ends of the electrolyte supply pipes 35, and the dispensers 38 of the current embodiment may be provided on ends of the curved electrolyte supply nozzles 37b. Then, an electrolyte may be uniformly supplied to the entirety of a base sheet 11 while stabilizing the flow field of the electrolyte, and thus the velocity of the electrolyte may be kept uniform in the width direction of the base sheet 11.

**[0085]** The inclined electrolyte supply nozzles 37a, the curved electrolyte supply nozzles 37b, the dispensers 38, or combinations thereof may be formed on the ends of the electrolyte supply pipes 35 to obtain all or some of the effects described in the embodiments of the present disclosure. Furthermore, non-uniform electro-deposition caused by an unstable flow field of an electrolyte supplied in a vertical direction may be reduced, and thus metal foil 50 having a more uniform thickness may be produced.

**[0086]** In addition, the electrolyte supply pipes 35 may include honey combs 36 wherein. Owing to the honey combs 36 disposed in the electrolyte supply pipes 35, an electrolyte supplied from the electrolyte supply pipes 35 to a base sheet 11 may form a laminar flow on the base sheet 11. In this case, the above-described phenomena in which the flow field of an electrolyte is unstable due to a vortex may be minimized. Furthermore, although an electrolyte is supplied at high speed to a base sheet 11, the base sheet 11 may be less vibrated when the electrical collide with the surface of the base sheet 11, and thus non-uniform electro-deposition may be reduced.

**[0087]** As shown in FIG. 8, the above-described electro-deposition may be continuously performed two or more times by using a plurality of (first and second) horizontal cells 30 and 130 arranged linearly. In this case, thicker metal foil 50 may be produced owing to the plurality of horizontal cells 30 and 130. That is, the thickness of thicker metal foil 50 may be adjusted to a desired valve, or although the feeding speed of a base sheet 11 is increased, metal foil 50 having a desired thickness may be produced with high productivity. For example, the first and second horizontal cells 30 and 130 may be used as follows. A metal electro-deposition layer 15 is formed on a base sheet 11 in the horizontal cell 30. Then, in the second horizontal cell 130, the same electrolyte as that used in the horizontal cell 30 is supplied to the base sheet 11 on which the electro-deposition layer 15 is formed in the first horizontal cell 30 so as to induce additional electro-deposition and thus to form an electro-deposition layer 15' on the base sheet 11. In this way, metal foil 50 may be formed.

**[0088]** Alternatively, in the first and second horizontal cells 30 and 130, different electrolytes may be supplied to a base sheet 11 to form metal foil 50 having a plurality of layers. That is, in this way, metal foil 50 having various functions may be formed. For example, in the first horizontal cell 30, a first electrolyte may be supplied to a base sheet 11 to form a first electro-deposition layer 15, and in the second horizontal cell 130, a second electrolyte different from the first electrolyte may be supplied to form a second electro-deposition layer 15' on the first electro-deposition layer 15. In this way, metal foil 50 having a plurality of layers of different metals may be formed by using the horizontal cells 30 and 130.

**[0089]** Metal ions of an electrolyte are not limited as long as the metal ions can be used in an electroforming process. For example, Cu, Fe, Ni, Zn, Cr, Co, Ag, Pd, Al, Sn, or an alloy thereof may be included in an electrolyte in the form of metal ions.

**[0090]** The electrolyte tank 40 may include an electrolyte heater 41 to heat an electrolyte, an electrolyte filter 42 to remove foreign substances such as slurry from the electrolyte, and an electrolyte pump 43 to supply the electrolyte to the horizontal cell 30.

**[0091]** An electrolyte used in electro-deposition may be collected in the electrolyte tank 40. For this, an electrolyte collecting pipe 45 may be provided. Since an electrolyte is returned to the electrolyte tank 40 after being used in electro-deposition, the concentration of metal ions of the electrolyte stored in the electrolyte tank 40 may be reduced below a range required for electro-deposition. Thus, it may be necessary to supplement the electrolyte with metal ions so as to maintain the metal ion concentration of the electrolyte at a predetermined level.

