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(54) **PLATING HAVING INCREASED THICKNESS AND REDUCED GRAIN SIZE**

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(57) **ABSTRACT**

Contacts that may be highly corrosion resistant, less susceptible to wear, and may be readily manufactured with a process that controls or reduces resource usage. Corrosion resistance and wear performance may be improved by providing a thicker plating that has a reduced tendency to crack and by using materials that act as catalysts. Wear performance may be improved by reducing grain size for a harder plating. An amount of resources needed may be reduced or controlled by using materials that plate well and by using a manufacturing process having a reduced number of steps.

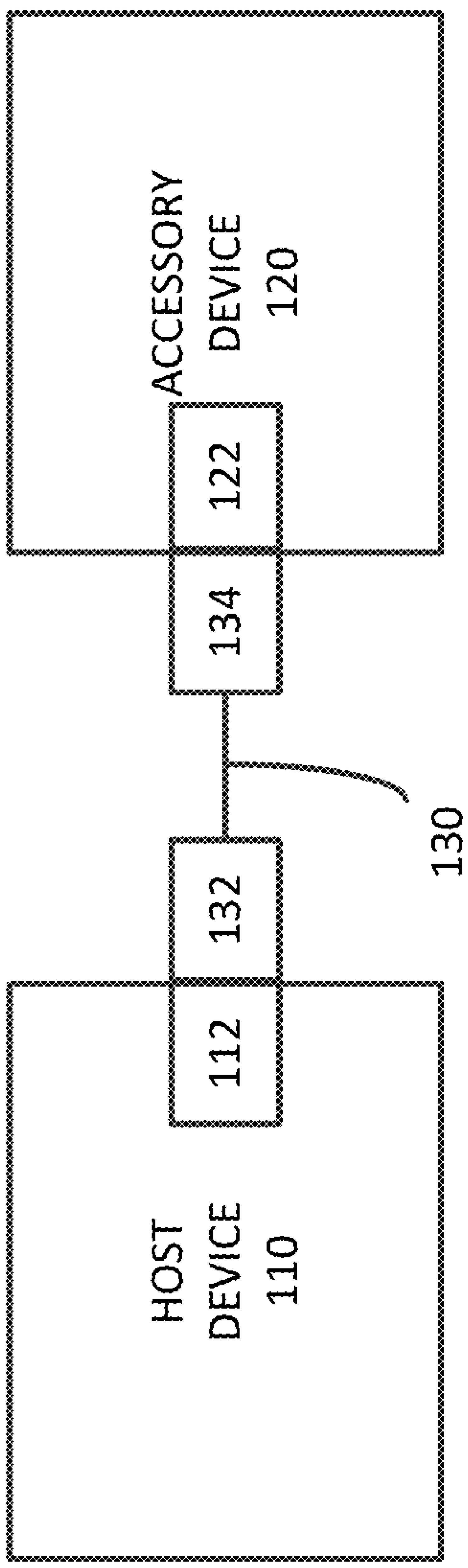

Figure 1

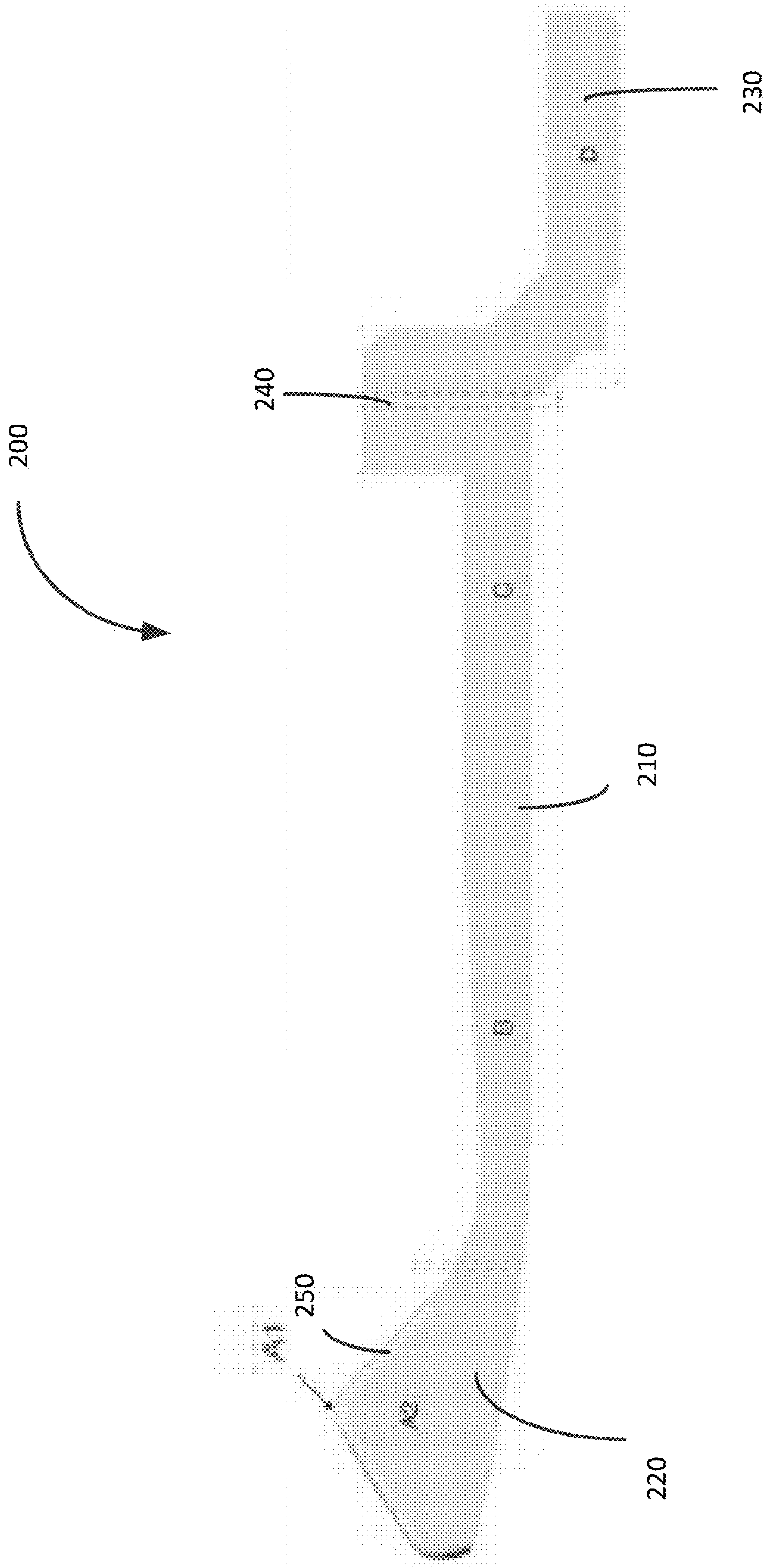

Figure 2

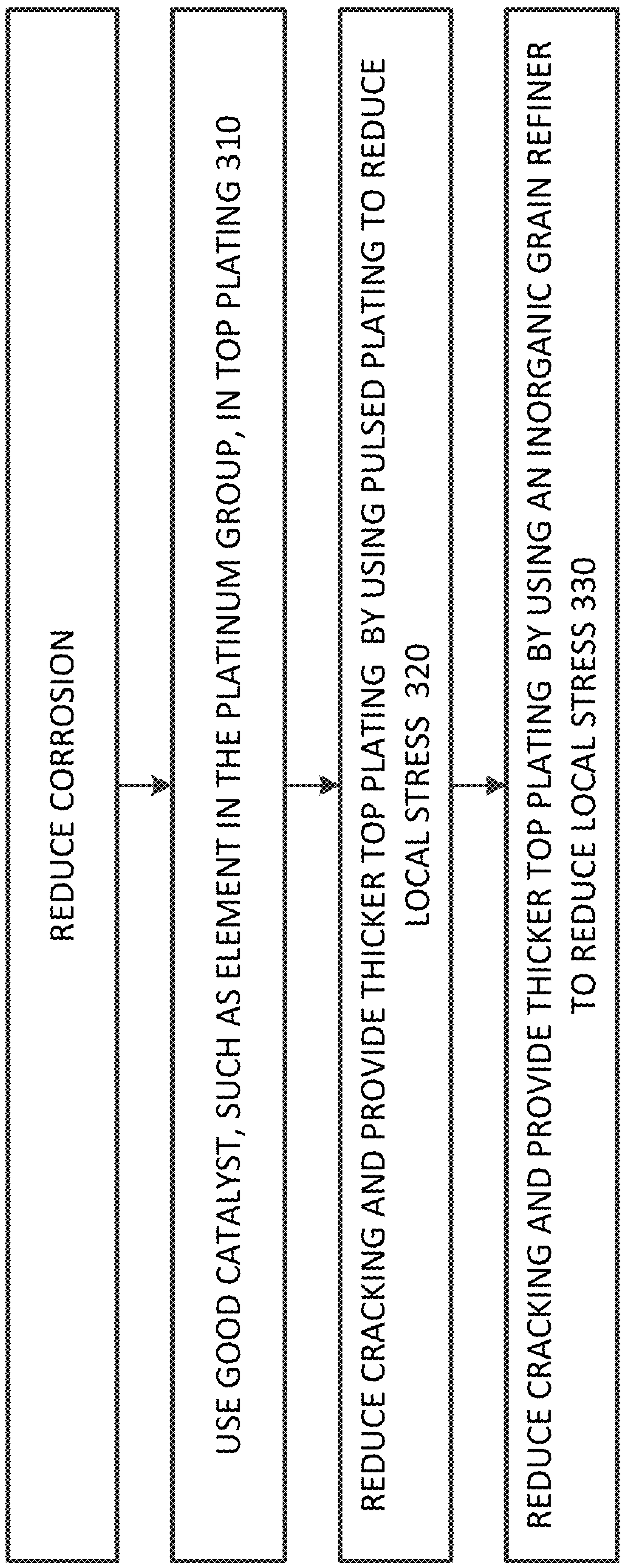
REDUCE CORROSION
USE GOOD CATALYST, SUCH AS ELEMENT IN THE PLATINUM GROUP, IN TOP PLATING 310
REDUCE CRACKING AND PROVIDE THICKER TOP PLATING BY USING PULSED PLATING TO REDUCE LOCAL STRESS 320
REDUCE CRACKING AND PROVIDE THICKER TOP PLATING BY USING AN INORGANIC GRAIN REFINER TO REDUCE LOCAL STRESS 330

