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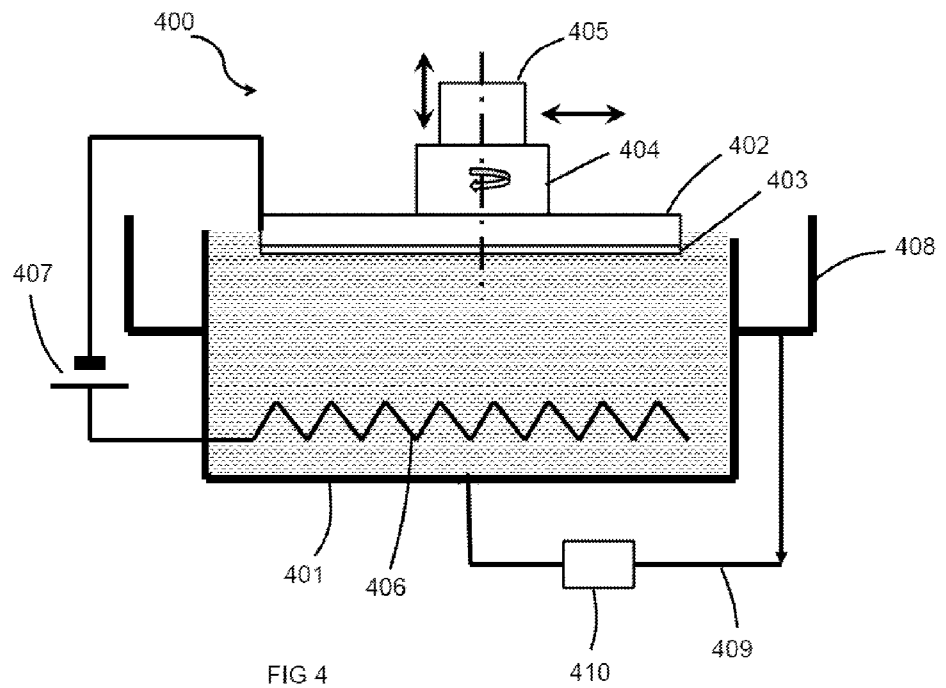

FIG 4

(57) Abstract: The present invention discloses plating apparatuses and plating methods for metal deposition on a substrate with pattern structures. In an embodiment, a plating apparatus comprises a plating bath configured to accommodate electrolyte, a substrate holding module configured to hold a substrate, and at least one driving device configured to drive the substrate holding module together with the substrate to horizontally vibrate and/or vertically vibrate during the substrate being immersed into the electrolyte to be plated. The present invention can enhance mass transfer during the substrate being plated by vibrating the substrate holding module so as to raise plating rate and uniformly plating on the pattern structures.

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PLATING APPARATUS AND PLATING METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention generally relates to semiconductor devices manufacturing, and more particularly relates to plating apparatus and plating method with electrolyte agitation for raising plating rate.

2. The Related Art

[0002] For manufacturing semiconductor devices, plating technology is commonly used for forming metal films in interconnect structures, such as trenches, holes, TSVs, etc. in dual damascene process, or for forming bumps or the like in advanced packaging process. With the rapid development of technology, not only higher requirements are put forward for plating quality, but also for plating rate. The plating rate becomes more and more important for both dual damascene process and advanced packaging process that because higher plating rate means higher through put.