**[0092]** As described above, a base sheet 11 on which an electro-deposition layer is formed is discharged from the base sheet supply device 10 through the exit conduct rolls 31'. Then, the electro-deposition layer formed on the base sheet 11 may be separated as metal foil 50 by a metal foil stripping device. Since the metal foil 50 (electro-deposition layer) is coupled to the base sheet 11 having oxide films by a surface tension between the metal foil 50 and the base sheet 11, the metal foil 50 may be separated from the base sheet 11 by applying a shearing force. That is, the metal foil stripping device may apply a shearing force (shearing stress) to the metal foil 50 to separate the metal foil 50 from the base sheet 11. For example, the metal foil stripping device may include a plurality of stripping rollers 51 capable of applying shearing forces. In addition, metal foil 50 may be separated from one or both sides of a base sheet 11 simultaneously or one after another by causing a velocity difference between the metal foil 50 and the base sheet 11.

**[0093]** After the metal foil 50 is separated from the base sheet 11, the metal foil 50 and the base sheet 11 may be wound by using coiling devices 55 and 72, respectively. For example, the coiling devices 55 and 72 may be cylindrical coiling devices. After proper amounts of the metal foil 50 and the base sheet 11 are coiled around the coiling devices 55 and 72, the metal foil 50 and the base sheet 11 may be cut and wound around other coiling devices 55 and 72. For example, a metal foil cutting device 54 and a base sheet cutting device 71 may be used. A base sheet 11 may be cut at a bonding line thereof.

**[0094]** According to an embodiment of the present disclosure, the horizontal electroforming apparatus 100 may include a post processing device to process metal foil 50 after the metal foil 50 is discharged from the horizontal cell 30. In this case, the metal foil 50 may be process after or before the metal foil 50 is separated from a base sheet 11. The post processing device may include post-cleaning devices 52, drying devices (not shown), and heat-treatment devices 53.

**[0095]** Since an electrolyte may remain on metal foil 50 electro-deposited on a base sheet 11, the metal foil 50 may be cleaned. For example, the post-cleaning devices 52 may remove an electrolyte and other foreign substrates remaining on metal foil 50 by using an acid solution and water. In addition, a soft brush may be used to effectively remove a remaining electrolyte. Such a cleaning process may be performed on an electro-deposition layer (metal foil 50) formed on a base sheet 11, or may be performed on the metal foil 50 after the metal foil 50 is separated from the base sheet 11.

**[0096]** After cleaning, air may be blown to the metal foil 50 at a high pressure so as to remove moisture from the metal foil 50. In addition, a high-temperature gas blower or a heater may be used to dry the metal foil 50.

**[0097]** The metal foil 50 formed by electroforming has a nanostructure, and a heat treatment process may be performed on the metal foil 50 to improve the nanostructure of the metal foil 50. Metal foil 50 formed by electroforming may be processed at different temperatures according to the use of the metal foil 50. For example, at 300°C to 600°C, the structure of metal foil 50 such as Fe foil may be changed from a nanostructure to a microstructure due to growth of abnormal grains. Such a change caused by growth of abnormal grains may result in errors when products are produced using the metal foil 50. For example, if electric circuits are formed on the metal foil 50, the electric circuits may be stripped or short-circuited in the following high-temperature process.

**[0098]** Therefore, if metal foil 50 is formed in a temperature range of abnormal grain growth, the metal foil 50 may be previously heat-treated to change the microstructure of the metal foil 50 so as to prevent the structure of the metal foil 50 from changing in the next processes. To this end, the heat-treatment devices 53 may be used. Process conditions of such a heat treatment process are not limited but may be varied according to a desired structure of metal foil 50. For example, such a heat treatment process may be performed at 300°C to 600°C. In addition, such a heat treatment process may be performed under an inert gas atmosphere such as a nitrogen or argon atmosphere to prevent surface oxidation, and methods such as induction heating, direct heating, and contact heating may be used.

**[0099]** While the method for manufacturing metal foil 50 by electroforming and the horizontal electroforming apparatus 100 have been described according to the embodiments of the present disclosure, it will be apparent to those skilled in the related art that modifications and variations could be made without departing from the spirit and scope of the present disclosure.

[Mode for Invention]

**[0100]** Hereinafter, some embodiments of the present disclosure will be described more specifically according to the following examples. However, the scope and spirit of the present disclosure are not limited to the examples.

Example 1

**[0101]** A simulation was performed. In the simulation, an electrolyte was supplied between a base sheet and anodes in the above-described apparatus while using horizontal anodes having a uniform thickness in the width direction thereof as the anodes and curved anodes (not divided into sub electrodes) such as shown in FIG. 3 as the anodes.