Figure 3

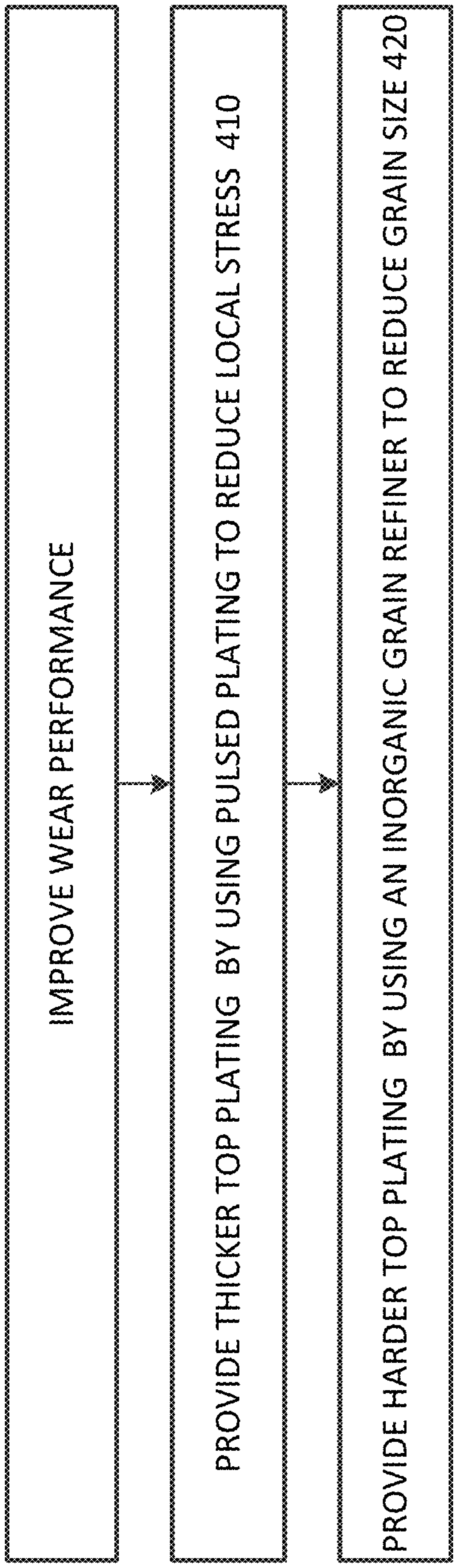
IMPROVE WEAR PERFORMANCE
PROVIDE THICKER TOP PLATING BY USING PULSED PLATING TO REDUCE LOCAL STRESS 410
PROVIDE HARDER TOP PLATING BY USING AN INORGANIC GRAIN REFINER TO REDUCE GRAIN SIZE 420

Figure 4

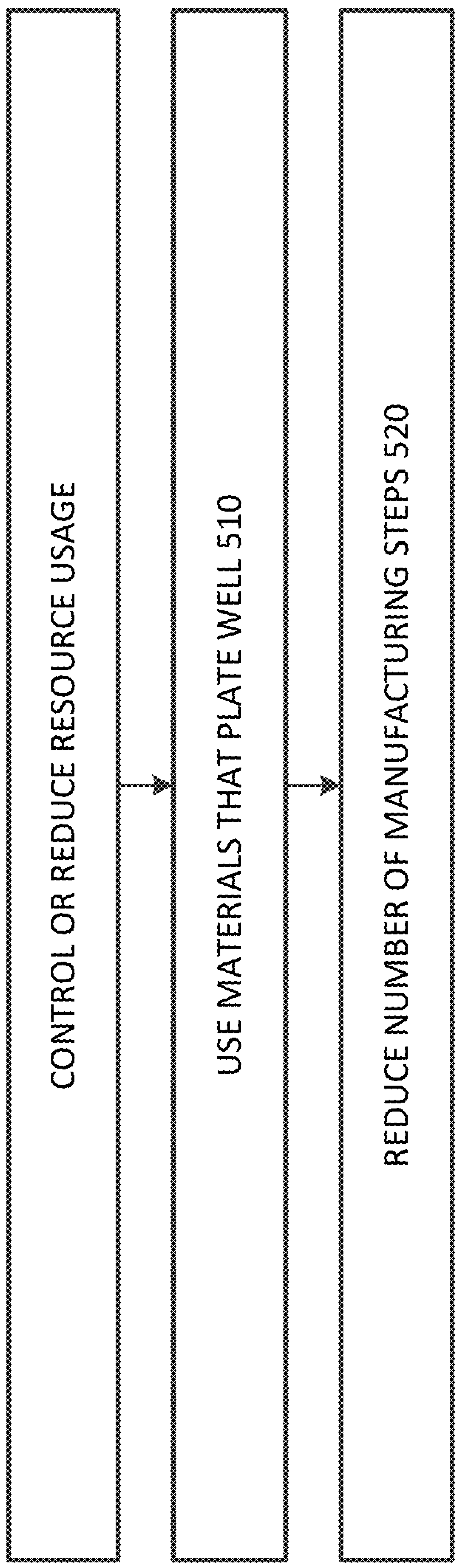
CONTROL OR REDUCE RESOURCE USAGE
USE MATERIALS THAT PLATE WELL 510
REDUCE NUMBER OF MANUFACTURING STEPS 520

Figure 5

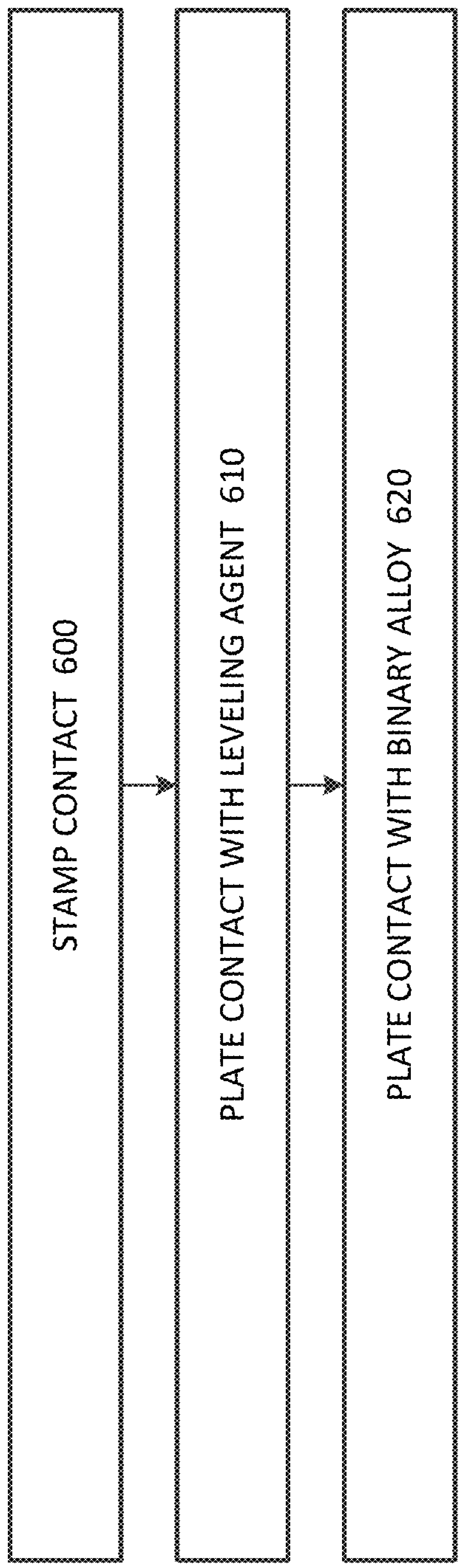
STAMP CONTACT 600
PLATE CONTACT WITH LEVELING AGENT 610
PLATE CONTACT WITH BINARY ALLOY 620

Figure 6

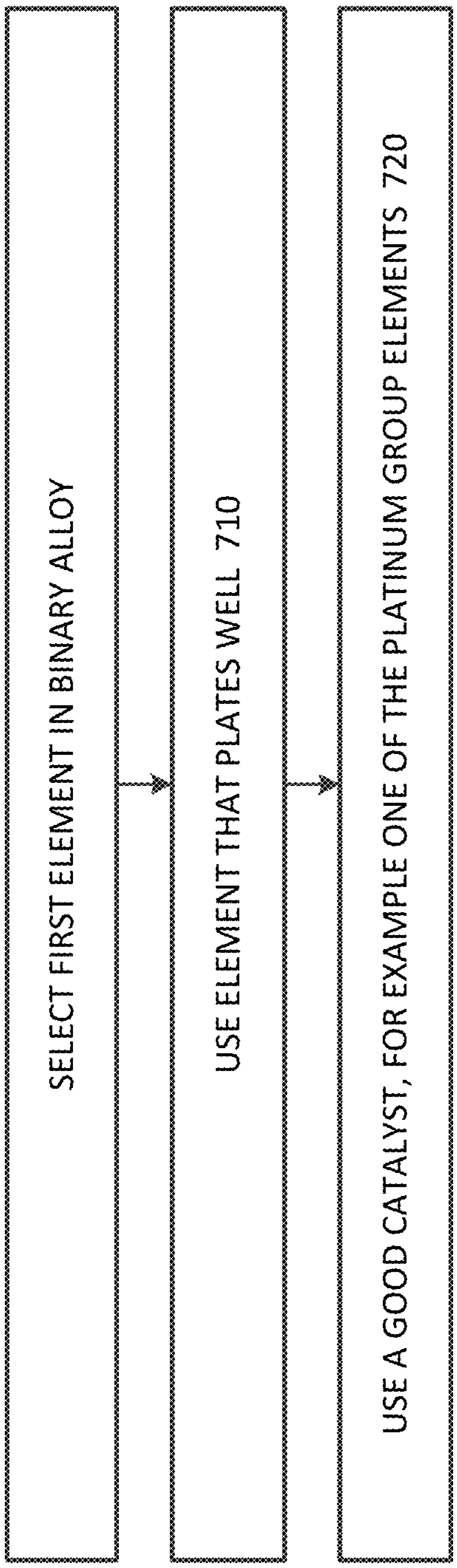
SELECT FIRST ELEMENT IN BINARY ALLOY
USE ELEMENT THAT PLATES WELL 710
USE A GOOD CATALYST, FOR EXAMPLE ONE OF THE PLATINUM GROUP ELEMENTS 720

