

APPARATUS FOR REGENERATING AN ETCHANT AND RECOVERING A METAL FROM THE ETCHANT AND A METHOD THEREOF

Field of Invention

[0001] The present invention relates to an apparatus for regenerating an etchant and recovering a metal from the etchant and a method thereof.

Background

[0002] Conventionally, metal stripping or etching is carried out using large amounts of chemicals to remove metals from the substrates. Substrates are soaked into stripper baths with chemical with high level of Oxidation Reduction Potential (ORP). A high ORP enables effective stripping of the metals from the substrate. However, as the stripping takes place, the ORP of the electrolyte decreases. When the ORP decreases to a level which the stripping is no longer efficient, the chemicals in the stripper bath are replaced. Large amounts of spent stripper baths are generated which adds to cost of waste treatment and also logistic issues. Hazardous materials that are not properly treated may create environmental and disposal problems.

[0003] A typical solution to the problem includes electrolytic stripping. This is accomplished by allowing the substrate with a metal coating to be the anode in an electrolysis cell with an electrolyte, and brass or stainless steel or other materials as the cathode. This allows reduction in chemical usage. However, the attack on the substrate is high as current supplied will oxidize substrate besides stripping metal and addition of inhibitor is necessary although not necessary effective. Moreover, the stripping is non-uniform as it is very much dependent on the distance between the anode and the cathode. Other solutions typically involve the use of expensive ion-exchange membranes in the electrolytic cell and such membranes are prone to clogging and worn-off, in electrolytic cells, and the use of electrolytic cells that focus on either regenerating stripping/etching solution or metal recovery efficiency but not both.

[0004] Therefore, it is necessary to come up with a cost-effective metal stripping/extraction treatment method. In addition, it would be an added benefit if the metal stripped in chemicals can be readily recovered as metal values, resulting in minimizing metal value loss.

Summary

[0005] According to various embodiments, the present invention provides an apparatus for regenerating an etchant and recovering a metal from the etchant. The apparatus includes an electrolytic cell having a first compartment and a second compartment separated from the first compartment via a permeable divider, such that the second compartment is in fluid communication with the first compartment through the divider, such that each of the first compartment and the second compartment are adapted to contain the etchant having an etchant level, such that, when the apparatus is in operation, the etchant level in the first compartment is maintained at a higher or lower level than the etchant level in the second compartment. The apparatus further includes a cathode and an anode disposed in the first compartment and the second compartment respectively, such that the cathode and the anode are electrically connectable to a first electrical source, and a stripping tank adapted to contain a substrate having a metal coating and the etchant adapted to remove the metal coating from the substrate, such that the stripping tank is in fluid communication with the first compartment and the second compartment, such that the stripping tank is adapted to channel the etchant to the first compartment and second compartment and is adapted to receive the etchant from the second compartment.

[0006] By maintaining different etchant levels in the respective compartments, a pressure head is created between the compartments to allow the flow of etchant from the compartment with the higher etchant level to the one with a lower etchant level. Together with the varying of current density across the electrodes, the apparatus may be used to segregate the ions in the etchant and improve the performance of the etchant.

[0007] According to various embodiments, the permeable divider may include a buffer compartment having a first permeable wall and a second permeable wall opposite the first permeable wall, such that the buffer compartment may be in fluid communication with the first compartment via the first permeable wall and may be in fluid communication with the second compartment via the second permeable wall, such that the buffer compartment may be in fluid communication with the stripping tank, such that the buffer compartment may be adapted to receive the etchant from the stripping tank so as to channel the etchant to the first compartment and second compartment, and such that the buffer compartment contains the etchant having an etchant level such that the etchant level may be maintained at a higher level than the etchant levels of the first compartment and the second compartment.

[0008] The buffer compartment may be adapted to buffer the flow of the etchant into the electrolytic cell so that the incoming etchant would not mix with the etchant in the first compartment and the second compartment and affect the ORP in each compartment. In addition, the buffer compartment provides a holding effect for the apparatus such that the buffer compartment may be adapted to hold the etchant therein before being released into the first compartment and the second compartment. In this way, the flow rate of the etchant may be controlled, e.g. via the pressure gradient and/or the permeable walls without the use of valves.

[0009] According to various embodiments, the electrolytic cell may be disposed at a higher elevation than the stripping tank, such that the etchant in the second compartment, when overflows, flows into the stripping tank.

[0010] The overflow arrangement allows the flow of the etchant from one compartment to another under gravity influence and without mechanical assistance, e.g. a pump. Therefore, the overflow arrangement may save energy.

[0011] According to various embodiments, the apparatus may further include a supplementary electrolytic cell fluidly connected to the electrolytic cell. The supplementary electrolytic cell may include a proximal compartment and a distal compartment separated from the proximal compartment via a permeable divider, such that the proximal compartment may be in fluid communication with the distal compartment through the permeable divider, a supplementary cathode and a supplementary anode disposed in the proximal compartment and the distal compartment respectively, such that the supplementary cathode and the supplementary anode are connected to a second electrical source, such that the proximal compartment may be in fluid communication with the first compartment and the distal compartment may be in fluid communication with the second compartment and the stripping tank, such that the proximal compartment may be adapted to receive the etchant from the first compartment and adapted to channel the etchant to the first compartment, and the distal compartment may be adapted to receive the etchant from the second compartment and adapted to channel the etchant to the stripping tank.

[0012] By adding the supplementary cell to the apparatus, the supplementary cell may boost the performance of the etchant thus enhancing the regenerative and recovery properties of the apparatus. In addition, the supplement cell provides control to control the performance of the

etchant depending on the emphasis on either the stripping performance or metal recovery quality.

[0013] According to various embodiments, the electrolytic cell may be disposed at a higher elevation than the supplementary electrolytic cell and the supplementary electrolytic cell may be disposed at a higher elevation than the stripping tank, such that the etchant of the second compartment, when overflows, flows into the distal compartment and the etchant of the distal compartment, when overflows, flows into the stripping tank.

[0014] The overflow arrangement allows the flow of the etchant from one compartment to another under gravity influence and without mechanical assistance, e.g. a pump. Therefore, the overflow arrangement may save energy.

[0015] According to various embodiments, the proximal compartment and the distal compartment, each compartment may include the etchant having an etchant level, such that the etchant level of the proximal compartment may be higher or lower than the etchant level of the distal compartment.

[0016] According to various embodiments, the first electrical source may be adapted to generate a first magnitude of current and the second electrical source may be adapted to generate a second magnitude of current, such that the first magnitude of current may be higher or lower than the second magnitude of current.

[0017] According to various embodiments, the anode and/or supplementary anode may include an inert material which does not react with the etchant.

[0018] According to various embodiments, the permeable divider may be made from a hydrophobic material. In this way, the flow rate of the etchant may be controlled.

[0019] According to various embodiments, the permeable divider may be charged. In this way, the separation of the ions in the buffer compartment may be enhanced.

[0020] According to various embodiments, the present invention further provides a method for regenerating an etchant and recovering a metal from the etchant using the apparatus as present above. The method includes channelling the etchant from the stripping tank into the first compartment and the second compartment of the electrolytic cell, maintaining the etchant level in the first compartment at a higher or lower level than the etchant level in the

second compartment when the apparatus may be in operation, and channelling the etchant from the second compartment of the electrolytic cell into the stripping tank.

[0021] According to various embodiments, the method may further include channelling the etchant from the stripping tank into the buffer compartment so as to channel the etchant into the first compartment and the second compartment and maintaining the etchant level of the buffer compartment to be at a higher level than the etchant levels of the first compartment and the second compartment.

[0022] According to various embodiments, channelling from the second compartment into the stripping tank includes overflowing the etchant from the second compartment into the stripping tank.

[0023] According to various embodiments, the method may further include channelling the etchant from the first compartment into the proximal compartment, channelling the etchant from the second compartment into the distal compartment, channelling the etchant from proximal compartment to the first compartment, and channelling the etchant from the distal compartment into the stripping tank.

[0024] According to various embodiments, the channelling the etchant from the second compartment to the distal compartment includes overflowing the etchant from the second compartment to the distal compartment and such that channelling the etchant from the distal compartment to the stripping tank includes overflowing the etchant from the second compartment to the distal compartment.

[0025] According to various embodiments, the method may further include maintaining the etchant level of the proximal compartment at a higher or lower level than that of the distal compartment.

[0026] According to various embodiments, the method may further include varying the first magnitude of current to be higher or lower than the second magnitude of current.

[0027] The apparatus of the present invention may be used to regenerate the etchant and recover the metal from the etchant simultaneously. In addition, the apparatus may be used to maintain the desired ORP at the anode compartment and the cathode compartment so as to obtain the desired ORP for the regeneration and recovery process. The method provides a sustainable stripping of metal by continuously regenerating the oxidizing agent and without

the need to dump stripping bath regularly. The present invention is able to generate etchant in a closed loop process thereby resulting in zero waste and simultaneously recovery of the metal that has been stripped off.

[0028] Therefore, the present invention provides a cost-effective metal stripping/extraction apparatus and treatment method which enables an added benefit of recovering the metal stripped in chemicals as metal values, resulting in minimizing metal value loss. In addition, the reduction in the use of chemical reduces chemical hazards and improves the environment.

Brief Description of Drawings

[0029] Fig. 1 shows a schematic elevation view of an example of an apparatus for regenerating an etchant and recovering a metal from the etchant.

[0030] Fig. 2 shows a schematic elevation view of an example of the apparatus in Fig. 1.

[0031] Fig. 3 shows a method for regenerating the etchant and recovering a metal from the etchant using the apparatus in Fig. 1.

[0032] Fig. 4A shows a schematic view of an example of the apparatus having a supplementary electrolytic cell fluidly connected to the electrolytic cell.

[0033] Fig. 4B shows a schematic elevation view of the apparatus in Fig. 4A.

[0034] Fig. 4C shows a schematic elevation view of the apparatus in Fig. 4A with the electrolytic cell and the supplementary cell each having etchant with a pressure gradient.

[0035] Fig. 5A shows a schematic view of an example of the apparatus with the electrolytic cell having a supplementary cell.

[0036] Fig. 5B shows a schematic elevation view of the apparatus in Fig. 5A.

[0037] Fig. 5C shows a schematic elevation view of the apparatus in Fig. 5A with the electrolytic cell and the supplementary cell each adapted to have a pressure gradient between the compartments therein.

[0038] Fig. 6A shows a schematic elevation view of an example of the apparatus having a supplementary cell with a supplementary buffer compartment as the divider.

[0039] Fig. 6B shows a schematic elevation view of the apparatus in Fig. 6A.

[0040] Fig. 7A shows a schematic elevation view of an example of the apparatus.