**[0102]** The width of the base sheet was set to be 1000 nm, and the velocity of the electrolyte was set to be 1000 in Reynolds number to cause a laminar flow.

**[0103]** After the simulation, current density distribution along the width of the base sheet was measured as shown in FIG. 9. In FIG. 9, positions along a half of the base sheet from an electrolyte supply pipe are denoted.

**[0104]** As shown in FIG. 9, in the case of using the horizontal anodes, current density started to noticeably increase after about the 300-mm position in a center-to-edge direction. However, in the case of using the curved anodes, current density was almost constant along the base sheet and started to gradually increase after about the 400-mm position.

**[0105]** Furthermore, in the case of using the curved anodes, the current density measured at the 500-mm position was lower than the current density measured at the 500-mm position in the case of using the horizontal anodes by about 35%, and a region having a uniform current density distribution was increased.

**[0106]** Based on the results, it may be understood that the distribution of current density can be more uniformly maintained by varying the shapes of anodes to vary the distance between a cathode and the anodes, as compared with the case of using horizontal anodes.

Example 2

**[0107]** Another simulation was performed for the cases in which an electrolyte supply nozzle such as shown in FIG. 10A, and curved injection nozzles such as shown in FIGS. 10B and 10C were used together with electrolyte supply pipes to supply an electrode through the nozzles, respectively. In each case, the electrolyte was supplied in a laminar flow condition and a turbulent flow condition, respectively, so as to evaluate the degree of stabilization of flow fields of the electrolyte.

**[0108]** Stream lines of the flow fields of the electrolyte in the simulation are shown in FIGS. 11A to 12C. FIGS. 11A to 11C show streamlines when the electrolyte was supplied in a laminar flow condition (Reynolds number Re = 1000), and FIGS. 12A to 12C show streamlines when the electrolyte was supplied in a turbulent flow condition (Reynolds number Re = 5000).

**[0109]** When the electrolyte was supplied to a laminar flow field as shown in FIG. 11A through the electrolyte supply nozzle as shown in FIG. 10A, the flow field was stabilized after the electrolyte flowed about 0.15 m. However, when the electrolyte was supplied to a laminar flow field as shown in FIG. 11B through the curved electrolyte supply nozzle as shown in FIG. 10B, the flow field was stabilized after the electrolyte flowed about 0.03 m, and when the electrolyte was supplied to a laminar flow field as shown in FIG. 11C through the curved electrolyte supply nozzle as shown in FIG. 10C, the flow field was also stabilized after the electrolyte flowed about 0.03 m.

**[0110]** From the above-described results, it may be understood that when an electrolyte is supplied to a laminar flow field as shown in FIGS. 11A to 11C, the flow field may be stabilized more rapidly in the case of using a curved electrolyte supply nozzle as shown in FIGS. 10B and 10C than in the case of using an electrolyte supply nozzle as shown in FIG. 10A. In addition, a uniform electro-deposition region may also be increased in the former case.

**[0111]** When the electrolyte was supplied to a turbulent flow field as shown in FIG. 12A through the electrolyte supply nozzle as shown in FIG. 10A, the flow field was stabilized after the electrolyte flowed about 0.15 m. However, when the electrolyte was supplied to a turbulent flow field as shown in FIG. 12B through the curved electrolyte supply nozzle as shown in FIG. 10B, the flow field was stabilized after the electrolyte flowed about 0.05 m, and when the electrolyte was supplied to a turbulent flow field as shown in FIG. 12C through the curved electrolyte supply nozzle as shown in FIG. 10C, the laminar flow field was also stabilized after the electrolyte flowed about 0.03 m.

**[0112]** From the above-described results, it may be understood that when an electrolyte is supplied to a turbulent flow field, the flow field may be stabilized more rapidly in the case of using a curved electrolyte supply nozzle like in the embodiments of the present disclosure than in the case of using a right-angled electrolyte supply pipe. In addition, a uniform electro-deposition region may also be increased in the former case.

## Claims

**1.** A horizontal electroforming apparatus comprising:

a base sheet supply device configured to continuously supply a flexible and conductive base sheet functioning as a cathode in one direction;
a horizontal cell comprising conduct rolls configured to apply a current to the base sheet while making contact with lateral edges of the base sheet and moving the base sheet, anodes spaced apart from one or both sides of the base sheet, an electrolyte supply device configured to supply an electrolyte containing metal ions to a horizontal passage formed by the base sheet and the anodes, and a current supply device configured to supply a current to the conduct rolls and the anodes to cause electro-precipitation of the metal ions on one or both sides of the base sheet; and
a stripping device configured to strip metal foil electro-deposited on one or both sides of the base sheet from the base sheet.