Figure 7

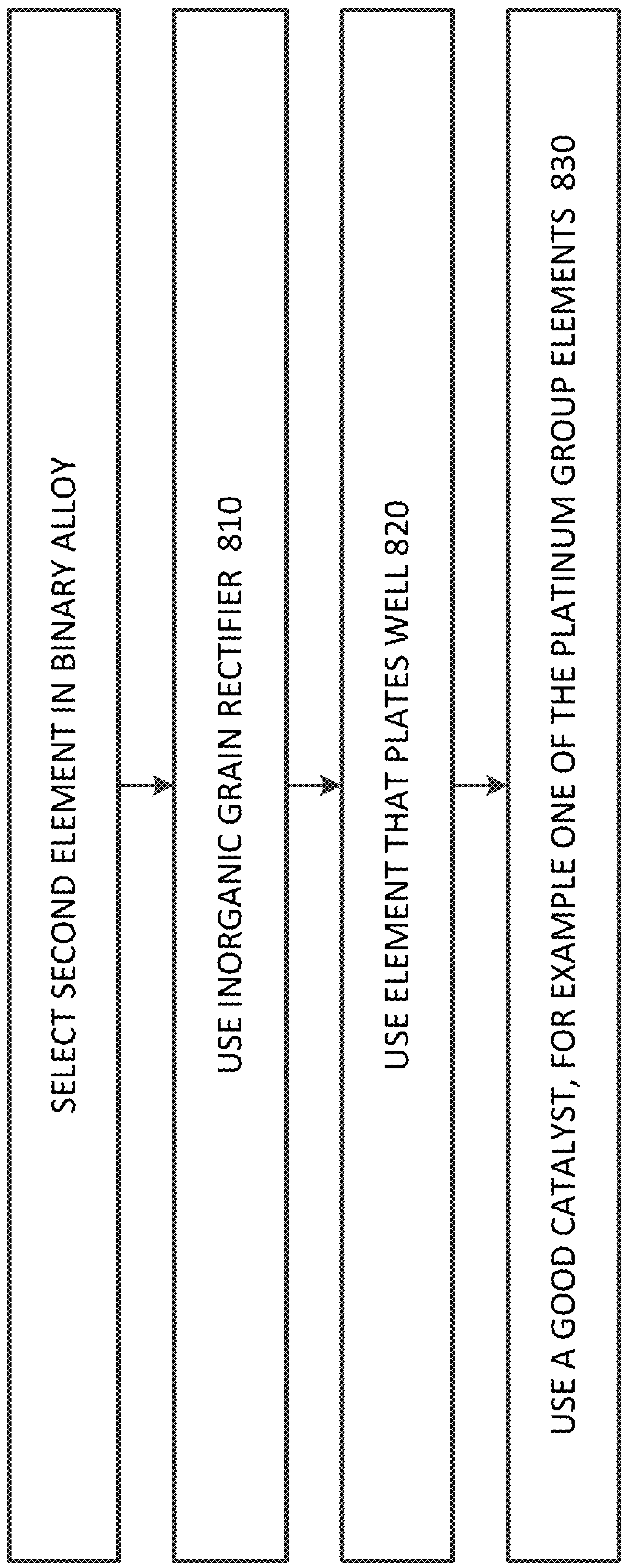
SELECT SECOND ELEMENT IN BINARY ALLOY
USE INORGANIC GRAIN RECTIFIER 810
USE ELEMENT THAT PLATES WELL 820
USE A GOOD CATALYST, FOR EXAMPLE ONE OF THE PLATINUM GROUP ELEMENTS 830