[0041] Fig. 7B shows a schematic elevation view of the apparatus in Fig. 7A with each compartment having a pressure gradient.

[0042] Fig. 8 shows a schematic view of an example of the apparatus.

[0043] Fig. 9 shows a graph of a typical ORP measurements over time of the apparatus.

Detailed Description

[0044] Fig. 1 shows a schematic elevation view of an example of an apparatus 100 for regenerating an etchant 118 and recovering a metal 152 from the etchant 118. Apparatus 100 includes an electrolytic cell 110 having a first compartment 112 and a second compartment 114 separated from the first compartment 112 via a permeable divider 116 such that the second compartment 114 is in fluid communication with the first compartment 112 through the divider 116. Each of the first compartment 112 and the second compartment 114 are adapted to contain the etchant 118 having an etchant level 112E, 114E such that, when the apparatus 100 is in operation, the etchant level 112E in the first compartment 112 is maintained at a higher or lower level than the etchant level 114E in the second compartment 112, e.g. 1-10cm higher or lower. Apparatus 100 includes a cathode 122 and an anode 124 disposed in the first compartment 112 and the second compartment 114 respectively. Cathode 122 and the anode 124 are electrically connectable to a first electrical source (not shown in Fig. 1). Apparatus 100 further includes a stripping tank 160 adapted to contain a substrate 150 having a metal coating 152 and the etchant 118 is adapted to remove the metal coating 152 from the substrate 150. Stripping tank 160 is in fluid communication with the first compartment 112 and the second compartment 114 of the electrolytic cell 110. Stripping tank 160 is adapted to channel the etchant 118 to the first compartment 112 and the second compartment 114 and is adapted to receive the etchant 118 from the second compartment 114. Stripping tank 160 may be in fluid communication with the first compartment 112 or the second compartment 114.

[0045] Etchant 118 may be transferred between the stripping tank 160 and the electrolytic cell 110 with or without mechanical assistance, e.g. via a pump. Second compartment 114 may be connected to the stripping tank 160 via a supply conduit 115, e.g. a pipe. Etchant 118 may be pumped from the second compartment 114 using a pump (not shown in Fig. 1) along

the first conduit 115. Stripping tank 160 may be fluidly connected to the first compartment 112 and the second compartment 114 via a return conduit 113. Return conduit 113 may have one end 113A connected to the stripping tank 160 and another end 113B connected to the first compartment 112 and the second compartment 114. Apparatus 100 may include a valve system 117 adapted to control the flow of the etchant 118 into the first compartment 112 and/or the second compartment 114. Apparatus 100 may include a fluid pump 119 along the return conduit 113 such that the fluid pump 119 may be adapted to pump the etchant 118 from the stripping tank 160 into the first compartment 112 and the second compartment 114. Anode 124 may be made from an inert material which does not react with the etchant 118.

[0046] In the electrolytic cell 110, the permeable divider 116 may extend across the width of the electrolytic cell 110 and separates the first compartment 112 and the second compartment 114 completely. While the permeable divider 116 is adapted to allow fluid communication, the permeable divider 116 may be adapted to reduce fluid flow through it. Although the fluid flow is reduced, the etchant 118 may still be able to flow through the divider 116 thus allowing flow of charged ions in the etchant 118 to flow through the divider 116. In this way, the etchant levels 112E, 114E between the first compartment 112 and the second compartment 114 may be maintained at different levels by controlling the flow of the etchant 118 from the first compartment 112 to the second compartment 114 and amount of etchant 118 entering the respective compartments. For example, the etchant level 112E in the first compartment 112 can be maintained at a higher level than the etchant level 114E of the second compartment 114 to that there may be a pressure gradient between the etchant 118 in the first compartment 112 and the second compartment 114. Due to the pressure gradient, the etchant 118 in the electrolytic cell 110 may be adapted to flow from the first compartment 112 into the second compartment 114 through the divider 116 and may be prevented from back flowing from the second compartment 114 to the first compartment 112. The purpose for the pressure gradient between the first compartment 112 and the second compartment 114 will be explained later. Permeable divider 116 may be a membrane, a diaphragm, or equivalent. Divider 116 may be made of a hydrophobic material, e.g. polypropylene, polyester and TeflonTM.

[0047] When the apparatus 100 in Fig. 1 is in operation, the metal coating 152 on the substrate 150 may be stripped off by the etchant 118. The chemical composition and suitability of the etchant 118 for stripping the metal coating 152 would be commonly known in the art. During the stripping process, the ORP of the etchant 118 would decrease until a

level which the etchant 118 may be less effective in stripping the metal coating 152 from the substrate 150. Etchant 118 may then be channelled or pumped into the first compartment 112 and second compartment 114. In the first compartment 112, the cathode 122 reduces the metal in the etchant 118 and the metal may be deposited onto the cathode 122. In the second compartment 114, the anode 124, being made from an inert material, oxidises but does not react with the etchant 118. In this way, the anode 124 may increase the ORP of the etchant 118 and therefore regenerates the etchant 118. As the cathode 122 recovers the metal from the etchant 118, the anode 124 regenerates the etchant 118 simultaneously. The regenerated etchant 118 may then be transferred back to the stripping tank 160 for the stripping process to continue until the stripping is completed.

[0048] Referring to the electrolytic cell 110, the rate of the regeneration of the etchant 118 at the anode 124 and the recovery of the metal at the cathode 122 may be controlled by controlling the current across the anode 124 and the cathode 122. As a skilled person would understand, the increase in the current density would increase the attractive force on the ions in the etchant 118 and causes the positive and negative ions in the etchant 118 to flow towards the respective electrodes. In addition, the efficiency may be controlled by controlling the pressure gradient between the first compartment 112 and the second compartment 114. By increasing the pressure gradient, the etchant 118 may be forced to flow from the compartment with the higher pressure, e.g. the first compartment 112, to the compartment with the lower pressure, e.g. the second compartment 114. By forcing the etchant 118 to flow in one direction and controlling the flow of ions in the etchant 118 using the current density, the apparatus 100 may be used to segregate the ions, i.e. catholytes and anolytes, in the etchant 118 and preventing the catholytes and anolytes from mixing, maintaining them at their respective electrodes.

[0049] By preventing the mixture, the ORP of the etchant 118 may be controlled to be at the desired level at the respective compartments 112,114. By passing a current density, e.g. 1-20ASD, to the compartments 112,114 of the electrolytic cell 110, the ORP of the etchant 118 at the respective compartments 112,114 may be set apart, as the etchant 118 at the cathode 122 may become more and more electron rich, and therefore ORP decreases, and the etchant 118 at the anode 124 becomes more and more electron deficient, and ORP increases. By increasing the ORP of the etchant 118 in the compartment 114, the etchant 118 would be more effective in stripping the metal coating 152 when it is transferred into the stripping tank

160. Conversely, by decreasing the ORP of the etchant 118 at the cathode 122, the metal deposition and therefore the recovery efficiency of the metal at the cathode 122 may be increased. As it has shown, the apparatus 100 may be used to control the efficiency of the etchant regeneration and metal recovery by controlling the ORP of the etchant 118. In addition, the apparatus 100 may be used to control the ORP of the etchant 118 at the respective electrodes 122,124 in the same electrolytic cell 110. It is possible to configure the apparatus 100 to have the etchant level 114E of the second compartment 114 to be higher than the etchant level 112E of the first compartment 112.

[0050] Fig. 2 shows a schematic elevation view of an example of the apparatus 200. For easy reference, the features in apparatus 200 that are the same features in apparatus 100 would have the same last two digits in the reference numerals. For example, the electrolytic cell 110 in apparatus 100 would be the same as the electrolytic cell 210 in the apparatus 200. Further, it would be clear that the features and their configurations that are described above in the apparatus 100 would similarly be applicable to apparatus 200 and vice versa. In the apparatus 200 of Fig. 2, the permeable divider 116 may be a buffer compartment 220 having a first permeable wall 220F and a second permeable wall 220S opposite the first permeable wall 220F. Buffer compartment 220 is in fluid communication with the first compartment 212 via the first permeable wall 220F and is in fluid communication with the second compartment 214 via the second permeable wall 220S. Buffer compartment 220 may be in fluid communication with the stripping tank 260. Stripping tank 260 may be in fluid communication with the first compartment 212 and the second compartment 214 via the buffer compartment 220. Apparatus 200 may be adapted to channel the etchant 218 from the second compartment 214 into the stripping tank 260 and channel the etchant 218 from the stripping tank 260 into the buffer compartment 220. First permeable wall 220F and second permeable wall 220S may be charged to enhance the separation of the ions in the buffer compartment 220.

[0051] Buffer compartment 220 may be fluidly connected to the stripping tank 260 via the return conduit 213. Apparatus 200 may include the pump 219 along the return conduit 213 to pump the etchant 218 from the stripping tank 260 into the buffer compartment 220. Buffer compartment 220 may extend across the width of the electrolytic cell 210 from one wall of the electrolytic cell 210 to another thereby separating the electrolytic cell 210 into the first compartment 212, the second compartment 214 and the buffer compartment 220. First

compartment 212, the second compartment 214 and the buffer compartment 220 each has an etchant level 212E,214E,220E. As mentioned earlier, the first permeable wall 220F and the second permeable wall 220S may reduce the fluid flow across the respective walls 220F,220S so that the etchant levels 212E,214E,220E may be maintained at the desired levels when etchant 218 is channelled into the respective compartments 212,214,220. As shown above, the buffer compartment 220 may be adapted to buffer the flow of the etchant 218 into the electrolytic cell 210 so that the incoming etchant 218 would not mix with the etchant 218 in the first compartment 212 and the second compartment 214 and affect the ORP in each compartment. Buffer compartment 220 may provide a holding effect for the apparatus 200 such that the buffer compartment 220 may be adapted to hold the etchant 218 therein before being released into the first compartment 212 and the second compartment 214. In this way, the flow rate of the etchant 218 may be controlled, e.g. via the pressure gradient and/or the permeable walls 220F,220S, without the use of valves.

[0052] Referring to Fig. 2, the etchant level 220E in the buffer compartment 220 may be adapted to be maintained at a higher level than the etchant level 212E of the first compartment 212 and the etchant level 212E in the first compartment 212 may be adapted to be maintained at a higher level than the etchant level 214E of the second compartment 214. Accordingly, the buffer compartment 220 has the highest pressure head of the etchant 218, followed by the etchant 218 in the first compartment 212, and the second compartment 214. As the etchant level 212E of the first compartment 212 is higher than the etchant level 214E of the second compartment 214, the etchant 218 may flow from the first compartment 212 to the second compartment 214 across the buffer compartment 220 but not vice versa. While the first permeable wall 220F and the second permeable wall 220S reduces the etchant 218 flow through the walls 220F,220S, they allow ions in the etchant 218 to pass through them. This is beneficial for the electro-deposition of the metal on the cathode 222. First permeable wall 220F and the second permeable wall 220S may be a membrane, a diaphragm, or equivalent. First permeable wall 220F and the second permeable wall 220S may be made from a hydrophobic material, e.g. polypropylene, polyester and TeflonTM.