**2.** The horizontal electroforming apparatus of claim 1, wherein the electrolyte supply device comprises an electrolyte supply nozzle configured to supply an electrolyte to one or both sides of the base sheet in the same direction as a moving direction of the base sheet, a direction opposite to the moving direction of the base sheet, or both directions.

**3.** The horizontal electroforming apparatus of claim 1, wherein a plurality of horizontal cells are provided, and the plurality of horizontal cells are arranged linearly, in a moving direction of the base sheet.

**4.** The horizontal electroforming apparatus of claim 1, further comprising a heat treatment device configured to perform a heat treatment such as induction heating, atmosphere heating, or direct heating on the metal foil electro-deposited on the base.

**5.** The horizontal electroforming apparatus of claim 1, wherein the stripping device comprises a plurality of rollers capable of causing a difference in shear force between the base sheet and the metal foil.

**6.** The horizontal electroforming apparatus of claim 1, wherein each of the anodes has a thickness decreasing from a center to edges thereof in a width direction of the base sheet.

**7.** The horizontal electroforming apparatus of claim 1, wherein an edge mask is disposed in the horizontal cell to prevent electro-precipitation of metal ions on the lateral edges of the base sheet.

**8.** The horizontal electroforming apparatus of claim 1, wherein each of the anodes is divided into a plurality of sub electrodes in a width direction of the base sheet.

**9.** The horizontal electroforming apparatus of claim 8, wherein the sub electrodes have different sizes.

**10.** The horizontal electroforming apparatus of claim 9, wherein different currents are supplied to the sub electrodes.

**11.** The horizontal electroforming apparatus of claim 1, wherein each of the anodes is divided into a plurality of sub electrodes in a moving direction of the base sheet.

**12.** The horizontal electroforming apparatus of claim 11, wherein the sub electrodes have different sizes.

**13.** The horizontal electroforming apparatus of claim 12, wherein different currents are supplied to the sub electrodes.

**14.** The horizontal electroforming apparatus of claim 3, wherein the electrolyte supply nozzle is inclined or curved to supply an electrolyte in a electrolyte-flow direction.

**15.** The horizontal electroforming apparatus of claim 14, wherein at least an end portion of the electrolyte supply pipe is separable, to supply an electrolyte in forward and backward directions relative to the moving direction of the base sheet.

**16.** The horizontal electroforming apparatus of claim 14, wherein the end portion has a sectional shape similar to the shape of a de Laval nozzle.

**17.** A method for manufacturing metal foil, the method comprising:

supplying an electrolyte containing metal ions to a surface of a flexible and conductive base

sheet which functions as a cathode and is horizontally fed in one direction;
forming an electro-deposition layer on one or both sides of the base sheet through electro-precipitation of the metal ions of the electrolyte on one or both sides of the base sheet, the electro-precipitation of the metal ions being caused by the base sheet and anodes spaced apart from one or both sides of the base sheet; and
stripping the electro-deposition layer from the base sheet as metal foil.

**18.** The method of claim 17, wherein one or both sides of the base sheet are coated with oxide films.

**19.** The method of claim 17, wherein the stripped metal foil is heat-treated at 300°C to 600°C.

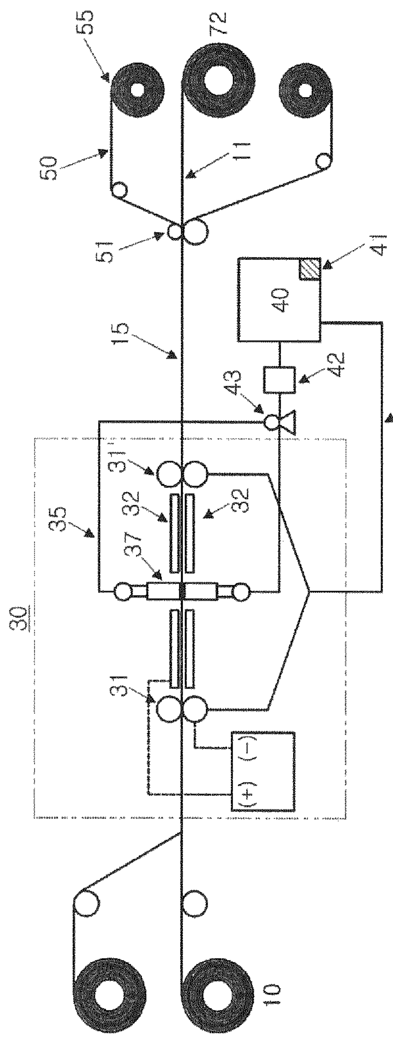
**20.** The method of claim 17, wherein the electrolyte is supplied to a horizontal passage formed between the base sheet and the anodes in the same direction as a moving direction of the base sheet and a direction opposite to the moving direction of the base sheet.