Figure 8

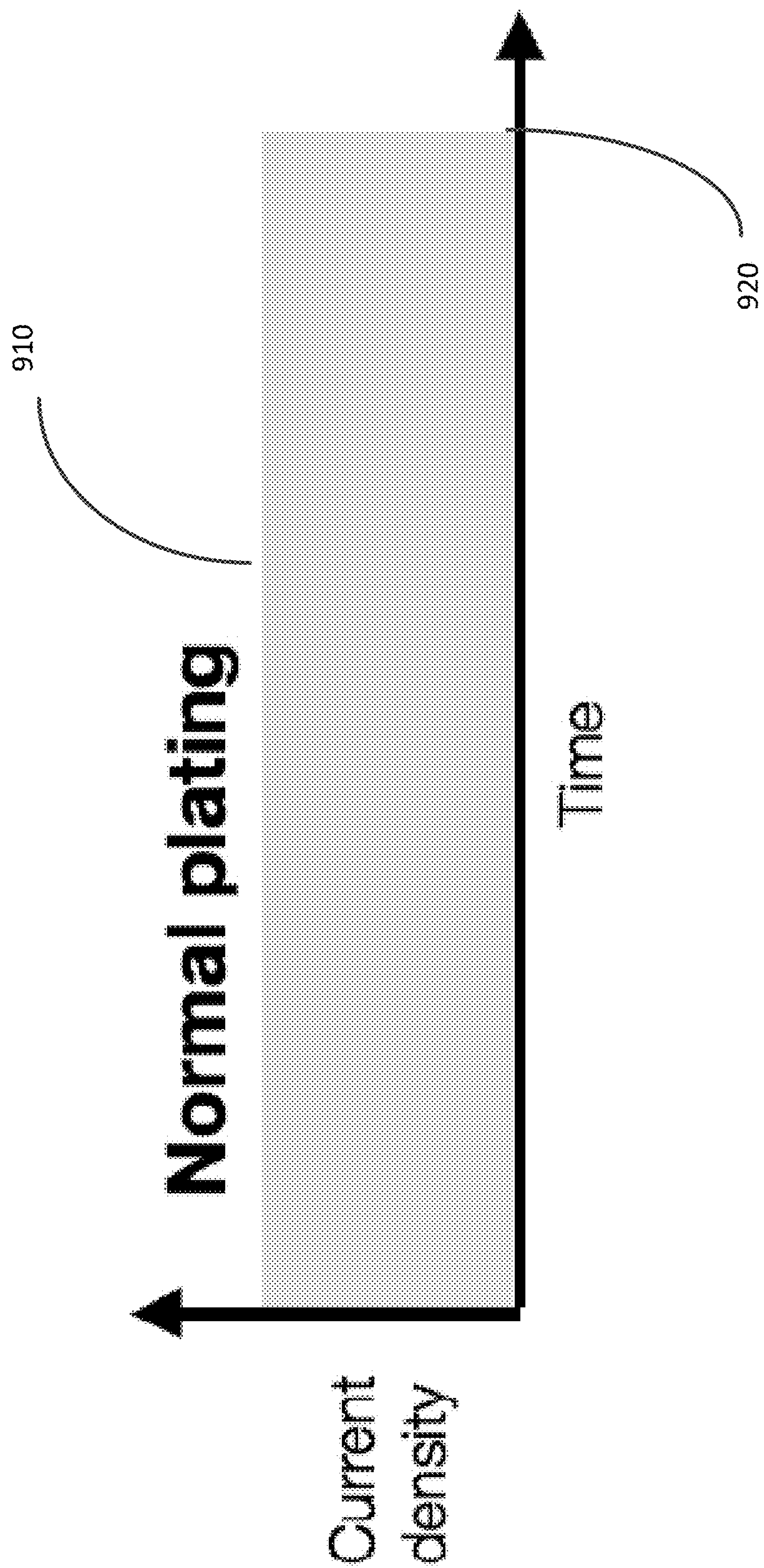

Figure 9

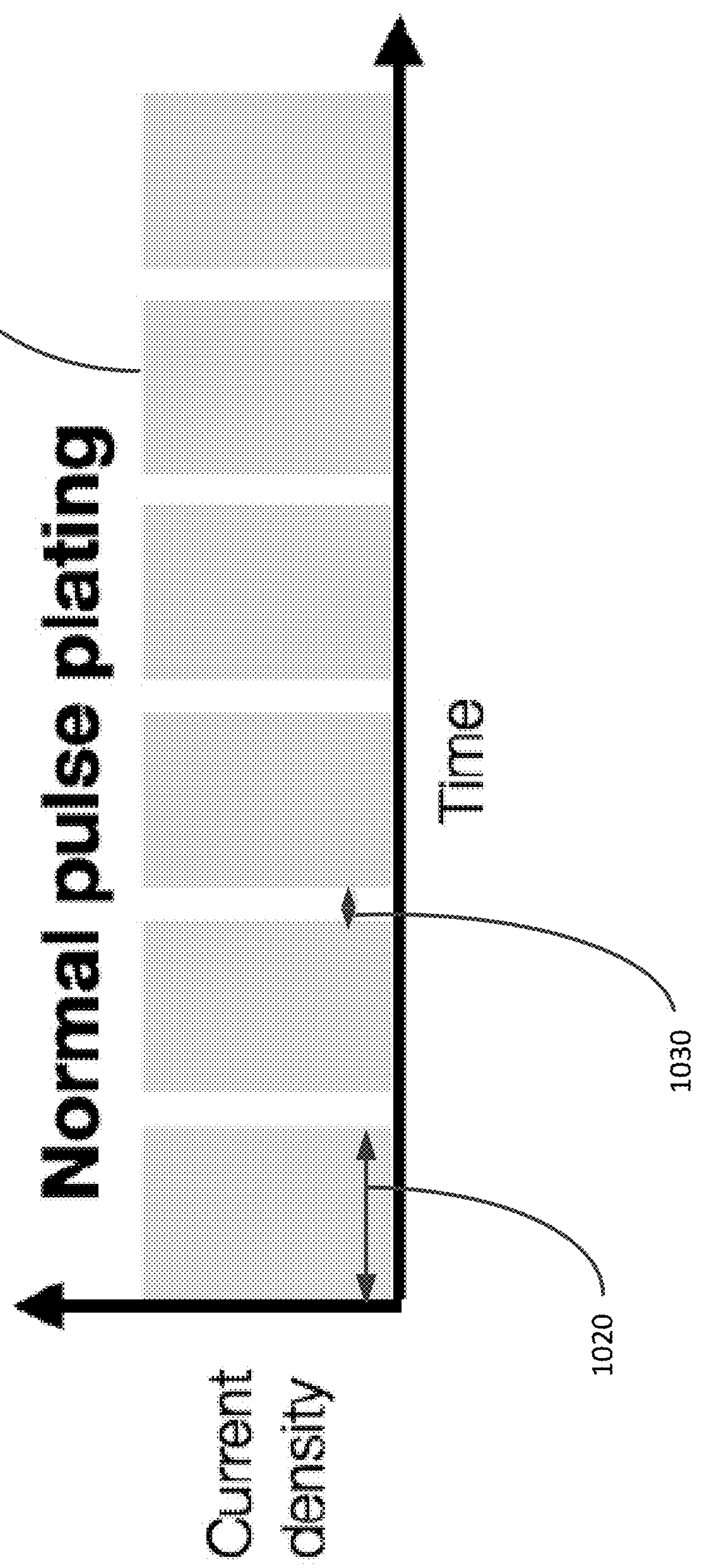

Figure 10

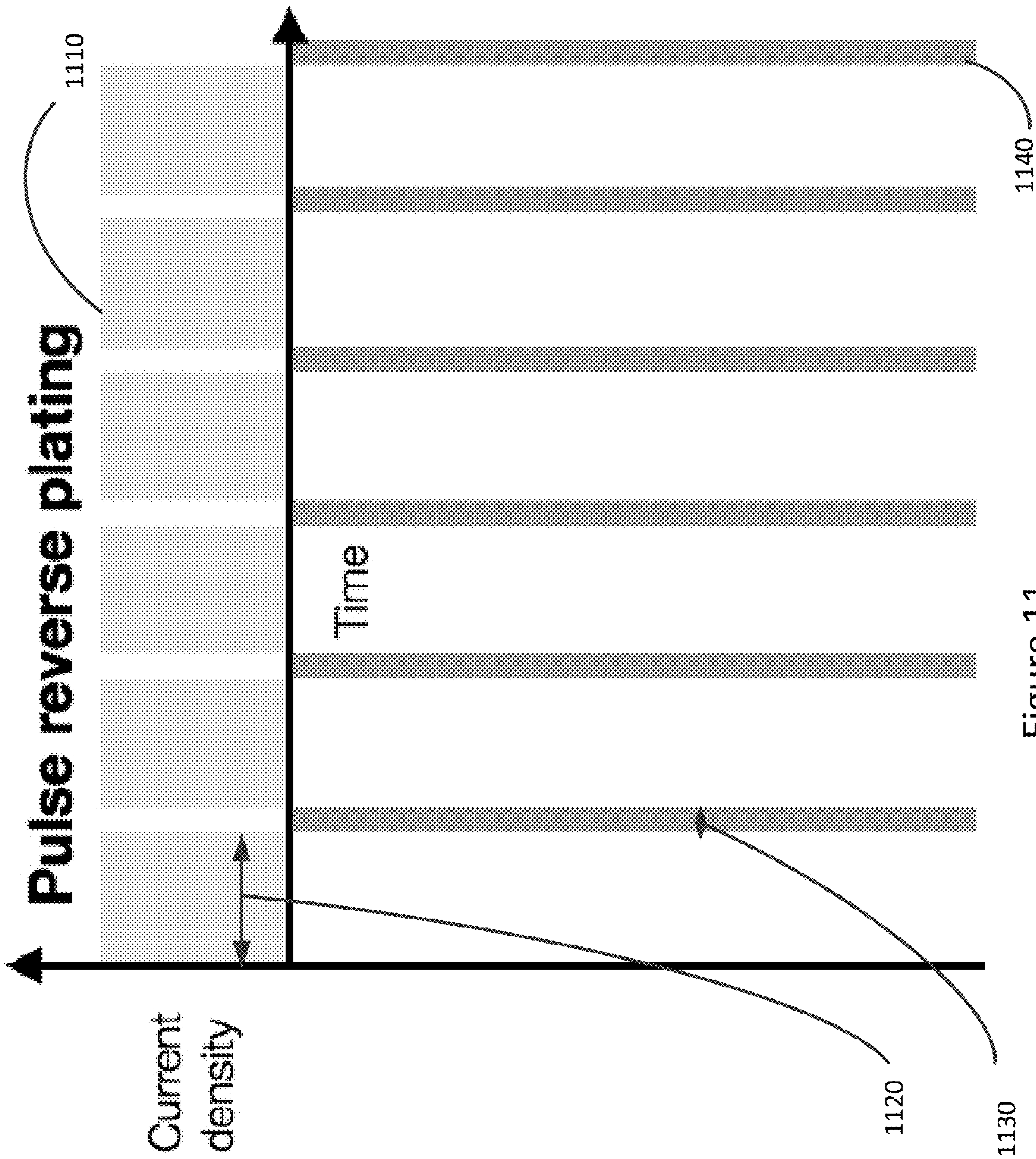
Pulse reverse plating
Current density
Time
1110
1120
1130
1140

Figure 11

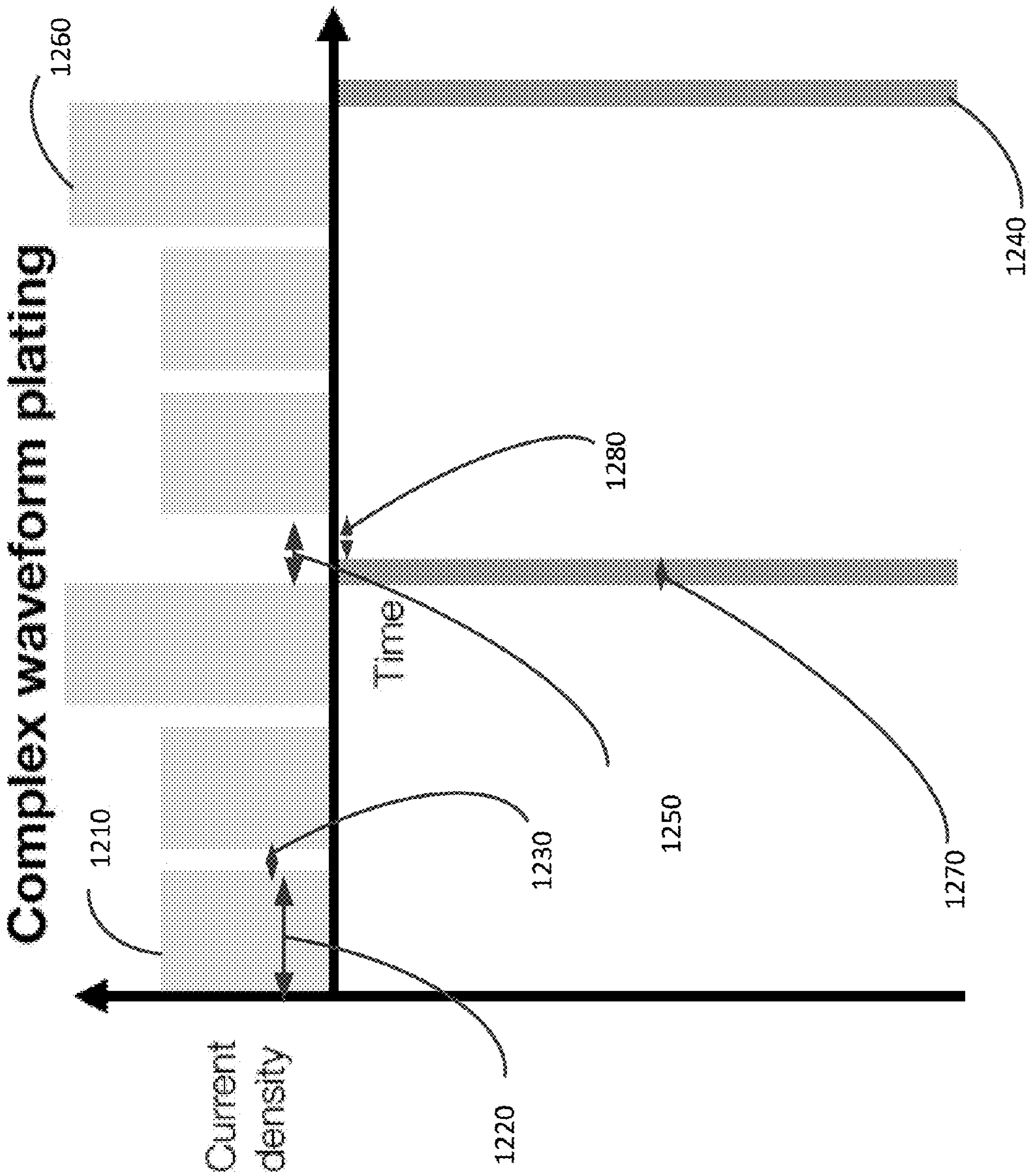
Complex waveform plating
Current density
Time
1210
1220
1230
1240
1250
1260
1270
1280

Figure 12

PLATING HAVING INCREASED THICKNESS AND REDUCED GRAIN SIZE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. provisional application No. 62/367,610, filed Jul. 27, 2016, which is incorporated by reference.

BACKGROUND

[0002] Electronic devices often include one or more connector receptacles though which they may provide and receive power and data. This power and data may be conveyed over cables that may include a connector insert at each end of a cable. The connector inserts may be inserted into connector receptacles in the communicating electronic devices.

[0003] The contacts in these various connectors may be exposed to liquids and fluids that may cause the contacts to corrode. For example, a user may purposely or inadvertently submerge an electronic device or a connector insert in a liquid. A user may spill a liquid or perspire on contacts on an electronic device or connector insert. This may cause one or more contacts to corrode, particularly where a voltage is present on the one or more contacts. This corrosion may impair the operation of the electronic device or cable and in severe cases may render the device or cable inoperable. This corrosion may also mar the appearance of the contacts. Where the contacts are at the surface of an electronic device or at the surface of a connector insert on a cable, such corrosion may be readily apparent to a user. Even when such corrosion does not reach the level of device impairment, it may create a negative impression in the mind of a user that may reflect poorly on the device or cable and the device or cable's manufacturer. This corrosion may be exacerbated by additional wear on the contacts.

[0004] These connector inserts may be inserted into the connector receptacles many times over the lifetime of a device. These repeated insertions may cause wear to occur on contacts on either or both the connector inserts and connector receptacles. Like corrosion, this wear may cause either connector to become worn looking. This wear may also provide a pathway for corrosion.

[0005] Some of these electronic devices may be very popular and may therefore be manufactured in great numbers. Therefore it may be desirable that these contacts be readily manufactured such that demand for the devices may be met. Also, it may be desirable to control or reduce the amount of resources used during the manufacturing process.

[0006] Thus, what is needed are contacts that may be highly corrosion resistant, less susceptible to wear, and may be readily manufactured with a process that controls or reduces resource usage.

SUMMARY

[0007] Accordingly, embodiments of the present invention may provide contacts that may be highly corrosion resistant, less susceptible to wear, and may be readily manufactured with a process that controls or reduces resource usage. These contacts may be located at a surface of an electronic device, at a surface of a connector insert on a cable, in a connector receptacle on an electronic device, or elsewhere.

[0008] These and other embodiments of the present invention may provide contacts that are highly corrosion resistant. These contacts may be plated with a material that acts as a catalyst in order to improve corrosion resistance. Specifically, the plating material may act as a catalyst to reduce water into oxygen, thereby preventing the plating material from dissolving into the water. These and other embodiments of the present invention may provide a plating that acts as a good catalyst by using one or more platinum group elements. These one or more platinum group elements may be combined with one or more other elements in various embodiments of the present invention.