[0053] By controlling the flow rates into the buffer compartment 220, e.g. 10-90 litres/min, the etchant levels 212E,214E,220E may be controlled. Apparatus 200 may include a valve system (not shown in Fig. 1) to control the flow of etchant 218 into the stripping tank 260. First compartment 212 may include a release valve (not shown in Fig. 2) to release the

etchant 218 in the first compartment 212 to maintain the etchant level 212E in the first compartment 212.

[0054] Etchant level 214 may be controlled by locating an outlet at the desired height along the compartment wall of the compartments. As shown in Fig. 2, the electrolytic cell 210 may include a base 210B. Second compartment 214 may include an outlet 214A located at a pre-determined height from the base 210B. Supply conduit 215 may be fluidly connected to the second compartment 214 at the outlet 214A such that the etchant 218 in the second compartment 214 may flow out of the second compartment 214 via the outlet 214A and into the supply conduit 215 at the pre-determined height and thereby maintaining the etchant 218 in the second compartment 214 at the required etchant level 214E. While it is not shown, the first compartment 212 may include an outlet located at a pre-determined height from the base 210B of the electrolytic cell 210. Accordingly, the height of the outlet of the first compartment 212 may be higher than the outlet 214A of the second compartment 214 so as to maintain a higher etchant level 212E in the first compartment 212 than the second compartment 214.

[0055] It may be appreciated that the second compartment 214 with outlets, e.g. outlet 214A, provides an efficient way of maintaining the etchant level 214E in the second compartment 214. By allowing the etchant 218 to flow out of the second compartment 214 at the required height, it may no longer be necessary to include the valve system to control the etchant level 214E in the second compartment 214. In this way, there may be increase in the reliability of the apparatus 200, i.e. less components, and savings in terms of energy and operation costs may be gained.

[0056] Similar to the example in Fig. 1, the etchant 218 may be channelled from the stripping tank 260 after the stripping process into the buffer compartment 220. Etchant 218 may be directed into the buffer compartment 220 via the return conduit 213. Etchant 218 may be pumped into the buffer compartment 220 by the pump 219. At the electrolytic cell 210, the etchant 218 may flow from the buffer compartment 220 into the first compartment 212 and the second compartment 214 due to the pressure gradient between the compartments. Once the etchant 218 in the second compartment 214 reaches the desired etchant level 214E or the outlet 214A, the etchant 218 may flow out of the second compartment 214 via the supply conduit 215 into the stripping tank 260.

[0057] While it is shown that the buffer compartment 220 operates in a multi etchant level configuration, the buffer compartment 220 may be operated in a configuration where the etchant levels in the compartments, i.e. the first compartment 212, the second compartment 214 and the buffer compartment 220 may be uniform.

[0058] Similar to the example in Fig. 1, the buffer compartment 220 has the same function as the divider 116 such that the buffer compartment 220 segregates the etchant 218 into the catholytic and anodic portions. Etchant 218 from the stripping tank 260 after stripping the metal coating 252 from the substrate 250, the ORP of the etchant 218 may be low. The low ORP etchant 218 may be channelled into the buffer compartment 220. In the buffer compartment 220, the etchant 218 may flow into the first compartment 212 or the second compartment 214 due to the pressure gradient between the compartments and the etchant 218 in the first compartment 212 may flow into the second compartment 214 through the buffer compartment 220 due to the pressure gradient between the respective compartments. By having the buffer compartment 220 and a lower etchant level 214E in the second compartment 214, the apparatus 200 prevents the anodic portion of the etchant 218 from flowing through against the pressure gradient and into the first compartment 212 and increasing its ORP upon mixing. In addition, a current is passed into the anode 224 and cathode 222 to control the attractive forces of the electrodes 222,224. The ORPs can be controlled in such a way that anodic portion of the etchant 218 may have a much higher ORP (oxidizing) than that of the catholytic portion of the etchant 218 (reducing). In this way, the ORP and therefore the stripping efficiency of the anodic portion of etchant 218 is increased while the ORP in the catholytic portion of the etchant 218 decreases thus provides an environment for reduction of metal ions to metals. As such, when the etchant 218 is transferred from the second compartment 214 into the stripping tank 260, the etchant 218 may be regenerated for stripping the metal coating 252 off the substrate 250.

[0059] The design of the apparatus 200 and the method of maintaining high ORP of etchant 216 by using three compartments configuration, i.e. the buffer compartment 220, the first compartment 212 and the second compartment 214, separated by a hydrophobic material, e.g. polypropylene or other hydrophobic materials, may allow a high current/volume ratio, e.g. 20-30 A/litre, at one electrode and a lower current/volume density at the other electrode of opposite polarity, while preventing mixing of catholytes with anolytes which will render ineffective functioning of the etchant 218. As a result, the use of expensive and short lifespan

membranes to maintain ORP of anode and cathode solutions is not necessary. In addition, it is possible to control the ORP of the etchant 218 by varying the concentration of compositions, temperature, agitation and current density.

[0060] Referring to Fig. 2, the electrolytic cell 210 may be disposed at a higher elevation than the stripping tank 260 such that the etchant 218 in the second compartment 214, when overflows, may flow into the stripping tank 260. As shown in Fig. 2, the stripping tank 260 may have an etchant level 260E. For the overflow to happen, the etchant level 214E may be higher than the etchant level 260E. As the etchant 218 in the second compartment 214 overflows at the pre-determined height, the etchant level 214E may be maintained at the desired height. In addition, the overflow arrangement between the stripping tank 260 and the second compartment 214 allows the flow of the etchant 218 from the second compartment 214 to the stripping tank 260 under gravity influence and without mechanical assistance, e.g. a pump. Therefore, the overflow arrangement may save energy.

[0061] Fig. 3 shows a method 1000 for regenerating the etchant 118 and recovering a metal from the etchant 118 using the apparatus 100. Method 1000 includes channelling the etchant 118 from the stripping tank 160 into the first compartment 112 and the second compartment 114 of the electrolytic cell 110 in 1010, maintaining the etchant level 112E in the first compartment 112 at a higher or lower level than the etchant level 114E in the second compartment 114 when the apparatus 100 is in operation in 1020, and channelling the etchant 118 from the second compartment 114 of the electrolytic cell 110 into the stripping tank 160 in 1030. Etchant 118 may be channelled from the stripping tank 160 into the first compartment 112 or the second compartment 114.

[0062] Fig. 4A shows a schematic view of an example of the apparatus 400 having a supplementary electrolytic cell 470 fluidly connected to the electrolytic cell 410. Supplementary cell 470 may be fluidly connected to any one of the examples shown in Fig. 1 and 2. Supplementary cell 470 may include a proximal compartment 472 and a distal compartment 474 separated from the proximal compartment 472 via a permeable divider 476, wherein the proximal compartment 472 is in fluid communication with the distal compartment 474 through the permeable divider 476. Supplementary cell 470 may include a cathode 482 and a supplementary anode 484 disposed in the proximal compartment 472 and the distal compartment 474 respectively. Supplementary cathode 482 and the supplementary

anode 484 may be connected to a second electrical source (not shown in Fig. 4). Proximal compartment 472 may be in fluid communication with the first compartment 412 and the distal compartment 474 may be in fluid communication with the second compartment 414 and the stripping tank 460 such that the proximal compartment 472 is adapted to receive the etchant 418 from the first compartment 412 and adapted to channel the etchant 418 to the first compartment 412 and the distal compartment 474 may be adapted to receive the etchant 418 from the second compartment 414 and adapted to channel the etchant 418 to the stripping tank 460.

[0063] Supplementary cell 470 may have the same configuration as the electrolytic cell 110 in Fig. 1. Etchant 418 may be transferred between the supplementary cell 470 and the stripping tank 460 and the electrolytic cell 410 via conduits. The transfer may be performed with or without mechanical assistance, e.g. via a pump. First compartment 412 may be fluidly connected to the proximal compartment 472 via first conduit 415A. Second compartment 414 may be connected to the distal compartment 474 of the supplementary cell 470 via a second supply conduit 415B. Distal compartment 474 may be fluidly connected to the stripping tank 460 via a third supply conduit 415C. Proximal compartment 472 may be fluidly connected to first compartment 412 via a first return conduit 413X, stripping tank 460 may be fluidly connected to the first compartment 412 via a second return conduit 413Y. Second return conduit 413Y may have one end 413YA connected to the stripping tank 460 and another end 413YB connected to the first compartment 412 and the second compartment 414. Apparatus 400 may include a valve system 417 adapted to control the flow of the etchant 418 into the first compartment 412 and/or the second compartment 414. Apparatus 400 may include a first fluid pump 419A along the first return conduit 413X such that the first fluid pump 419A may be adapted to pump the etchant 418 from the proximal compartment 472 into the first compartment 412. Apparatus 400 may include a second fluid pump 419B along the second return conduit 413Y such that the second fluid pump 419B may be adapted to pump the etchant 418 from the stripping tank 460 into the first compartment 412 and/or the second compartment 414. Supplementary anode 424 may be made from an inert material which does not react with the etchant 418.

[0064] When the apparatus 400 in Fig. 4A is in operation, the metal coating 452 on the substrate 450 (refer to Fig. 4B) may be stripped off by the etchant 418. During the stripping process, the ORP of the etchant 418 would decrease until a level which the etchant 418 may

no longer be effective in stripping the metal coating 452 from the substrate 450. Etchant 418 may then be channelled or pumped into the first compartment 412 and the second compartment 414. In the first compartment 412, the cathode 422 reduces the metal in the etchant 418 and the metal may be deposited onto the cathode 422. In the second compartment 414, the anode 424, being made from an inert material, oxidises but does not react with the etchant 418. In this way, the anode 424 may increase the ORP of the etchant 418 and therefore regenerates the etchant 418. As the cathode 422 recovers the metal from the etchant 418, the anode 424 regenerates the etchant 418 simultaneously.

[0065] Fig. 4B shows a schematic elevation view of the apparatus 400 in Fig. 4A. Electrolytic cell 410, as explained in Fig. 1, may be adapted to increase the ORP of the anodic portion of the etchant 418 and decrease the ORP of the catholytic portion of the etchant 418. In this way, the etchant 418 may be regenerate for the stripping tank 460 and the recovery of the metal from the etchant 418 may be improved.