**21.** The method of claim 17, wherein different electrolytes are supplied to both the sides of the base sheet.

**22.** The method of claim 17, wherein prior to the stripping of the electro-deposition layer, the method further comprises: secondarily supplying an electrolyte; and secondarily forming an electro-deposition layer.

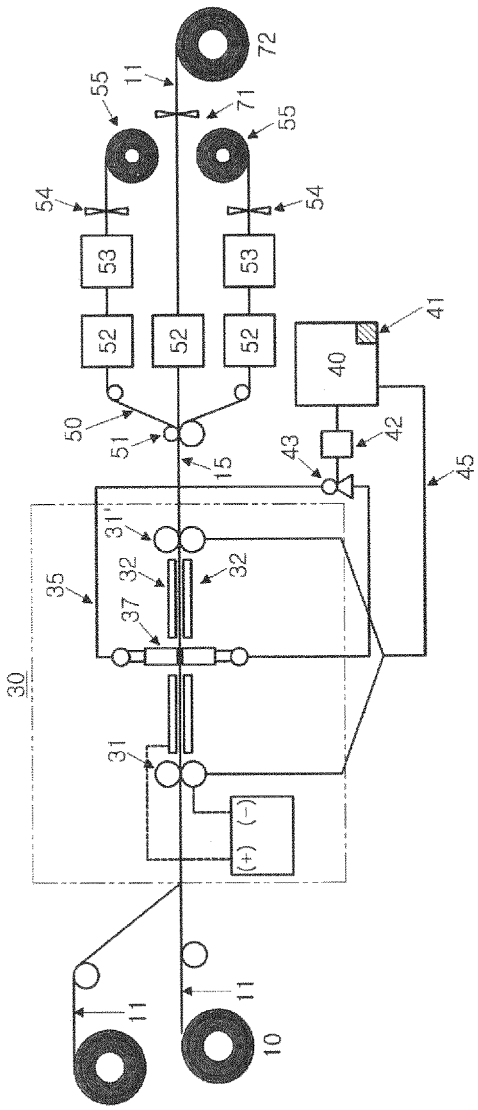
**23.** The method of claim 22, wherein different electrolytes are supplied in the supplying of the electrolyte and the secondary supplying of the electrolyte.

**24.** The method of claim 23, wherein the metal foil has a multi-layer structure.




100

FIG. 1


72
11
55
71
55
54
54
53
53
52
52
52
41
40
50
51
15
43
42
45
30
31'
32
32
35
37
31
(+)
(-)
11
11
10