[0009] These and other embodiments of the present invention may further improve corrosion resistance by providing a plating layer for contacts where the plating layer has reduced localized stress. This reduced stress may result in a reduced tendency to crack. This reduction in cracking may prevent moisture from seeping through cracks in the plating layer and reaching an underlying layer, which may be more susceptible to corrosion. These and other embodiments of the present invention may provide a plating for a contact where the plating is performed using an alternating or pulsed signal, such as a voltage or current. This alternating or pulsed voltage or current may provide a plating that has reduced local stresses. Further, the use of this pulsed plating may help to reduce grain size of the material being plated. Grain size may further be reduced by using a grain refiner. The use of pulsed plating and a grain refiner may aid in reducing local stresses.

[0010] These and other embodiments of the present invention may further improve corrosion resistance by providing a plating layer having an increased thickness. This increased thickness may provide more material to be dissolved by moisture or removed by wear before more vulnerable underlying layers of the contact may be reached. This increased thickness may also reduce the chances that a crack in the plating layer may reach from a surface of the contact to the vulnerable underlying layers. These and other embodiments of the present invention may use pulsed plating and a grain refiner to provide good leveling and small grains such that thicker plating may be achieved.

[0011] These and other embodiments of the present invention may provide contacts that are less susceptible to wear. Again, these contacts may be plated with a layer having an increased thickness. This increased thickness may provide more material to wear away before such wear either becomes noticeable or becomes a possible corrosion problem.

[0012] These and other embodiments of the present invention may further improve wear by providing a plating layer having a reduced grain size. This reduced grain size may increase a hardness of the plating layer, thereby reducing its tendency to wear. In various embodiments of the present invention grain size may be reduced by using a material that reduces an energy at the grain boundaries of the plating material.

[0013] These and other embodiments of the present invention may provide contacts that may be readily manufactured with a process that controls or reduces resource usage. For example, embodiments of the present invention may provide plating layers for contacts where the materials are chosen for their ability to plate well. This ability may simplify manufacturing and improve yields. These embodiments of the present invention may provide a plating stack for contacts that has a reduced number of steps. This simplification to the manufacturing process may help to control or reduce the usage of resources, such as precious metals.

[0014] Again, these and other embodiments of the present invention may provide a plating for a contact where the plating is performed using an alternating or pulsed voltage or current. The use of this pulsed plating may help to reduce grain size of the material being plated. This reduction in stress and reduced grain size may allow a thicker plating to be achieved for better corrosion resistance and for better wear performance. The alternating voltage or current may also help to provide a more level surface for the resulting plating. This more level surface may further help to improve the wear performance of the resulting contact. In these and other embodiments of the present invention, plating may be done using a constant or DC voltage or current, or other types of varying voltage or currents may be used.

[0015] These and other embodiments of the present invention may provide a method of plating a contact. A substrate for the contact may be formed of copper or other material. The substrate may be stamped or otherwise formed. A first plating may be applied to the substrate to smooth surface defects caused by the stamping process. This first plating may be copper or other material that may be used as a leveling agent. A second plating may be applied over the first plating. Either or both of the first plating and the second plating may be done using an alternating voltage or current, a constant or DC voltage or current, or other type of voltage or current waveform. This process may include a limited number of plating and other manufacturing process steps. This limited number of plating layers may reduce a risk of adhesion issues between layers. The limited number of manufacturing process steps may reduce or control resource usage and provide an effective way to provide contacts having good corrosion and wear performance.

[0016] In these and other embodiments of the present invention, the second plating may be formed using a binary alloy. The binary alloy may include a first element that is selected for its ability to plate onto a contact. This ability to plate may help to simplify the manufacturing process and help to reduce or control an amount of resources, such as precious metals, consumed. The first element may further be selected to provide a good catalyst such that water on a contact is converted into oxygen. This may help to prevent the plated material from dissolving in the presence of moisture, particularly when a contact is providing a voltage.

[0017] In these and other embodiments of the present invention, a second element in the binary alloy may be selected based on its ability to act as a grain refiner. Specifically, the second element may be selected for its ability to reduce interfacial energy at the grain boundaries of the binary alloy as it is plated on a contact for the purpose of stabilizing a fine grain size and avoiding grain growth. This smaller grain size may allow binary alloy to be more thickly plated. The resulting plating may also reduce local stress in the plating, which may reduce cracking and thereby improve corrosion resistance. The smaller grain size may further increase hardness, which may improve wear resistance.

[0018] In these and other embodiments of the present invention, the second element in the binary alloy may further be selected based on its ability to be plate well. This ability to plate well may simplify the manufacturing process and may help to reduce or control an amount of resources that are consumed. The second element may also be selected based on its ability to act as a catalyst to reduce water to oxygen.

[0019] In these and other embodiments of the present invention, the first element may be an element in a first group consisting of platinum, palladium, iridium, osmium, rhodium, and ruthenium. In these and other embodiments of the present invention, the first element may be an element in a first group consisting of platinum, palladium, iridium, osmium, and rhodium. In these and other embodiments of the present invention, the first element may be an element in a first group consisting of rhodium, iridium, platinum, and rhenium. In these and other embodiments of the present invention, the first element may be rhodium.

[0020] In these and other embodiments of the present invention, the second element may be an element in a second group consisting of platinum, palladium, iridium, osmium, rhodium, and ruthenium. In these and other embodiments of the present invention, the second element may be an element in a second group consisting of platinum, palladium, iridium, ruthenium, osmium, and rhodium. In these and other embodiments of the present invention, the second element may be an element in a second group consisting of molybdenum, niobium, tungsten, rhenium, iridium, iron, nickel, rhodium, and ruthenium. In these and other embodiments of the present invention, the second element may be iridium. In these and other embodiments of the present invention, the second element may be ruthenium.

[0021] In these and other embodiments of the present invention, the first element may be rhodium and the second element may be iridium. In these and other embodiments of the present invention, the first element may be rhodium and the second element may be one of molybdenum, niobium, and tungsten. In these and other embodiments of the present invention, the first element may be iridium and the second element may be one of rhenium and tungsten. In these and other embodiments of the present invention, the first element may be platinum and the second element may be one of iridium, iron, nickel, rhenium, rhodium, ruthenium, and tungsten.

[0022] In these and other embodiments of the present invention, the first element may be rhenium and the second element may be tungsten.

[0023] The use of one of these materials as the second element may provide an inorganic grain refiner. The use of an inorganic grain refiner may reduce the amount of hydrogen in the plating, which may further reduce the tendency of the plating to crack.

[0024] In these and other embodiments of the present invention, the first element may comprise approximately 90 percent of the binary alloy by weight, while the second element may comprise approximately 10 percent of the binary alloy. In these and other embodiments of the present invention, the first element may comprise approximately 95 percent of the binary alloy while the second element may comprise approximately 5 percent of the binary alloy. In these and other embodiments of the present invention, the first element may comprise approximately 99 percent of the binary alloy while the second element may comprise approximately 1 percent of the binary alloy. In these and other embodiments of the present invention, the first element may be at least approximately 80 percent, 90 percent, 95 percent, in the range of 80-99 percent, or other percentage by weight. In these and other embodiments of the present invention, the second element may be at least approximately 20 percent, 10 percent, 5 percent, in the range of 1-20 percent, or other percentage by weight. In these and other embodiments of the present invention, the first element may be rhodium and the second element may be ruthenium. The binary alloy may have a thickness in the range of 0.5 to 2 microns, from 1 to 4 microns, from 2 to 6 microns, or more than 6 microns. It may have a thickness of 2 microns, 3 microns, 4 microns, 5 microns, or more than 5 microns. In these and other embodiments of the present invention, the binary alloy may have a greater thickness, such as 10-50 microns, 50-100 microns, 100-150 microns, or more than 150 microns. For example, it may have a thickness of 60 microns, 80 microns, 100 microns, 120 microns, 140 microns, or more than 140 microns.

[0025] In these and other embodiments of the present invention, the first element may comprise more than or approximately 99.5 percent of the binary alloy while the second element may comprise less than or approximately 0.5 percent of the binary alloy, where the percentages are by weight. This may be particularly true where the first element is rhodium and the second element is iridium. Iridium may not plate well, and keeping its percentage to a minimum may reduce some of the complications that may otherwise result.

[0026] These and other embodiments of the present invention may provide a contact. A substrate for the contact may be formed of copper or other material. The substrate may be stamped or otherwise formed. The contact may have a first plating over the substrate to smooth surface defects caused by the stamping process. This first plating may be copper or other material that may be used as a leveling agent. The contact may further have a second plating over the first plating. Either or both of the first plating and the second plating layers may be provided using an alternating or pulsed voltage or current, though in these and other embodiments of the present invention an alternating or pulsed voltage or current is not used.

[0027] In these and other embodiments of the present invention, other layers, such as barrier layers to prevent corrosion of internal structures may be included. For example, barrier layers, such as zinc barrier layers, may be used to protect magnets or other internal structures from corrosion by cladding or plating layers. Catalyst layers may be used to improve the rate of deposition for other layers, thereby improving the manufacturing process. These catalyst layers may be formed of palladium or other material. Stress separation layers, such as those formed of copper, may also be included in these and other embodiments of the present invention, including the above contacts. Other scratch protection, passivation, and corrosion resistance layers may also be included.

[0028] While embodiments of the present invention are well-suited to contacts and their method of manufacturing, these and other embodiments of the present invention may be used to improve the corrosion resistance of other structures. For example, electronic device cases and enclosures, connector housings and shielding, battery terminals, magnetic elements, measurement and medical devices, sensors, fasteners, various portions of wearable computing devices such as clips and bands, bearings, gears, chains, tools, or portions of any of these, may be covered with a precious-metal alloy and plating layers as described herein and otherwise provided for by embodiments of the present invention. The precious-metal alloy and plating layers for these structures may be formed or manufactured as described herein and otherwise provided for by embodiments of the present invention. For example, magnets and other structures for fasteners, connectors, speakers, receiver magnets, receiver magnet assemblies, microphones, and other devices may have their corrosion resistance improved by structures and methods such as those shown herein and in other embodiments of the present invention.

[0029] In various embodiments of the present invention, the components of contacts and their connector assemblies may be formed in various ways of various materials. For example, contacts and other conductive portions may be formed by stamping, coining, metal-injection molding, machining, micro-machining, 3-D printing, or other manufacturing process. The conductive portions may be formed of stainless steel, steel, copper, copper-nickel-silicon alloy, copper titanium, phosphor bronze, palladium, palladium silver, or other material or combination of materials, as described herein. They may be plated or coated with nickel, gold, palladium, or other material, as described herein. The nonconductive portions, such as the housings and other portions, may be formed using injection or other molding, 3-D printing, machining, or other manufacturing process. The nonconductive portions may be formed of silicon or silicone, Mylar, Mylar tape, rubber, hard rubber, plastic, nylon, elastomers, liquid-crystal polymers (LCPs), ceramics, or other nonconductive material or combination of materials.