[0066] Unlike the embodiment in Fig. 1, the etchant 418 in the first compartment 412 may be transferred into the proximal compartment 472 of the supplementary cell 470 and the etchant 418 in the second compartment 414 may be transferred into the distal compartment 474. At this stage, the supplementary cell 470 acts like booster to boost the ORP of the respective portions of the etchant 418, i.e. increases the ORP of the anodic portion of the etchant 418 and decreases the ORP of the catholytic portion of the etchant 418. When the etchant 418 enters the proximal compartment 472 of the supplementary cell 470, the supplementary cathode 482 of the supplementary cell 470 may further decrease the ORP of the etchant 418 in the proximal compartment 472. Concurrently, when the etchant 418 enters the distal compartment 474 of the supplementary cell 470, the supplementary anode 484 may further increase the ORP of the etchant 418 in the distal compartment 474. Similarly, the divider 476 are adapted to segregate the anolytes and catholytes from each other, preventing them from mixing together thereby decreasing the magnitude of the respective ORPs. The ORP of the etchant 418 in the proximal compartment 472 and the distal compartment 474 may be controlled by at least one of the following: current density, pH and conductivity of the etchant 418. In the scenario that the supplementary cell 470 is used as a booster, the regenerated etchant 418, after being boosted, may be channelled from the distal compartment 474 into the stripping tank 460 for the stripping process to continue until the stripping is completed. Etchant 418 in the proximal compartment 472 may be channelled back to the first

compartment 412. As shown, the etchant 418 may be recycled back into the first compartment 412. After a few cycles, the ORP of the etchant 418 in the first compartment 412 and the proximal compartment 472 may be in equilibrium or substantially the same.

[0067] As shown in Fig. 4B, the electrolytic cell 410 may have a uniform etchant level in the first compartment 412 and second compartment 414. In such a configuration, the segregation of the catholyte and anolyte in the etchant 418 may be controlled by the current density and the divider 476.

[0068] Conversely, by controlling the current density of the supplementary cell 470, it is possible to perform the opposite effects of a booster. It is possible to decrease the ORP of the anodic portion of the etchant 418 and increase the ORP of the catholytic portion of the etchant 418. As such, it would be clear that the supplementary cell 470 may be used as an additional control to control the ORP of the etchant 418 depending on the emphasis on either the stripping performance or metal recovery quality.

[0069] Fig. 4C shows a schematic elevation view of the apparatus 400 in Fig. 4A with the electrolytic cell 410 and the supplementary cell 470 each having etchant 418 with a pressure gradient. While it is shown in Fig. 4B that the supplementary cell 470 may be configured to have a uniform etchant level within the supplementary cell 470, where the etchant levels 472E, 474E may be the same for both the proximal compartment 472 and distal compartment 474, the apparatus 400 may have a pressure gradient between the proximal compartment 472 and distal compartment 474. As explained earlier in Fig. 1, as the etchant level 472E of the proximal compartment 472 is higher than the etchant level 474E of the distal compartment 474, the etchant 418 may flow from the proximal compartment 472 to the distal compartment 474 across the divider 476 but not vice versa. Etchant level 472E of the proximal compartment 472 may be lower than the etchant level 474E of the distal compartment 474. Therefore, the ORP of the etchant 418 in the respective compartments 472, 474 in the supplementary cell 470 may be controlled by controlling at least one of the following: pressure gradient, current density, pH or conductivity of the etchant 418.

[0070] Fig. 5A shows a schematic view of an example of the apparatus 500 with the electrolytic cell 510 having a supplementary cell 570. As shown in Fig. 5A, the apparatus 500 may include the electrolytic cell 510 having a first compartment 512, a second compartment 514 and a buffer compartment 520 separating the first compartment 512 and the second

compartment 514. Buffer compartment 520 may include a first permeable wall 520F and a second permeable wall 520S opposite the first permeable wall 520F. Apparatus 500 may include the supplementary cell 570 in fluid communication with the electrolytic cell 510 and the stripping tank 560. Supplementary cell 570 may include the proximal compartment 572 and a distal compartment 574 separated from the proximal compartment 572 via a permeable divider 576, such that the proximal compartment 572 is in fluid communication with the distal compartment 574 through the permeable divider 576. Supplementary cell 570 may include a supplementary cathode 582 and a supplementary anode 584 disposed in the proximal compartment 572 and the distal compartment 574 respectively. Supplementary cathode 582 and the supplementary anode 584 may be connected to a second electrical source (not shown in Fig. 5A). Buffer compartment 520 may be in fluid communication with the first compartment 512 via the first permeable wall 520F and may be in fluid communication with the second compartment 514 via the second permeable wall 520S. Buffer compartment 520 may be in fluid communication with the stripping tank 560. Stripping tank 560 may be in fluid communication with the first compartment 512 and the second compartment 514 via the buffer compartment 520. Proximal compartment 572 may be in fluid communication with the first compartment 512 and the distal compartment 574 may be in fluid communication with the second compartment 514 and the stripping tank 560. Proximal compartment 572 may be adapted to receive the etchant 518 from the first compartment 512 and adapted to channel the etchant 518 to the first compartment 512 and the distal compartment 574 may be adapted to receive the etchant 518 from the second compartment 514 and adapted to channel the etchant 518 to the stripping tank 560. Stripping tank 560 may be adapted to channel the etchant 518 from the stripping tank 560 into the buffer compartment 520.

[0071] Fig. 5B shows a schematic elevation view of the apparatus 500 in Fig. 5A. As shown in Fig. 5B, the etchant levels 512E, 514E, 520E within the electrolytic cell 510 may be the same throughout the first compartment 512, the second compartment 514 and the buffer compartment 520. Further, the etchant levels 572E, 574E within the supplementary cell 570 may be the same throughout the proximal compartment 572 and the distal compartment 574. As shown in Fig. 5B, the arrangement of the apparatus 500 is similar to the apparatus 100 in Fig. 1. The main difference is that the etchant levels 512E, 514E in the electrolytic cell 510 in apparatus 500 is the same throughout the first compartment 512, the second compartment 514 and the buffer compartment 520. In addition, the apparatus 500 in Fig. 5B includes the

supplementary cell 570 fluidly connected to and between the electrolytic cell 510 and the stripping tank 560. It is possible to maintain the etchant levels 512E,514E,520E within each of the compartments 512,514,520 in the electrolytic cell 510 to be different like the apparatus 200 in Fig. 2. It is also possible to maintain the etchant level 572E,574E within each of the compartments 572,574 in the supplementary cell 570 to be different like the apparatus 400 in Fig. 4C.

[0072] As explained, the buffer compartment 520 may provide the effect of holding the etchant 518 before distributing it to the first compartment 512 and the second compartment 514. This would have the benefit of controlling the inflow of the etchant 518 without the use of a valve system.

[0073] Fig. 5C shows a schematic elevation view of the apparatus 500 in Fig. 5A with the electrolytic cell 510 and the supplementary cell 570 each adapted to have a pressure gradient between the compartments therein. As shown in Fig. 5C, the etchant level 520E in the buffer compartment 520 may be adapted to be maintained at a higher level than the etchant level 512E of the first compartment 512 and the etchant level 514E in the second compartment 514. Etchant level 512E in the first compartment 512 may be adapted to be maintained at a higher level than the etchant level 514E of the second compartment 514. Accordingly, the buffer compartment 520 has the highest pressure head of the etchant 518, followed by the etchant 518 in the first compartment 512, and the second compartment 514. As the etchant level 512E of the first compartment 512 is higher than the etchant level 514E of the second compartment 514, the etchant 518 may flow from the first compartment 512 to the second compartment 514 across the buffer compartment 520 but not vice versa. Etchant level 572E of the proximal compartment 572 may be higher than the etchant level 574E of the distal compartment 574. As a result, the etchant 518 may flow from the proximal compartment 572 to the distal compartment 574 across the divider 576 but not vice versa.

[0074] Although Fig. 5C shows both the electrolytic cell 510 and the supplementary cell 570 having the pressure gradient, it is clear that the apparatus 500 can be arranged to have only one of the electrolytic cell 510 and the supplementary cell 570 to have the pressure gradient.

[0075] Fig. 6A shows a schematic elevation view of an example of the apparatus 600 having a supplementary cell 670 with a supplementary buffer compartment 620B as the divider. As shown in Fig. 6A, the apparatus 600 may include the supplementary cell 670 having a

proximal compartment 672, a distal compartment 674 and a supplementary buffer compartment 620B separating the proximal compartment 672 and the distal compartment 674 such that the proximal compartment 672 may be in fluid communication with the distal compartment 674 through the supplementary buffer compartment 620B. Buffer compartment 620B may include a first permeable wall 620BF and a second permeable wall 620BS opposite the first permeable wall 620BF. Supplementary buffer compartment 620B may be in fluid communication with the proximal compartment 672 via the first permeable wall 620BF and may be in fluid communication with the distal compartment 674 via the second permeable wall 620BS. Supplementary cell 670 may be in fluid communication with the electrolytic cell 610 and the stripping tank 660. Supplementary cell 670 may include a supplementary cathode 682 and a supplementary anode 684 disposed in the proximal compartment 672 and the distal compartment 674 respectively. Supplementary cathode 682 and the supplementary anode 684 may be connected to the second electrical source (not shown in Fig. 6A). Proximal compartment 672 may be in fluid communication with the first compartment 612 and the distal compartment 674 may be in fluid communication with the second compartment 614 and the stripping tank 660. Buffer compartment 620 may be in fluid communication with the supplementary buffer compartment 620B and the stripping tank 660. Stripping tank 660 may be in fluid communication with the first compartment 612 and the second compartment 614 via the buffer compartment 620. Proximal compartment 672 may be adapted to receive the etchant 618 from the first compartment 612 and adapted to channel the etchant 618 back to the first compartment 612 and the distal compartment 674 may be adapted to receive the etchant 618 from the second compartment 614 and adapted to channel the etchant 618 to the stripping tank 660. Supplementary buffer compartment 620B may be adapted to receive the etchant 618 from the buffer compartment 620 and channel the etchant 618 back to the buffer compartment 620. Stripping tank 660 may be adapted to channel the etchant 618 from the stripping tank 660 into the buffer compartment 620. Etchant 618 may be channelled between the compartments 612,614,672,674 and the stripping tank 660 with mechanical assistance, e.g. via a pump.

[0076] As shown in Fig. 6A, the apparatus 600 may include an anodic loop 692 comprising the second compartment 614, the distal compartment 674 and the stripping tank 660 where the anodic portion of the etchant 618 may flow through each compartment and back to the second compartment 614. Similarly, the apparatus 600 may include a catholytic loop 694

comprising the first compartment 612, the proximal compartment 672 and the stripping tank 660 where the catholytic portion of the etchant 618 may flow through each compartment and back to the first compartment 612. Apparatus 600 may include the mixed loop 696 comprising the buffer compartment 620 and the supplementary buffer compartment 620B where the etchant 618 may flow from the buffer compartment 620 into the supplementary buffer compartment 620B and back to the buffer compartment 620 again.