100

FIG. 2

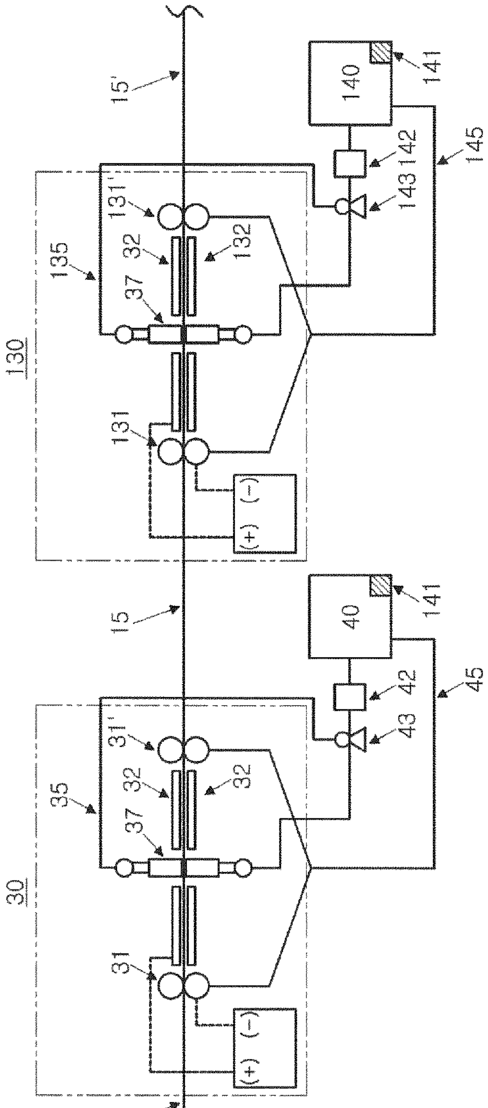

15'
140
141
142
143
145
130
135
131'
32
132
37
131
(+) (-)
15
40
141
42
43
45
30
35
31'
32
32
37
31
(+) (-)
11