[0030] Embodiments of the present invention may provide contacts that may be located in, or may connect to, various types of devices, such as portable computing devices, tablet computers, desktop computers, laptops, all-in-one computers, wearable computing devices, cell phones, smart phones, media phones, storage devices, keyboards, covers, cases, portable media players, navigation systems, monitors, power supplies, adapters, remote control devices, chargers, and other devices. These contacts may provide pathways for signals that are compliant with various standards such as Universal Serial Bus (USB), High-Definition Multimedia Interface® (HDMI), Digital Visual Interface (DVI), Ethernet, DisplayPort, Thunderbolt™, Lightning, Joint Test Action Group (JTAG), test-access-port (TAP), Directed Automated Random Testing (DART), universal asynchronous receiver/transmitters (UARTs), clock signals, power signals, and other types of standard, non-standard, and proprietary interfaces and combinations thereof that have been developed, are being developed, or will be developed in the future. In various embodiments of the present invention, these interconnect paths provided by these contacts may be used to convey power, ground, signals, test points, and other voltage or current, current, data, or other information.

[0031] Various embodiments of the present invention may incorporate one or more of these and the other features described herein. A better understanding of the nature and advantages of the present invention may be gained by reference to the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] FIG. **1** illustrates an electronic system according to an embodiment of the present invention;

[0033] FIG. **2** illustrates a contact according to an embodiment of the present invention;

[0034] FIG. **3** illustrates a method of reducing corrosion according to an embodiment of the present invention;

[0035] FIG. **4** illustrates a method of improving wear performance according to an embodiment of the present invention;

[0036] FIG. **5** illustrates a method of controlling or reducing resource usage according to an embodiment of the present invention;

[0037] FIG. **6** illustrates a method of manufacturing a contact according to an embodiment of the present invention;

[0038] FIG. **7** illustrates a method of selecting an element as a first element in a binary alloy according to an embodiment of the present invention;

[0039] FIG. **8** illustrates a method of selecting an element as a second element in a binary alloy according to an embodiment of the present invention;

[0040] FIG. **9** illustrates a DC waveform of a current flowing through a contact during plating according to an embodiment of the present invention;

[0041] FIG. **10** illustrates a pulsed waveform of a current flowing through a contact during plating according to an embodiment of the present invention;

[0042] FIG. **11** illustrates a pulsed waveform of a current flowing through a contact during plating according to an embodiment of the present invention; and

[0043] FIG. **12** illustrates another pulsed waveform of a current flowing through a contact during plating according to an embodiment of the present invention.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0044] FIG. **1** illustrates an electronic system according to an embodiment of the present invention. This figure, as with the other included figures, is shown for illustrative purposes and does not limit either the possible embodiments of the present invention or the claims.

[0045] In this example, host device **110** may be connected to accessory device **120** in order to share data, power, or both. Specifically, connector receptacle **112** on host device **110** may be connected to connector receptacle **122** on accessory device **120** via cable **130**. Cable **130** may include connector insert **132** that may be inserted into connector receptacle **112** on host device **110** and connector insert **134** that may be inserted into connector receptacle **122** on accessory device **120**. In these and other embodiments of the present invention, contacts of connector receptacle **112** on host device **110** may be in physical contact and directly and electrically connected to contacts of connector receptacle **122** on accessory device **120**.

[0046] The contacts in these various connector receptacles **112** and **122** and connector inserts **132** and **134** may be vulnerable to exposure to liquids or other fluids. This exposure, particularly when there are voltages present on the exposed contacts, may lead to their corrosion. This corrosion may mar the contacts and may be readily apparent to a user. This corrosion may lead to a reduction in operation of the device and may even render the device inoperable. Even when such corrosion does not reach the level of device impairment, it may create a negative impression in the mind of a user that may reflect poorly on the device and the device's manufacturer. Also, the connector inserts **132** and **134** may be inserted into connector receptacles **112** and **122** many times. This repeated insert may lead to wear of the various contacts.

[0047] Accordingly, these and other embodiments of the present invention may provide contacts for connector assemblies that may be highly corrosion resistant and have improved wear performance. But ordinarily such an increase in corrosion resistance may lead to a reduction in manufacturability and an increase in resource usage. Accordingly, these and other embodiments of the present invention may provide contacts that are readily manufactured and may be manufactured with a process that controls or reduces resource usage. An example of one such contact is shown in the following figure.

[0048] FIG. **2** illustrates a contact according to an embodiment of the present invention. This or similar contacts may be used in a connector insert, such as connector insert **132** and **134**, or connector receptacles, such as connector receptacles **112** and **122** in FIG. **1**. Contact **200** may include beam portion **210** between contacting portion **220** and surface-mount contacting portion **230**. Contacting portion **220** may mate with a contact in a corresponding connector when the connector having contact **200** is mated with the corresponding connector. Surface-mount contacting portion **230** may be soldered to a contact on a printed circuit board, flexible circuit board, or other appropriate substrate in an electronic device housing the connector having contact **200**. A stabilizing portion **240** may be inserted in a housing forming the connector having contact **200**.

[0049] During manufacturing, one or more contacts **200** may be attached to a carrier (not shown.). The carrier may be detached from the contacts **200** at the end of manufacturing, or at another time during manufacturing. The carrier may be attached to surface-mount contacting portion **230** or other portion of contact **200**.

[0050] Contacting portion **220** may include a surface **250**. Surface **250** may be exposed to moisture such as sweat, water or other fluids. These fluids may cause corrosion of contact **200**. This corrosion may be particularly exacerbated by the presence of a voltage on contact **200**. Surface **250** may also engage a corresponding surface in a corresponding connector. This may lead to wear of surface **250** of contact **200**. Further, contacts **200** may be manufactured in very high numbers. Accordingly, these and other embodiments of the present invention may provide contacts **200** that are corrosion resistant, have good wear performance, and may be readily manufactured with a process that controls or reduces resource usage. Examples of methods of providing corrosion resistance, good wear performance, and controlling or reducing resource usage are shown in the following figures.

[0051] FIG. **3** illustrates a method of improving corrosion resistance according to an embodiment of the present invention. Embodiments of the present invention may provide contacts that may be plated with a material that acts as a catalyst in order to improve corrosion resistance. Specifically, in act **310**, the plating material may operate as a catalyst to reduce water into oxygen, thereby preventing the plating material from dissolving into the water. Embodiments of the present invention may provide a plating that acts as a good catalyst by using one or more platinum group elements. These one or more platinum group elements may be combined with one or more other elements in various embodiments of the present invention.

[0052] In act **320**, these and other embodiments of the present invention may further improve corrosion resistance by providing a plating layer for contacts where the plating layer has reduced localized stress. This reduced stress may result in a reduced tendency to crack. This reduction in cracking may prevent moisture from seeping through cracks in the plating layer and reaching an underlying layer, which may be more susceptible to corrosion. These and other embodiments of the present invention may provide a plating for a contact where the plating is performed using an alternating or pulsed signal, such as a voltage or current. This alternating or pulsed voltage or current may provide a plating that has reduced local stresses. Further, the use of this pulsed plating may help to reduce grain size of the material being plated. Grain size may further be reduced by using a grain refiner. The use of pulsed plating and a grain refiner may aid in reducing local stresses.

[0053] In act **330**, these and other embodiments of the present invention may further improve corrosion resistance by providing a plating layer having an increased thickness. This increased thickness may provide more material to be dissolved by moisture or removed by wear before more vulnerable underlying layers of the contact may be reached. This increased thickness may also reduce the chances that a crack in the plating layer may reach from a surface of the contact to the vulnerable underlying layers. These and other embodiments of the present invention may use pulsed plating and a grain refiner to provide good leveling and small grains such that a thicker plating may be achieved.

[0054] FIG. **4** illustrates a method of improving wear performance according to an embodiment of the present invention. Again, in act **410**, these contacts may be plated with a layer having an increased thickness. This increased thickness may provide more material to wear away before such wear either becomes noticeable or becomes a possible corrosion problem. In act **420**, wear may be further improved by providing a plating layer having a reduced grain size. This reduced grain size may increase a hardness of the plating layer, thereby reducing its tendency to wear. In various embodiments of the present invention, grain size may be reduced by employing an inorganic grain refiner. This grain refiner may reduce the energy at grain boundaries of the plating material, making them less likely to attract additional atoms and grow in size.

[0055] FIG. **5** illustrates a method of controlling or reducing resource usage according to an embodiment of the present invention. In act **510**, materials for contact plating layers may be chosen for their ability to plate well. This may simplify the manufacturing process and help to improve yields. In act **520**, these and other embodiments of the present invention may provide a plating stack for contacts that has a reduced number of steps. This simplification to the manufacturing process may help to reduce or control an amount of resources, such as precious metals, consumed. An example of one such manufacturing process is shown in the following figure.

[0056] FIG. **6** illustrates a method of manufacturing a contact according to an embodiment of the present invention. A substrate for the contact may be formed of copper, bronze, copper alloy, or other material. The substrate may be stamped or otherwise formed, in act **600**. A first plating may be applied to the substrate to smooth surface defects caused by the stamping process, in act **610**. This first plating may be copper or other material that may be used as a leveling agent. A second plating may be applied over the first plating in act **620**. The second plating may be done using a binary alloy. Either or both of the first plating and the second plating may be done using an alternating voltage or current. For example, the second step may be performed by applying an alternating or other voltage or current to a contact. The contact may be at least partially submerged in a bath comprising the binary alloy. This process may include a limited number of plating and other manufacturing process steps. This limited number of plating layers may reduce a risk of adhesion issues between layers. The limited number of manufacturing process steps may reduce or control resource usage and provide an effective way to provide contacts having good corrosion and wear performance. Methods of selecting elements for a binary alloy and examples are shown below and in the following figures.

[0057] FIG. **7** illustrates a method of selecting an element as a first element in a binary alloy according to an embodiment of the present invention. The binary alloy may include a first element that is selected for its ability to plate onto a contact, in act **710**. This ability to plate may help to simplify the manufacturing process and help to reduce or control an amount of resources used during the manufacturing process. The first element may further be selected to provide a good catalyst such that water on a contact is converted into oxygen, in act **720**. This may help to prevent the plated material from dissolving in the presence of moisture, particularly when a contact is providing a voltage.

[0058] FIG. **8** illustrates a method of selecting an element as a second element in a binary alloy according to an embodiment of the present invention. A second element in the binary alloy may be selected based on its ability to act as a grain refiner in act **810**. Specifically, the second element may be selected for its ability to reduce an energy at the grain boundaries of the binary alloy as it is plated on a contact. This smaller grain size may allow binary alloy to be plated thicker. The resulting plating may also reduce local stress in the plating, which may reduce cracking and thereby improve corrosion resistance. The smaller grain size may further increase hardness, which may improve wear and corrosion resistance.