[0077] Fig. 6B shows a schematic elevation view of the apparatus 600 in Fig. 6A. As shown in Fig. 6B, the electrolytic cell 610 and the supplementary cell 670 may each be configured to have the pressure gradient therein. As explained earlier, it may be possible for one or both the electrolytic cell 610 and the supplementary cell 670 of the apparatus 600 to each have a uniform etchant level through the compartments in the respective cells. While the flow of the etchant 618 through the electrolytic cell 610 and the supplementary cell 670 have been explained earlier, the mixed loop 696 of Fig. 6A and Fig. 6B may be further explained. As shown in Fig. 6A, the etchant 618 in the buffer compartment 620 may be channelled into the supplementary buffer compartment 620B in the supplementary cell 670 and back again. In this way, the ORP of the etchant 618 between the buffer compartment 620 and supplementary buffer compartment 620B in the mixed loop 696 may be close to equilibrium. It would be clear to a skilled person that the arrangement of the apparatus 600 is a combination of the features as described in the earlier examples. Therefore, it would be understood that the description for the respective features would be relevant to respective components the apparatus 600 and may be incorporated accordingly.

[0078] Fig. 7A shows a schematic elevation view of an example of the apparatus 700. Apparatus 700 is substantially similar to the apparatus 400 in Fig. 4B except that the electrolytic cell 710 may be disposed at a higher elevation than the supplementary electrolytic cell 770 and the supplementary electrolytic cell 770 may be disposed at a higher elevation than the stripping tank 760, such that the etchant 718 of the second compartment 714, when overflows, flows into the distal compartment 774 and the etchant 718 of the distal compartment 774, when overflows, flows into the stripping tank 760. As shown in Fig. 7A, the second compartment 714, the distal compartment 774 and the stripping tank 760 may each have an etchant level 714E, 774E, 760E. For the overflow to happen, the etchant level 714E may be higher than the etchant level 774E, which may be higher than etchant level 760E. In addition, the overflow arrangement between the second compartment 714 and the

distal compartment 774, and between the stripping tank 760 and the second compartment 714 allow the flow of the etchant 718 from the second compartment 714 to the distal compartment 774 and from the distal compartment 774 to the stripping tank 760 to flow under gravity influence and without mechanical assistance, e.g. a pump. Therefore, the overflow arrangement may save energy.

[0079] Fig. 7B shows a schematic elevation view of the apparatus 700 in Fig. 7A with each compartment having a pressure gradient. As shown in Fig. 7B, the first compartment 712 may include an outlet 712A for the outflow of the etchant 718 from the first compartment 712 into the proximal compartment 772. Accordingly, the outlet 712A may be located at a pre-determined height from the base 710B of the electrolytic cell 710 so as to maintain etchant level 712E of the etchant 718 in the first compartment 712 at the required level. Second compartment 714 may also include an outlet 714A for the outflow of the etchant 718 from the second compartment 714 into the distal compartment 774. As the etchant 718 in the second compartment 714 overflows at the pre-determined height, the etchant level 714E may be maintained at the desired height. Understandably, the height of the outlet 712A of the first compartment 712 may be higher than the height of the outlet 714A of the second compartment 714 so as to maintain the etchant level 712E of the first compartment 712 to be higher than the etchant level 714E of the second compartment 714. Similarly, the same arrangement of the compartment outlets may be implemented for the supplementary cell 770 to achieve the same effect of maintaining the pressure difference between the compartments 772,774. Similarly, the distal compartment 774 may include an outlet 774A at a pre-determined height from the base 770B along the wall 770W of the distal compartment 774 so that the etchant 718 in the distal compartment 774 may flow out of the distal compartment 774 at the required etchant level 774E. Proximal compartment 772 may also include an outlet 772A at a pre-determined height from the base 770B along the wall 770W of the proximal compartment 772 so that the etchant 718 in the proximal compartment 772 may flow out of the proximal compartment 772 at the required etchant level 772E.

[0080] Fig. 8 shows a schematic view of an example of the apparatus 800. As shown in Fig. 8, the apparatus 800 may include the electrolytic cell 810, the stripping tank 860 and a plurality of supplementary cells 870. Depending on the requirement of the apparatus 800, it may be possible to include one or more supplementary cells 870 between the electrolytic cell 810 and the stripping tank 860. In addition to the first electrical source (not shown in Fig. 8)

of the electrolytic cell 810, each of the plurality of supplementary cells 870 may include an electrical source (not shown in Fig. 8) for the respective cathode and the anode. Apparatus 800 may be configured to provide different current density to each of the plurality of supplementary cells 870 and the electrolytic cell 810. First electrical source of the apparatus 800 may be adapted to generate a first magnitude of current and the second electrical source may be adapted to generate a second magnitude of current, wherein the first magnitude of current may be higher or lower than the second magnitude of current. In this way, it may be possible to control the regeneration and recovery efficiency of the respective cells as explained earlier. With the plurality of the supplementary cells 870 connected in series, the metal recovery at first compartment 812 (catholytic) of the electrolytic cell 810 may be optimized as this configuration may keep the ORP of the etchant 818 as low as possible to facilitate metal deposition. At the same time, the configuration may keep the ORP of the etchant 818 in the second compartment 874 (anodic) of the supplementary cell 870 as high as necessary to regenerate the etchant 818 to be channelled to the stripping tank 860.

[0081] The design of the apparatus 800 and the method of maintaining high ORP of etchant 818 by using three compartments configuration, i.e. the buffer compartment 820, the first compartment 812 and the second compartment 814, separated by a hydrophobic material, e.g. polypropylene or other hydrophobic materials, may allow a high current/volume ratio, e.g. 20-30 A/litre, at one electrode and a lower current/volume density at the other electrode of opposite polarity, while preventing mixing of catholytes with anolytes which will render ineffective functioning of the etchant 818. As a result, the use of expensive and short lifespan membranes to maintain ORP of anode and cathode solutions is not necessary.

[0082] Fig. 9 shows a graph 900 of a typical ORP measurements over time for C (cathode), T1 (anode in electrolytic cell) and T2 (anode supplementary cell). As shown, the ORP for the catholytic portion of the etchant decreases at a faster rate initially and stabilizes over time. The ORP of anodic portion of the etchant in the first compartment of the electrolytic cell and the distal compartment of the supplementary cell increases at a faster rate initially but the rate decreases over time.

[0083] While the embodiments are shown to illustrate the concept of the invention, it would be clear to a person skilled in the art that the elements shown in the embodiment need not be

confined to the embodiments only and may be interchanged or combined with other embodiments to form embodiments that illustrate the concept of the invention.

Claim

1. An apparatus for regenerating an etchant and recovering a metal from the etchant, the apparatus comprising:

an electrolytic cell comprising,

a first compartment and a second compartment separated from the first compartment via a permeable divider, wherein the second compartment is in fluid communication with the first compartment through the divider, wherein the permeable divider is adapted to allow the etchant to flow therethrough from the first compartment to the second compartment or vice versa, wherein each of the first compartment and the second compartment are adapted to contain the etchant having an etchant level, wherein, when the apparatus is in operation, the etchant level in the first compartment is maintained at a higher or lower level than the etchant level in the second compartment, wherein the etchant flows from the compartment with the higher etchant level to the compartment with the lower etchant level,

a cathode and an anode disposed in the first compartment and the second compartment respectively, wherein the cathode and the anode are electrically connectable to a first electrical source and the anode is inert to the etchant, and

a stripping tank adapted to contain a substrate having a metal coating and the etchant adapted to remove the metal coating from the substrate, wherein the stripping tank is in fluid communication with the first compartment and the second compartment, wherein the stripping tank is adapted to channel the etchant to the first compartment and second compartment and is adapted to receive the etchant from the second compartment.

2. The apparatus of claim 1, wherein the permeable divider comprises a buffer compartment having a first permeable wall and a second permeable wall opposite the first permeable wall, wherein the buffer compartment is in fluid communication with the first compartment via the first permeable wall and is in fluid communication with the second compartment via the second permeable wall, wherein the buffer compartment is in fluid communication with the stripping tank, wherein the buffer compartment is adapted to receive the etchant from the stripping tank so as to channel the etchant to the first compartment and second compartment, and wherein the buffer compartment contains the etchant having an

etchant level wherein the etchant level is maintained at a higher level than the etchant levels of the first compartment and the second compartment.

3. The apparatus of claim 1 or 2, wherein the electrolytic cell is disposed at a higher elevation than the stripping tank, wherein the etchant in the second compartment, when overflows, flows into the stripping tank.

4. The apparatus of any one of claims 1 to 3, wherein the apparatus further comprises a supplementary electrolytic cell fluidly connected to the electrolytic cell, the supplementary electrolytic cell comprising,

a proximal compartment and a distal compartment separated from the proximal compartment via a permeable divider, wherein the proximal compartment is in fluid communication with the distal compartment through the permeable divider,

a supplementary cathode and a supplementary anode disposed in the proximal compartment and the distal compartment respectively, wherein the supplementary cathode and the supplementary anode are connected to a second electrical source,

wherein the proximal compartment is in fluid communication with the first compartment and the distal compartment is in fluid communication with the second compartment and the stripping tank, wherein the proximal compartment is adapted to receive the etchant from the first compartment and adapted to channel the etchant to the first compartment, and the distal compartment is adapted to receive the etchant from the second compartment and adapted to channel the etchant to the stripping tank.

5. The apparatus of claim 4, wherein the electrolytic cell is disposed at a higher elevation than the supplementary electrolytic cell and the supplementary electrolytic cell is disposed at a higher elevation than the stripping tank, wherein the etchant of the second compartment, when overflows, flows into the distal compartment and the etchant of the distal compartment, when overflows, flows into the stripping tank.

6. The apparatus of claim 4 or 5, wherein the proximal compartment and the distal compartment, each compartment comprises the etchant having an etchant level, wherein the etchant level of the proximal compartment is higher or lower than the etchant level of the distal compartment.