FIG. 3

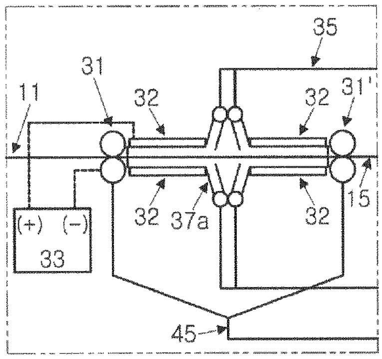



FIG. 4

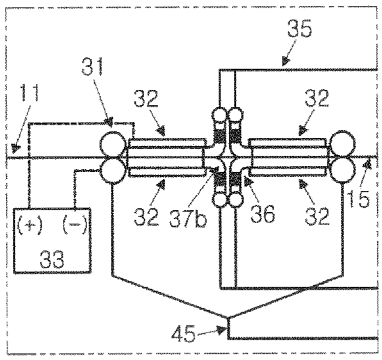



FIG. 5

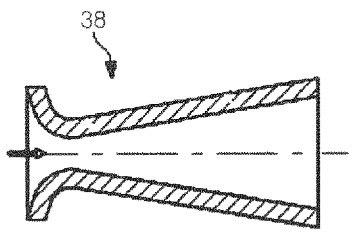



FIG. 6

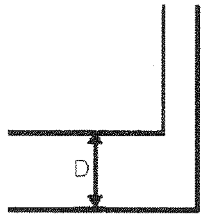



FIG. 7A

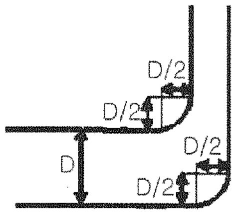



FIG. 7B

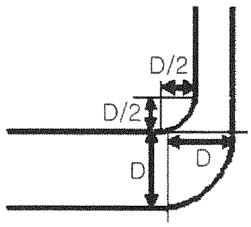



FIG. 7C

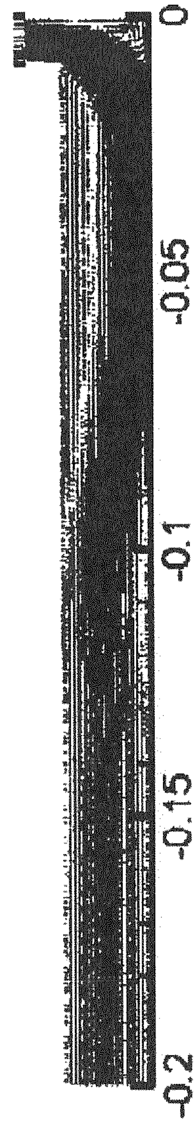



FIG. 8A

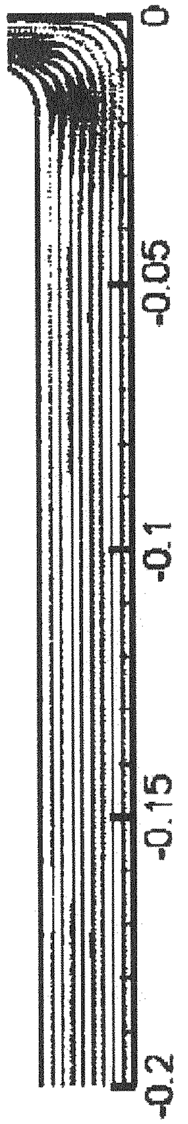



FIG. 8B

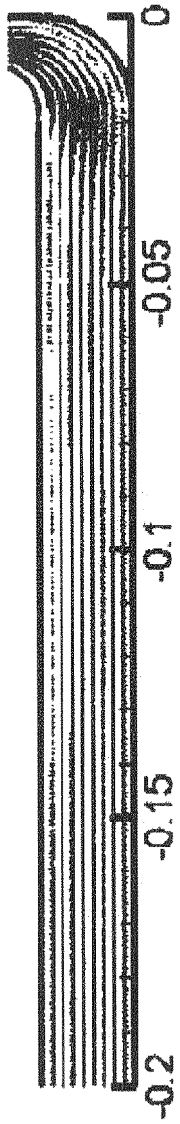



FIG. 8C

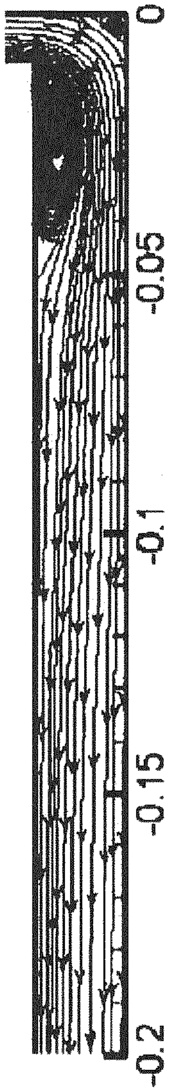



FIG. 9A

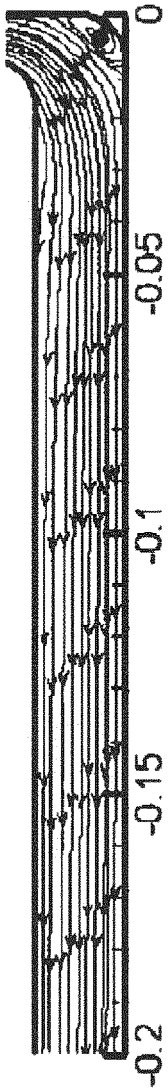



FIG. 9B

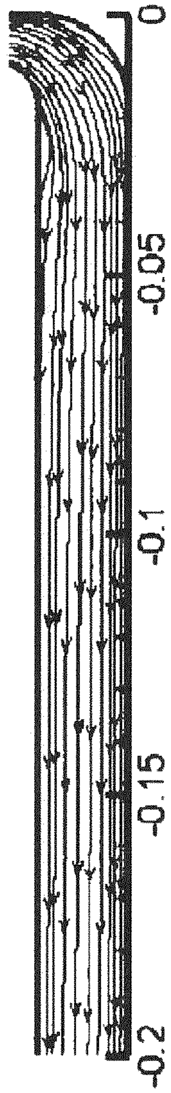



FIG. 9C

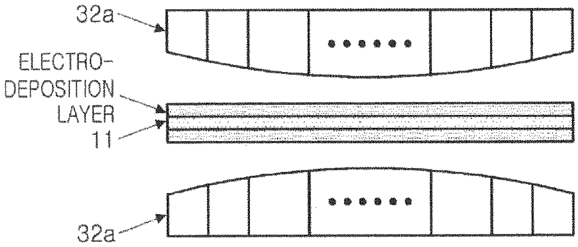

32a
ELECTRO-
DEPOSITION
LAYER
11
32a

FIG. 10

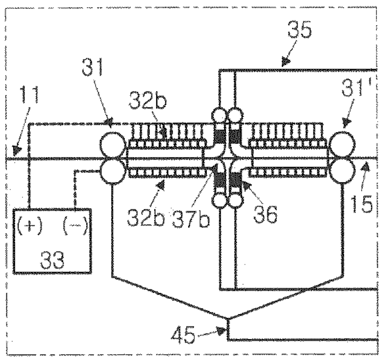

35
31
11
32b
31'
15
(+)
(-)
33
32b
37b
36
45

FIG. 11

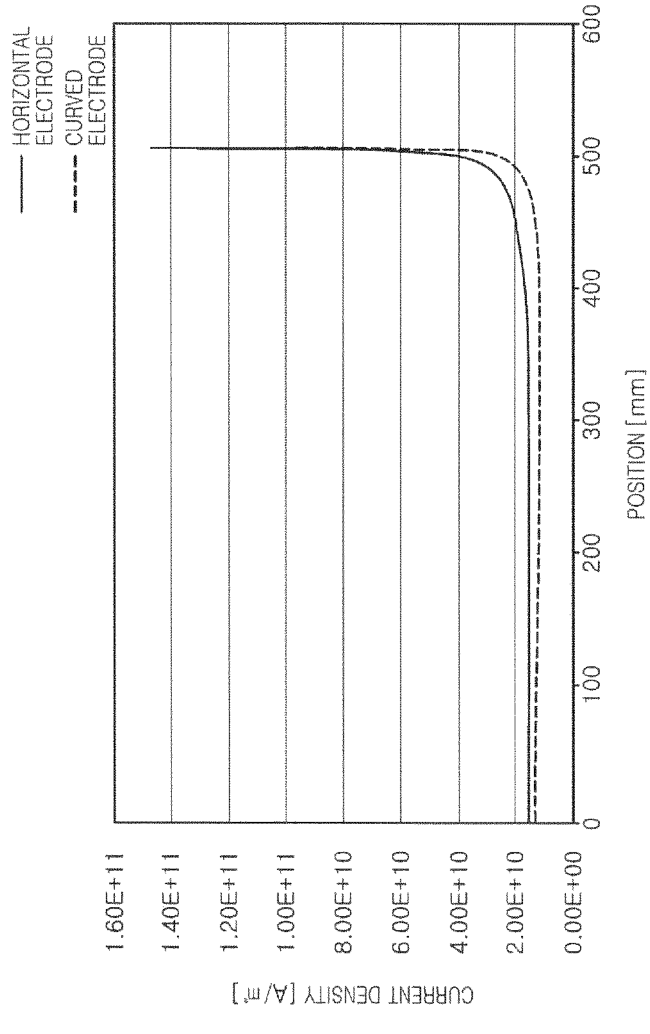

HORIZONTAL ELECTRODE
CURVED ELECTRODE
CURRENT DENSITY [A/㎡]
1.60E+11
1.40E+11
1.20E+11
1.00E+11
8.00E+10
6.00E+10
4.00E+10
2.00E+10
0.00E+00
0
100
200
300
400
500
600
POSITION [mm]

FIG. 12

## INTERNATIONAL SEARCH REPORT

International application No.
**PCT/KR2012/009684**

A. CLASSIFICATION OF SUBJECT MATTER

***C25D 1/04(2006.01)i, C25D 1/20(2006.01)i, C25D 17/00(2006.01)i, C25D 21/12(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)
C25D 1/04; C25D 7/06; B01D 35/00; C25D 3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: cathode, seedbed, split electrode, horizontal cell, electrolyte, electroforming apparatus