[0059] In these and other embodiments of the present invention, the second element in the binary alloy may further be selected based on its ability to be plate well, in act **820**. This ability to plate well may simplify the manufacturing process and may help to reduce or control an amount of resources used. In act **830**, the second element may also be selected based on its ability to act as a catalyst to reduce water to oxygen.

[0060] In these and other embodiments of the present invention, the first element may be an element in a first group consisting of platinum, palladium, iridium, osmium, rhodium, and ruthenium. In these and other embodiments of the present invention, the first element may be an element in a first group consisting of platinum, palladium, iridium, osmium, and rhodium. In these and other embodiments of the present invention, the first element may be an element in a first group consisting of rhodium, iridium, platinum, and rhenium. In these and other embodiments of the present invention, the first element may be rhodium.

[0061] In these and other embodiments of the present invention, the second element may be an element in a second group consisting of platinum, palladium, iridium, osmium, rhodium, and ruthenium. In these and other embodiments of the present invention, the second element may be an element in a second group consisting of platinum, palladium, iridium, ruthenium, osmium, and rhodium. In these and other embodiments of the present invention, the second element may be an element in a second group consisting of molybdenum, niobium, tungsten, rhenium, iridium, iron, nickel, rhodium, and ruthenium. In these and other embodiments of the present invention, the second element may be iridium. In these and other embodiments of the present invention, the second element may be ruthenium.

[0062] In these and other embodiments of the present invention, the first element may be rhodium and the second element may be iridium. In these and other embodiments of the present invention, the first element may be rhodium and the second element may be one of molybdenum, niobium, and tungsten. In these and other embodiments of the present invention, the first element may be iridium and the second element may be one of rhenium and tungsten. In these and other embodiments of the present invention, the first element may be platinum and the second element may be one of iridium, iron, nickel, rhenium, rhodium, ruthenium, and tungsten. In these and other embodiments of the present invention, the first element may be rhenium and the second element may be tungsten.

[0063] The use of one of these materials as the second element may provide an inorganic grain refiner. The use of an inorganic grain refiner may reduce the amount of hydrogen in the plating, which may further reduce the tendency of the plating to crack.

[0064] In these and other embodiments of the present invention, the first element may comprise approximately 90 percent of the binary alloy while the second element may comprise approximately 10 percent of the binary alloy. In these and other embodiments of the present invention, the first element may comprise approximately 95 percent of the binary alloy while the second element may comprise approximately 5 percent of the binary alloy. In these and other embodiments of the present invention, the first element may comprise approximately 99 percent of the binary alloy while the second element may comprise approximately 1 percent of the binary alloy. In these and other embodiments of the present invention, the first element may be at least approximately 80 percent, 90 percent, 95 percent, in the range of 80-99 percent, or other percentage by weight. In these and other embodiments of the present invention, the second element may be at least approximately 20 percent, 10 percent, 5 percent, in the range of 1-20 percent, or other percentage by weight. In these and other embodiments of the present invention, the first element may be rhodium and the second element may be ruthenium. The binary alloy may have a thickness in the range of 0.5 to 2 microns, from 1 to 4 microns, from 2 to 6 microns, or more than 6 microns. It may have a thickness of 2 microns, 3 microns, 4 microns, 5 microns, or more than 5 microns. In these and other embodiments of the present invention, the binary alloy may have a greater thickness, such as 10-50 microns, 50-100 microns, 100-150 microns, or more than 150 microns. For example, it may have a thickness of 60 microns, 80 microns, 100 microns, 120 microns, 140 microns, or more than 140 microns.

[0065] In these and other embodiments of the present invention, the first element may comprise more than or approximately 99.5 percent of the binary alloy while the second element may comprise less than or approximately 0.5 percent of the binary alloy. This may be particularly true where the first element is rhodium and the second element is iridium. Iridium may not plate well, and keeping its percentage to a minimum may reduce some of the complications that may otherwise result.

[0066] In these and other embodiments of the present invention, including the above contacts, other layers, such as barrier layers to prevent corrosion of internal structures may be included. For example, barrier layers, such as zinc barrier layers, may be used to protect magnets or other internal structures from corrosion by cladding or plating layers. Catalyst layers may be used to improve the rate of deposition for other layers, thereby improving the manufacturing process. These catalyst layers may be formed of palladium or other material. Stress separation layers, such as those formed of copper, may also be included in these and other embodiments of the present invention, including the above contacts. Other scratch protection, passivation, and corrosion resistance layers may also be included.

[0067] For example, in FIG. **2**, a substrate for contact **200** may be formed of copper, bronze, copper alloy or other material. Surface-mount contacting portion **230** of contact **200** may be plated with a layer of nickel and a gold flash. This may provide a good layer for soldering the surface-mount contacting portion **230** to a contact on a printed circuit board, flexible circuit board, or other appropriate substrate. It may simplify manufacturing to allow the nickel and gold layers to cover the entire contact. In this case, a copper leveling layer may be used as a leveling agent and the copper layer may then be covered with the nickel and gold layers. A binary alloy may be plated over the nickel and gold afterward. The gold may assist in the adhesion of the binary alloy. In these and other embodiments of the present invention, the copper leveling layer over the contact may have a thickness of 2 microns, 3 microns, 4 microns, 5 microns, or more than 5 microns. In these and other embodiments of the present invention, the binary alloy may have a greater thickness, such as 10-50 microns, 50-100 microns, 40-120 u, 100-150 microns, or more than 150 microns. For example, it may have a thickness of 60 microns, 80 microns, 100 microns, 120 microns, 140 microns, or more than 140 microns. The nickel layer may be formed of nickel or a nickel alloy, such as an electroless nickel plating, nickel tungsten, or other material. The gold flash may have a thickness of 1 micron, 2 microns, 2.2 microns, 2.4 microns, 2.6 microns, 2.8 microns, 3 micron, 4 microns, 5 microns, or more than 5 microns. A binary alloy layer may then be plated over the contact. In these and other embodiments of the present invention, one or more of these layers may be omitted, and one or more other layers may be included.

[0068] Again, in these and other embodiments of the present invention, plating of one or more layers, such as a binary alloy layer, may be performed using a signal such as an alternating voltage or current, though in these and other embodiments of the present invention, a constant or DC voltage or current may be used. This binary alloy layer may be plated over the gold flash or other layer in the example above. Some examples are shown in the following figures.

[0069] FIG. **9** illustrates a DC waveform of a current flowing through a contact during plating according to an embodiment of the present invention. In this example, a constant or DC current having an amplitude **910** may flow through a contact submerged in a bath for a duration **920**.

[0070] In these and other embodiments of the present invention, the DC current may have various amplitudes **910**. For example, the DC current may have an amplitude **910** of 1 amps/square decimeter, (ASD), between 1-5 ASD, 4 ASD, between 4-8 ASD, 4 ASD, 6 ASD, 8 ASD, 10 ASD, 12 ASD, between 5-8 ASD, between 6-12 ASD, 14 ASD, between 10-20 ASD, 16 ASD, 20 ASD, between 20-30 ASD, 25 ASD, 30 ASD, 35 ASD, between 30-40 ASD, 40 ASD, 45 ASD, 50 ASD, between 40-60 ASD, or more than 60 ASD, or it may have another amplitude.

[0071] Using a DC waveform as shown may result in an uneven distribution of the plating material. In these and other embodiments of the present invention, plating on portions of a contact near a carrier used during manufacturing may be undesirably thin, while plating on portions of the contact away from the carrier may be excessively thick and subject to cracking. (Again, a contact, such as contact **200** in FIG. **2**, may be attached to a carrier at or near surface-mount contacting portion **230**.) This cracking may result in an increase in the rate of corrosion of the contact. Similarly, a contact portion having an undesirably thin plating may not be adequately protected and may also be subject to corrosion. This uneven distribution of plating may be reduced by using shielding. This shielding may reduce a localized current flow current thereby helping to prevent plating in various areas from becoming excessively thick while other portions remain undesirably thin.

[0072] Again, in these and other embodiments of the present invention, an alternating or pulsed signal, such as a voltage or current, may be applied to, or may flow through, the contact during plating to improve plating uniformity. Examples are shown in the following figures.

[0073] FIG. **10** illustrates a pulsed waveform of a current flowing through a contact during plating according to an embodiment of the present invention. In this example, an alternating or pulsed current having amplitude **1010** may flow through a contact submerged in a bath for a number of pulses. The pulses may be on for a time **1020** and may be off for a time **1030**. Off times **1030** may allow time for ions to migrate to a surface of the contact. This migration may improve uniformity of the plated material. In these and other embodiments of the present invention, a shorter on time **1020** and a longer off time **1030** may improve uniformity of the plated material. The current density, the amplitude **1010**, can be increased to shorten plating time and increase manufacturing throughput.

[0074] In these and other embodiments of the present invention, on times **1020** and off times **1030** of the pulses may have various durations, while the pulses may have various amplitudes **1010**. For example, the pulses may have an amplitude **1010** of 1 ASD, between 1-5 ASD, 4 ASD, between 4-8 ASD, 4 ASD, 6 ASD, 8 ASD, 10 ASD, 12 ASD, between 5-8 ASD, between 6-12 ASD, 14 ASD, between 10-20 ASD, 16 ASD, 20 ASD, between 20-30 ASD, 25 ASD, 30 ASD, 35 ASD, between 30-40 ASD, 40 ASD, 45 ASD, 50 ASD, between 40-60 ASD, or more than 60 ASD, or they may have another amplitude. On time **1020**, may have a duration of 1 milliseconds (ms), 2 ms, between 2-5 ms, 4 ms, 5 ms, 6 ms, between 4-8 ms, 8 ms, 10 ms, between 7-14 ms, 12 ms, 14 ms, 18 ms, between 10-20 ms, 20 ms, 22 ms, 25 ms, between 15-30 ms, between 20-30 ms, 30 ms, 35 ms, 40 ms, or more than 40 ms. Off time **1030**, may have a duration of 1 milliseconds (ms), 2 ms, between 2-5 ms, 4 ms, 5 ms, 6 ms, between 4-8 ms, 8 ms, 10 ms, between 7-14 ms, 12 ms, 14 ms, 18 ms, between 10-20 ms, 20 ms, 22 ms, 25 ms, between 15-30 ms, between 20-30 ms, 30 ms, 35 ms, 40 ms, or more than 40 ms. The on times **1020** and off times **1030** may have the same or different values.