7. The apparatus of any one of claims 4 to 6, wherein the first electrical source is adapted to generate a first magnitude of current and the second electrical source is adapted to generate a second magnitude of current, wherein the first magnitude of current is higher or lower than the second magnitude of current.
8. The apparatus of any one of claims 1 to 7, wherein the anode and/or supplementary anode comprise an inert material which does not react with the etchant.
9. The apparatus of any one of claims 1 to 8, wherein the permeable divider is made from a hydrophobic material.
10. The apparatus of claim 9, wherein the permeable divider is charged.
11. A method for regenerating an etchant and recovering a metal from the etchant using the apparatus of any one of claims 1 to 10, the method comprising:
 - channelling the etchant from the stripping tank into the first compartment and the second compartment of the electrolytic cell, the first compartment and the second compartment separated via the permeable divider adapted to allow flow from the first compartment to the second compartment or vice versa via the permeable divider,
 - maintaining the etchant level in the first compartment at a higher or lower level than the etchant level in the second compartment when the apparatus is in operation, wherein the etchant flows from the compartment with the higher etchant level to the compartment with the lower etchant level, and
 - channelling the etchant from the second compartment of the electrolytic cell into the stripping tank.
12. The method of claim 11, wherein the method further comprises channelling the etchant from the stripping tank into the buffer compartment so as to channel the etchant into the first compartment and the second compartment and maintaining the etchant level of the buffer compartment to be at a higher level than the etchant levels of the first compartment and the second compartment.

13. The method of claim 11 or 12, wherein channelling from the second compartment into the stripping tank includes overflowing the etchant from the second compartment into the stripping tank.

14. The method of any one of claims 11 to 13, wherein the method further comprises channelling the etchant from the first compartment into the proximal compartment, channelling the etchant from the second compartment into the distal compartment, channelling the etchant from proximal compartment to the first compartment, and channelling the etchant from the distal compartment into the stripping tank.

15. The method of claim 14, wherein the channelling the etchant from the second compartment to the distal compartment includes overflowing the etchant from the second compartment to the distal compartment and wherein channelling the etchant from the distal compartment to the stripping tank includes overflowing the etchant from the second compartment to the distal compartment.

16. The method of claim 14 or 15, wherein the method further comprises maintaining the etchant level of the proximal compartment at a higher or lower level than that of the distal compartment.

17. The method of any one of claims 11 to 16, wherein the method further comprises varying the first magnitude of current to be higher or lower than the second magnitude of current.

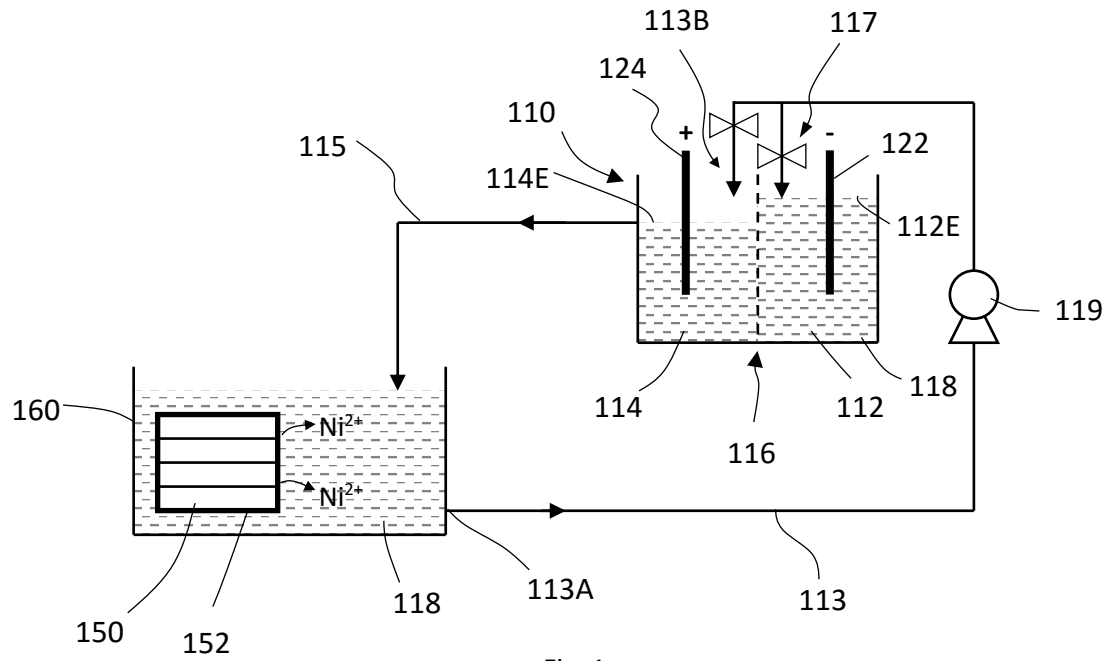
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Fig. 1

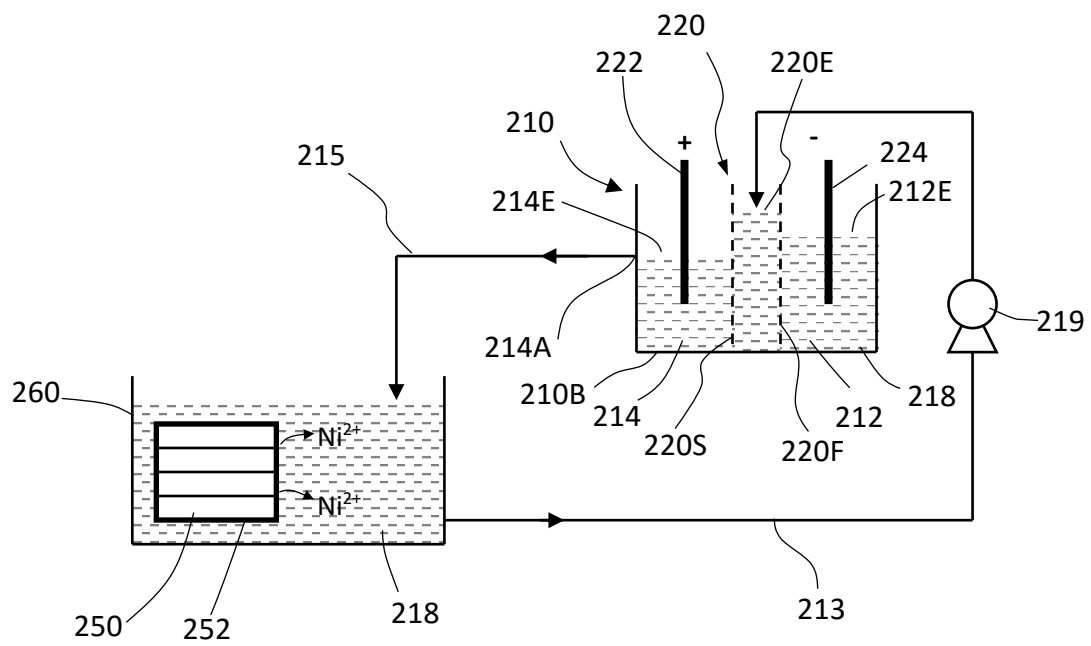
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Fig. 2

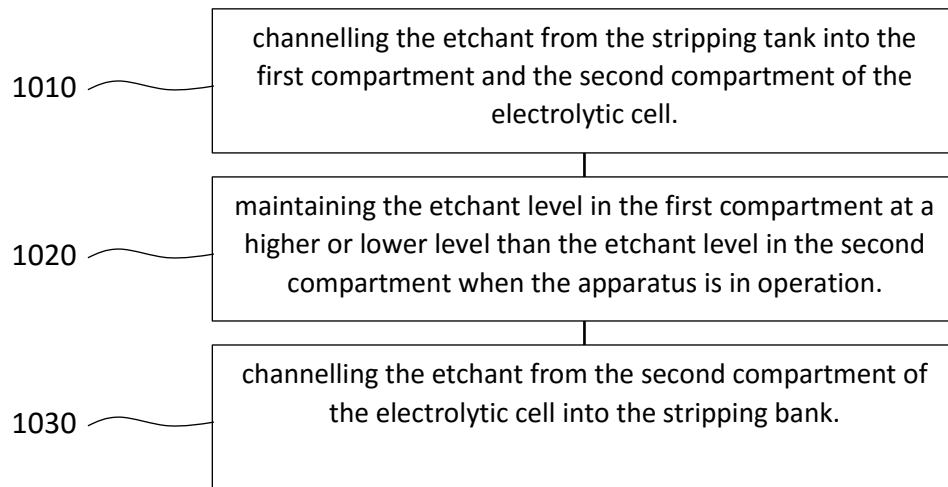
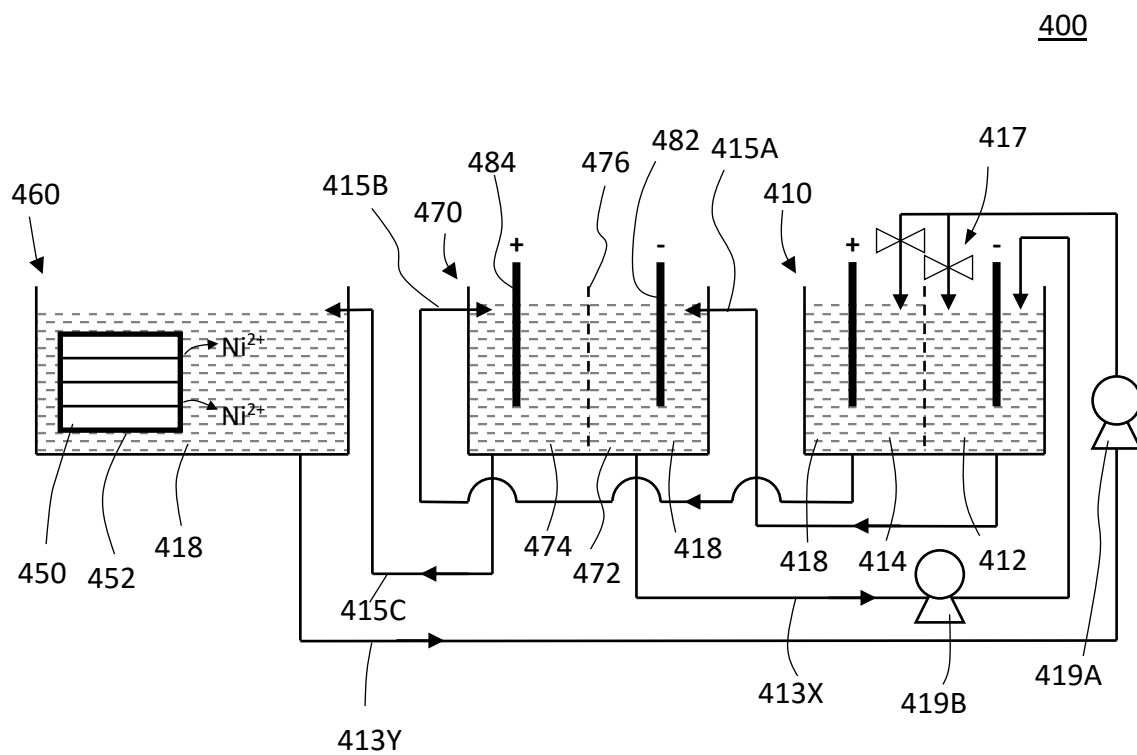
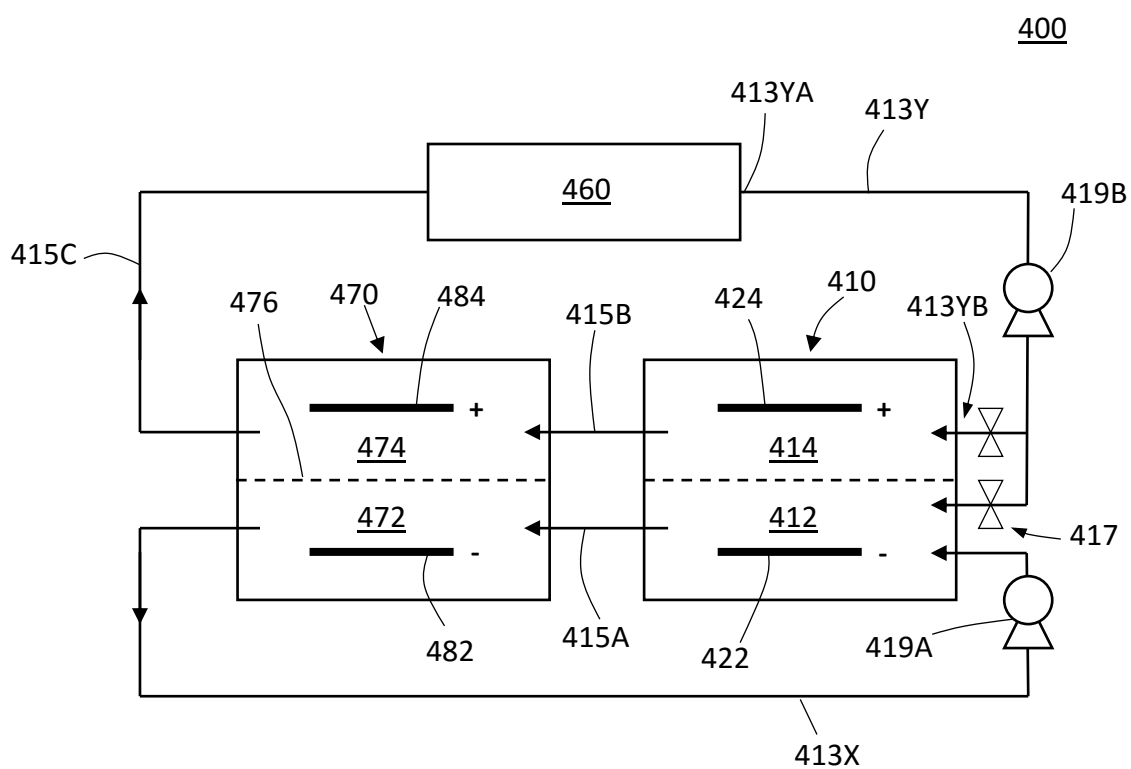
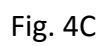
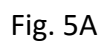