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y<br>A | JP 2000-109993 A (SUMITOMO SPECIAL METALS CO LTD et al.) 18 April 2000<br>See abstract, paragraphs 0028,0038,0045, figure 1 | 1-9,11-12,17-20<br>10,13-16,21-24 |
| Y<br>A | JP 06-073595 A (NKK CORP) 15 March 1994<br>See paragraphs 0002,0008,0011, figure 1 | 1-9,11-12,17-20<br>10,13-16,21-24 |
| Y | KR 10-2010-0049357 A (POSCO) 12 May 2010<br>See figures 1,2 | 7 |
| Y | KR 10-0428576 B1 (POSCO) 28 April 2004<br>See claim 1, figures 4,7 | 6,8,9,11,12 |

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 27 MARCH 2013 (27.03.2013) | **29 MARCH 2013 (29.03.2013)** |

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**INTERNATIONAL SEARCH REPORT**
Information on patent family members

International application No.
**PCT/KR2012/009684**

| Patent document cited in search report | Publication date | Patent family member | Publication date |
|---|---|---|---|
| JP 2000-109993 A | 18.04.2000 | JP 03-076565 B2<br>JP 3076565 B2 | 09.06.2000<br>14.08.2000 |
| JP 06-073595 A | 15.03.1994 | NONE | |
| KR 10-2010-0049357 A | 12.05.2010 | NONE | |
| KR 10-0428576 B1 | 28.04.2004 | NONE | |

Form PCT/ISA/210 (patent family annex) (July 2009)

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- US 4948434 A **[0003]**
- KR 19990064747 **[0004]**
- KR 20040099972 **[0004]**