[0075] FIG. **11** illustrates a pulsed waveform of a current flowing through a contact during plating according to an embodiment of the present invention. In this example, forward alternating or pulsing current having amplitude **1110** may flow through a contact submerged in a bath for a number of pulses having a duration **1120**. These durations **1120** may be separated by gaps **1130**. Gaps **1130** may allow time for ions to migrate to a surface of the contact. This migration may improve uniformity in the plated material. Reverse current pulses having amplitude **1140** may flow during the gaps **1130**. Reverse current pulses having amplitudes **1140** may improve uniformity and control grain size.

[0076] In these and other embodiments of the present invention, duration **1120** and gaps **1130** of the pulses may have various durations, while the forward and reverse pulses may have various amplitudes **1110** and **1140**. For example, the pulses may have amplitudes **1110** and **1140** of 1 ASD, between 1-5 ASD, 4 ASD, between 4-8 ASD, 4 ASD, 6 ASD, 8 ASD, 10 ASD, 12 ASD, between 5-8 ASD, between 6-12 ASD, 14 ASD, between 10-20 ASD, 16 ASD, 20 ASD, between 20-30 ASD, 25 ASD, 30 ASD, 35 ASD, between 30-40 ASD, 40 ASD, 45 ASD, 50 ASD, between 40-60 ASD, or more than 60 ASD, or they may have another amplitude. Durations **1120** and gaps **1130** may have a duration of 1 ms, 2 ms, between 2-5 ms, 4 ms, 5 ms, 6 ms, between 4-8 ms, 8 ms, 10 ms, between 7-14 ms, 12 ms, 14 ms, 18 ms, between 10-20 ms, 20 ms, 22 ms, 25 ms, between 15-30 ms, between 20-30 ms, 30 ms, 35 ms, 40 ms, or more than 40 ms. Amplitudes **1110** and **1140** may have the same or different values. Durations **1120** and gaps **1130** may have the same or different durations.

[0077] FIG. **12** illustrates another pulsed waveform of a current flowing through a contact during plating according to an embodiment of the present invention. In this example, a pulsing current having amplitude **1210** may flow through a contact submerged in a bath for a number of pulses having duration **1220**. These pulses may be separated by gaps **1230** where current does not flow, at least in a substantial amount. Gaps **1230** may allow time for ions to migrate to a surface of the contact. This migration may improve uniformity in the plated material. After current pulses having amplitude **1210** have flowed through the contact, a current pulse having a larger amplitude **1260** may flow through the contact. The smaller amplitude pulses having amplitude **1210** may act to primarily plate one of the elements in the binary alloy, while the larger pulses having amplitude **1260** may cause the second element in the binary alloy to plate on the contact. A gap **1250** may follow these larger pulses having amplitude **1260** and may be longer than gap **1230**. Reverse current pulses having amplitude **1240** may flow during a portion **1270** of the gaps **1250**, while current does not flow, at least in a substantial amount, for the remaining portion **1280** of the gap **1250**. Reverse current pulses having amplitude **1240** may improve uniformity and control grain size.

[0078] In these and other embodiments of the present invention, duration **1220** and gaps **1230** and **1250** of the pulses may have various durations, while the forward and reverse pulses may have various amplitudes **1210**, **1240**, and **1260**. For example, the pulses may have amplitudes **1210**, **1240**, and **1260** of 1 ASD, between 1-5 ASD, 4 ASD, between 4-8 ASD, 4 ASD, 6 ASD, 8 ASD, 10 ASD, 12 ASD, between 5-8 ASD, between 6-12 ASD, 14 ASD, between 10-20 ASD, 16 ASD, 20 ASD, between 20-30 ASD, 25 ASD, 30 ASD, 35 ASD, between 30-40 ASD, 40 ASD, 45 ASD, 50 ASD, between 40-60 ASD, or more than 60 ASD, or they may have another amplitude. Durations **1220** and gaps **1230** and **1250** may have durations of 1 ms, 2 ms, between 2-5 ms, 4 ms, 5 ms, 6 ms, between 4-8 ms, 8 ms, 10 ms, between 7-14 ms, 12 ms, 14 ms, 18 ms, between 10-20 ms, 20 ms, 22 ms, 25 ms, between 15-30 ms, between 20-30 ms, 30 ms, 35 ms, 40 ms, or more than 40 ms. Amplitudes **1210**, **1240**, and **1260** may have the same or different values. Durations **1220** and gaps **1230** and **1250** may have the same or different durations.

[0079] In these and other embodiments of the present invention, the plating may be done by applying a DC or pulsed signal to a contact while the contact is at least partially submerged in a bath. In these and other embodiments of the present invention, the contact may be submerged before a signal is applied to the contact, or a signal may be applied to the contact before submersion, or these events may occur simultaneously. In these and other embodiments of the present invention, these events may occur in either order or simultaneously.

[0080] A contact **200** has been shown above. In these and other embodiments of the present invention, other types of contacts may be made and they may be used in different locations. For example, they may be located at a surface of a device enclosure, in a connector insert, in a connector receptacle, or in another contacting structure. Also, while contact **200** is shown as having a particular shape, these shapes may vary in these and other embodiments of the present invention.

[0081] While embodiments of the present invention are well-suited to contacts and their method of manufacturing, these and other embodiments of the present invention may be used to improve the corrosion resistance of other structures. For example, electronic device cases and enclosures, connector housings and shielding, battery terminals, magnetic elements, measurement and medical devices, sensors, fasteners, various portions of wearable computing devices such as clips and bands, bearings, gears, chains, tools, or portions of any of these, may be covered with a precious-metal alloy and plating layers as described herein and otherwise provided for by embodiments of the present invention. The precious-metal alloy and plating layers for these structures may be formed or manufactured as described herein and otherwise provided for by embodiments of the present invention. For example, magnets and other structures for fasteners, connectors, speakers, receiver magnets, receiver magnet assemblies, microphones, and other devices may have their corrosion resistance improved by structures and methods such as those shown herein and in other embodiments of the present invention.

[0082] In these and other embodiments of the present invention, the components of contacts and their connector assemblies may be formed in various ways of various materials. For example, contacts and other conductive portions may be formed by stamping, metal-injection molding, machining, micro-machining, 3-D printing, or other manufacturing process. The conductive portions may be formed of stainless steel, steel, copper, copper-nickel-silicon alloy, copper titanium, phosphor bronze, palladium, palladium silver or other material or combination of materials. They may be plated or coated with nickel, gold, or other material. The nonconductive portions, such as the housings and other portions may be formed using injection or other molding, 3-D printing, machining, or other manufacturing process. The nonconductive portions may be formed of silicon or silicone, Mylar, Mylar tape, rubber, hard rubber, plastic, nylon, elastomers, liquid-crystal polymers (LCPs), ceramics, or other nonconductive material or combination of materials.

[0083] Embodiments of the present invention may provide contacts and their connector assemblies that may be located in, and may connect to, various types of devices, such as portable computing devices, tablet computers, desktop computers, laptops, all-in-one computers, wearable computing devices, cell phones, smart phones, media phones, storage devices, keyboards, covers, cases, portable media players, navigation systems, monitors, power supplies, adapters, remote control devices, chargers, and other devices. These contacts and their connector assemblies may provide pathways for signals that are compliant with various standards such as Universal Serial Bus (USB), High-Definition Multimedia Interface (HDMI), Digital Visual Interface (DVI), Ethernet, DisplayPort, Thunderbolt, Lightning, Joint Test Action Group (JTAG), test-access-port (TAP), Directed Automated Random Testing (DART), universal asynchronous receiver/transmitters (UARTs), clock signals, power signals, and other types of standard, non-standard, and proprietary interfaces and combinations thereof that have been developed, are being developed, or will be developed in the future. In various embodiments of the present invention, these interconnect paths provided by these contacts and connectors may be used to convey power, ground, signals, test points, and other voltage, current, data, or other information.

[0084] The above description of embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form described, and many modifications and variations are possible in light of the teaching above. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. Thus, it will be appreciated that the invention is intended to cover all modifications and equivalents within the scope of the following claims.

What is claimed is:

1. A method of forming a contact, the method comprising:

plating the contact with a binary alloy by:

receiving a contact;

applying an alternating signal to the contact; and

at least partially submerging the contact in a bath, the bath comprising:

a first element in a first group consisting of platinum, palladium, iridium, osmium, rhodium, and ruthenium; and

a second element in a second group consisting of platinum, palladium, iridium, osmium, rhodium, and ruthenium, where the second element is different from the first element.

2. The method of claim **1** wherein the first group consists of platinum, palladium, iridium, osmium, and rhodium.

3. The method of claim **2** wherein the second group consists of platinum, palladium, iridium, ruthenium, osmium, and rhodium.

4. The method of claim **1** wherein the first element is rhodium and the second element is ruthenium.

5. The method of claim **1** further comprising, before plating the contact with a binary alloy, stamping the contact.

6. The method of claim **5** further comprising, after stamping the contact and before plating the contact with a binary alloy, plating at least a portion of the contact with a leveling agent.

7. The method of claim **6** wherein the leveling agent is copper.

8. A method of forming a contact, the method comprising:

plating the contact with a binary alloy by:

selecting a first element by choosing a good catalyst that plates well;

selecting a second element by choosing an inorganic grain refiner that is a good catalyst,

applying an alternating signal to the contact; and

at least partially submerging the contact in a bath comprising the binary alloy.

9. The method of claim **8** wherein the first element is one of a group consisting of platinum, palladium, iridium, osmium, and rhodium.

10. The method of claim **9** wherein the second element is one of a group consisting of platinum, palladium, iridium, ruthenium, osmium, and rhodium.

11. The method of claim **8** wherein the first element is rhodium and the second element is ruthenium.

12. The method of claim **11** wherein the binary alloy is approximately 99 percent rhodium and approximately 1 percent ruthenium.

13. The method of claim **12** wherein the binary alloy is approximately 90 percent rhodium and approximately 10 percent ruthenium.

14. A method of forming a contact, the method comprising:

stamping a contact;

plating at least a first portion of the contact with a leveling agent; and

plating a least a portion of the first portion of the contact with a binary alloy by:

applying a signal to the contact; and

at least partially submerging the contact in a bath.

15. The method of claim **14** wherein the binary alloy comprises:

a first element in a first group consisting of platinum, palladium, iridium, osmium, rhodium, and ruthenium; and

a second element in a second group consisting of platinum, palladium, iridium, osmium, rhodium, and ruthenium, where the second element is different from the first element.

16. The method of claim **15** wherein the first group consists of platinum, palladium, iridium, osmium, and rhodium.

17. The method of claim **16** wherein the second group consists of platinum, palladium, iridium, ruthenium, osmium, and rhodium.

18. The method of claim **17** wherein the first element is rhodium and the second element is ruthenium.

19. The method of claim **17** wherein the binary alloy is approximately 90 percent rhodium and approximately 10 percent ruthenium.

20. The method of claim **14** wherein the leveling agent is copper.

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