Fig. 3





500



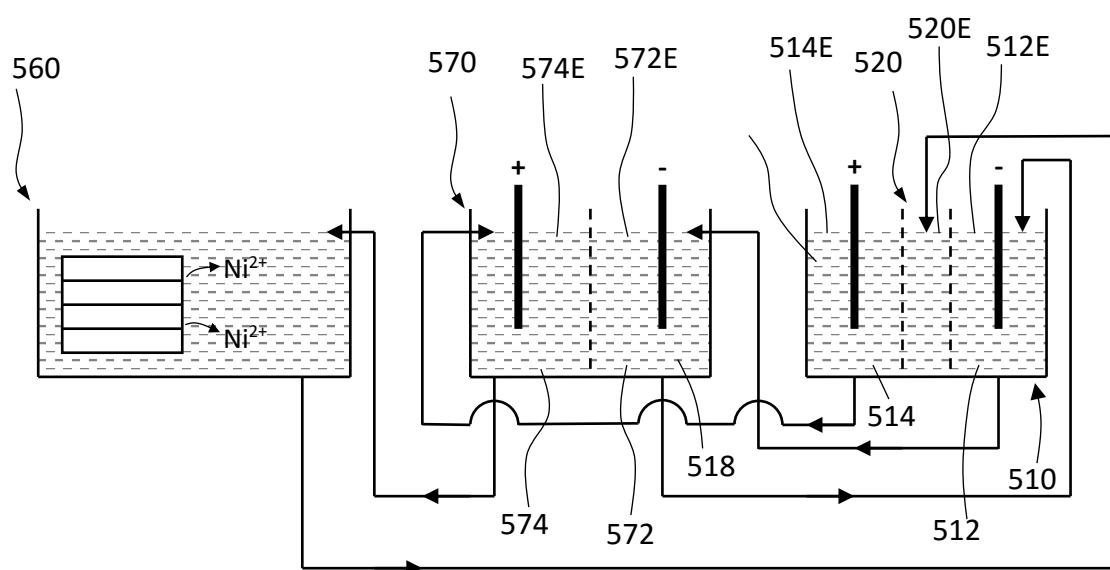
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Fig. 5B

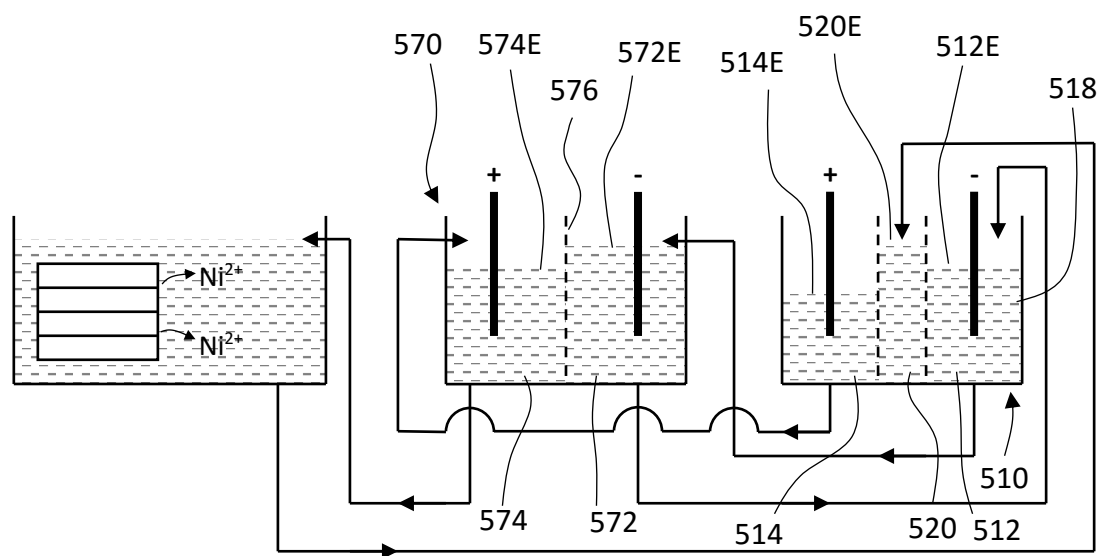
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Fig. 5C

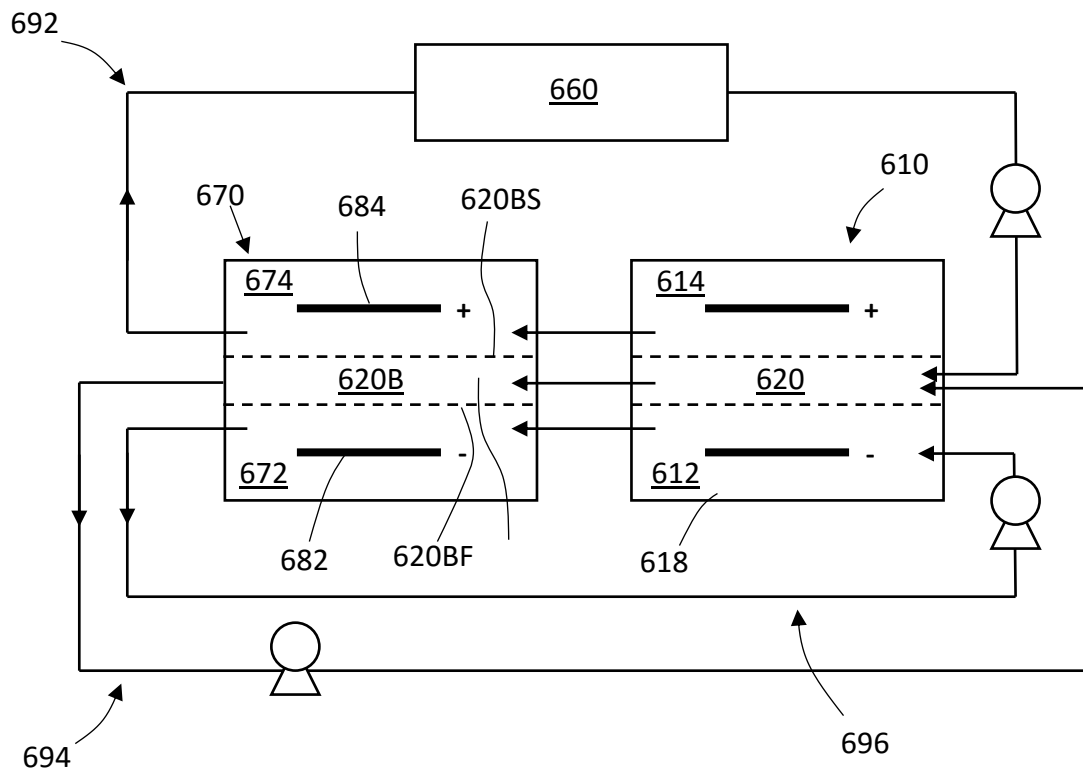
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Fig. 6A

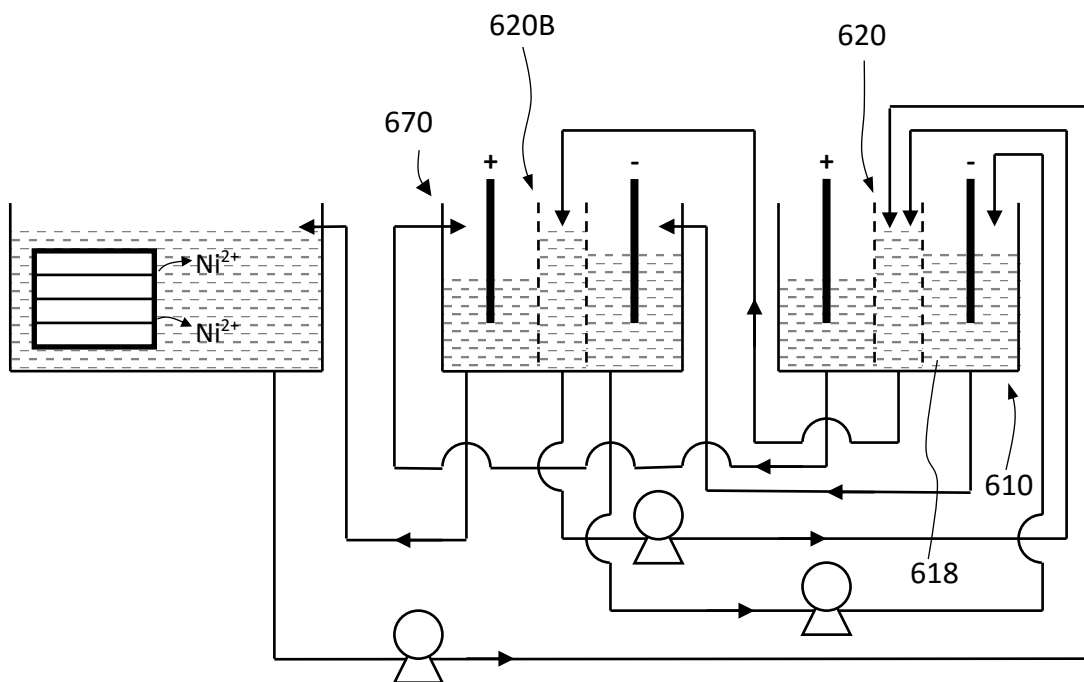
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Fig. 6B

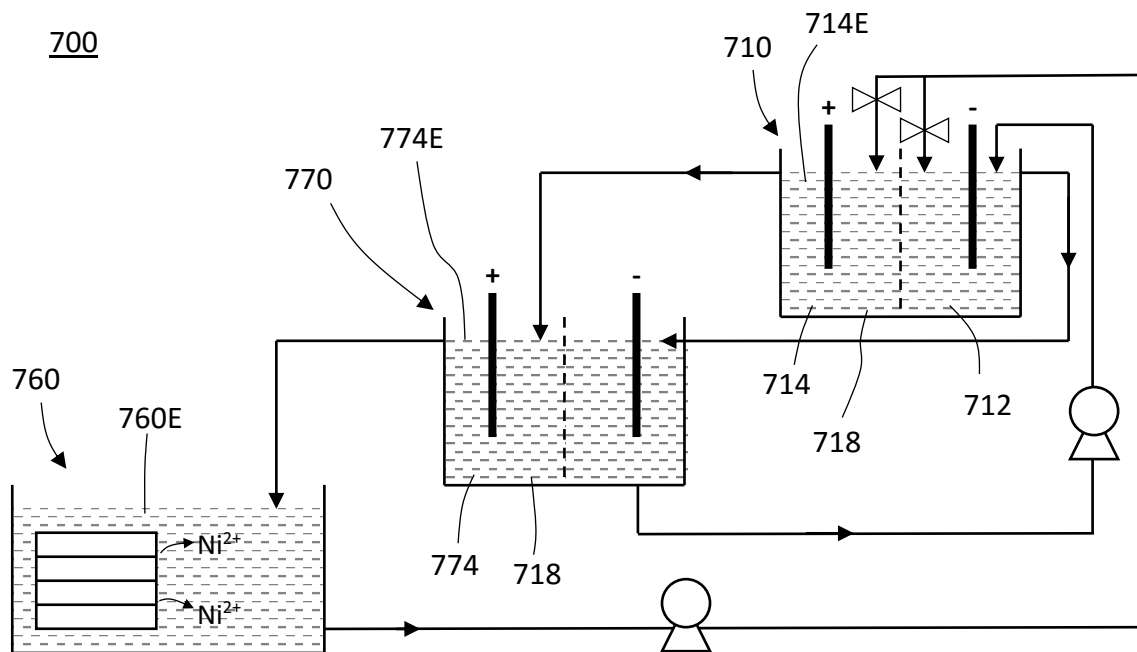


Fig. 7A

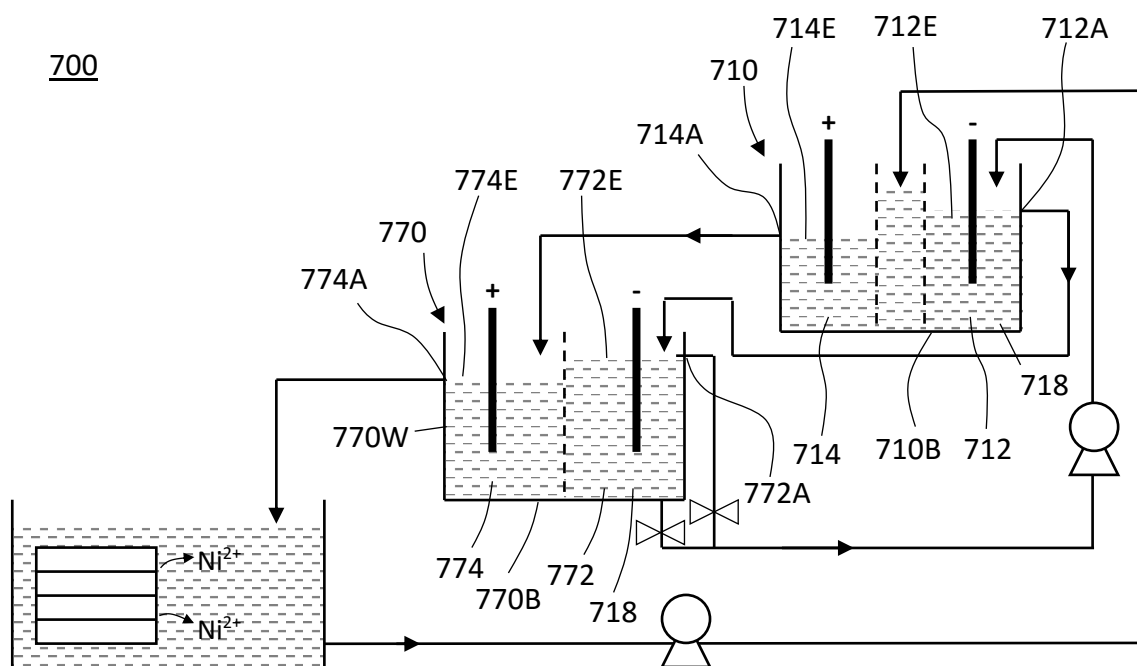


Fig. 7B

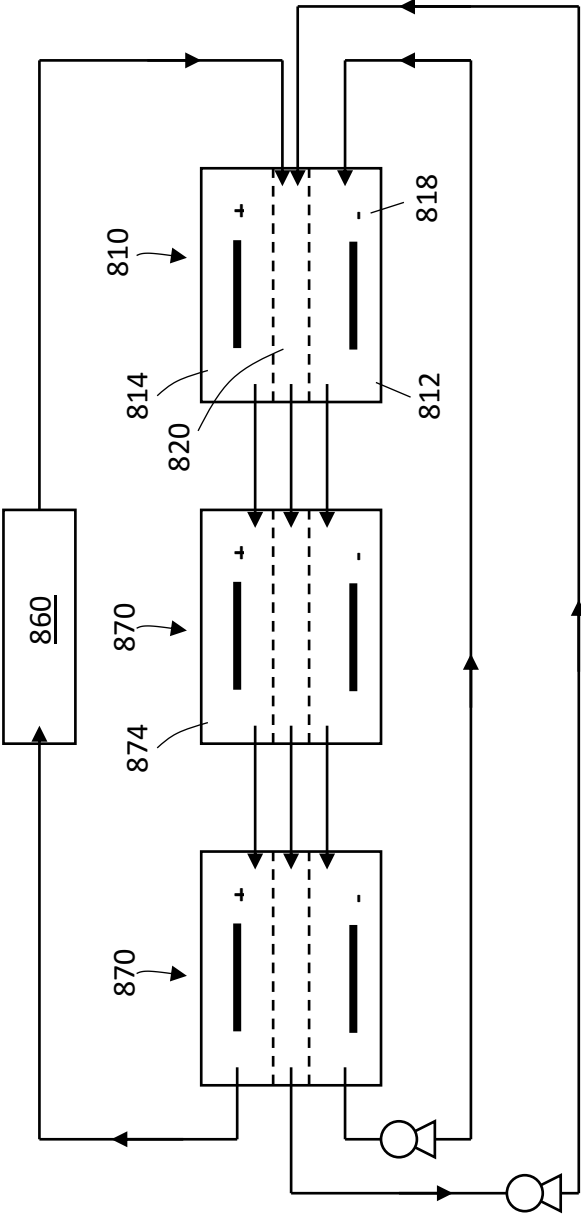


Fig. 8

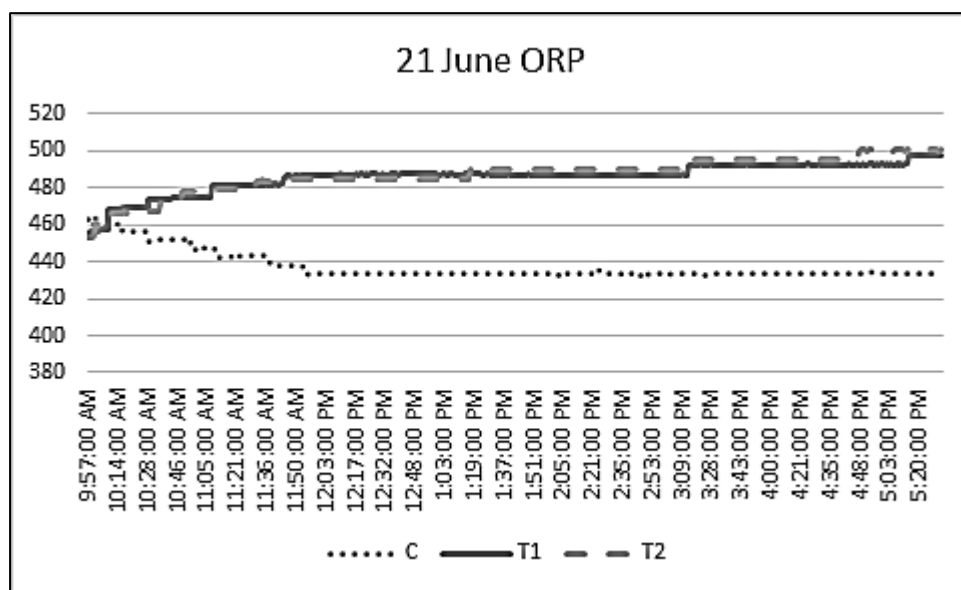


Fig. 9