[0003] Generally, the plating rate is related to the following factors, for example, composition of electrolyte, temperature of electrolyte, and agitation of electrolyte, thereinto, the agitation of electrolyte is further related to, for example, electrolyte flow rate, rotation speed of a substrate to be plated, and vibration applied to the electrolyte. At present, there are several ways to enhance the agitation of electrolyte so as to enhance mass transfer during plating to raise plating rate. One way is to use a flow shaping plate in conjunction with a flow diverter, where a flow port configured to enhance transverse flow. Although this way can control electrolyte flow dynamics for obtaining effective mass transfer during plating to obtain a high uniformity of plating, however, if the electrolyte flow is too strong from one side to another side over a substrate, the electrolyte flow will affect additives distribution in the electrolyte. Specifically, the flow rate of electrolyte at the side near the flow port is fast, and the flow rate of electrolyte at another side far away from the flow port is slow. Therefore, the flow rate of electrolyte across the center to edge of the substrate is not uniform. More specifically, the flow rate of electrolyte is strong at the flow port which is at edge of the substrate, and the flow rate of electrolyte is getting weaker and weaker while the electrolyte is flowing through the center of the substrate to another side of the substrate far away from the flow port. Many additives are sensitive to the flow rate of electrolyte, especially the plating leveler. If the flow rate of electrolyte is too strong and the distribution of the flow rate of electrolyte is not uniform across the entire substrate, the leveler is easier to adhere on the substrate surface where the flow rate of electrolyte is stronger, and thus the plating uniformity will be not good. Meanwhile, for micro structures in a semiconductor device, for example, bumps' profile will also be affected. The bumps' profile will be tilt due to the leveler sensitive to the flow rate of electrolyte. Although by rotating the substrate is capable of compensating the non-symmetric, however, the rotation speed of the substrate varies during plating process, which is very common in the industry, which will still lead to plating non-uniformity.

[0004] Another way of enhancing the agitation of electrolyte is to use a paddle, which utilizes paddle vibration to enhance the agitation of electrolyte. The drawback of this way is that since the paddle is generally set between a diffusion plate and a substrate to be plated, the high speed movement of the paddle will cause bubbles in the electrolyte, and the bubbles will attach on the substrate surface, where will be no plating, so that a plating quality issue will be caused. Another issue caused by the paddle is that since the paddle has many openings, and the pattern and size of the openings will affect the electric field distribution, which may cause the plating uniformity issue on the substrate. Furthermore, when the paddle is used to agitate the flow adjacent to the substrate surface, it can create shadows in the electric field within the electrolyte and it will cause the uniformity problem on the plated substrates.

[0005] Besides, in order to achieve higher plating rate, the electrolyte has different formula from lower speed plating electrolyte. Taking Cu plating as an example, the traditional plating rate is at 2-5 ASD, for the plating rate higher than 8 ASD, more specifically form 8 to 30ASD, the Cu ions concentration in the electrolyte is higher and the additives will be more complex. The higher plating rate, the more difficult to control the film or bump profile. And as the device structure becomes more complicated, such as there are both trenches and big pad structures within one die, the leveler needs to be stronger. Also wafer level uniformity is also difficult to control by plating at high speed. At both wafer level and within die to achieve better results during plating, the additives in the electrolyte, such as accelerator, leveler and suppressor need to co-work with each other.

[0006] Therefore, there are shortcomings in the current ways of agitation of electrolyte. It is necessary to propose a new way of agitation of electrolyte to raise plating rate as well as plating uniformity.

SUMMARY OF THE INVENTION

[0007] Accordingly, an object of the present invention is to provide a plating apparatus for metal deposition on a substrate with pattern structures. The plating apparatus comprises a plating bath configured to accommodate electrolyte, a substrate holding module configured to hold a substrate, and at least one driving device configured to drive the substrate holding module together with the substrate to horizontally vibrate and/or vertically vibrate during the substrate being immersed into the electrolyte to be plated.

[0008] Accordingly, another object of the present invention is to provide a plating method for metal deposition on a substrate with pattern structures. The plating method comprises the following steps: loading a substrate in a substrate holding module to be held by the substrate holding module; making the substrate immerse into electrolyte accommodated in a plating bath; driving the substrate holding module together with the substrate to horizontally vibrate and/or vertically vibrate during the substrate being immersed into the electrolyte to be plated.

[0009] Accordingly, an object of the present invention is to provide a plating apparatus for metal deposition on a substrate with pattern structures. The plating apparatus comprises a plating bath configured to accommodate electrolyte, a substrate holding module configured to hold a substrate, a rotating actuator configured to drive the substrate holding module together with the substrate to rotate, and a controller, configured to control the rotating actuator to rotate N turns and then reversely rotate N turns, which are alternately applied for a number of cycles, the N is equal to or less than 3.0.

[0010] Accordingly, another object of the present invention is to provide a plating method for metal deposition on a substrate with pattern structures. The plating method comprises the following steps: loading a substrate in a substrate holding module to be held by the substrate holding module; making the substrate immerse into electrolyte accommodated in a plating bath; driving the substrate holding module together with the substrate to rotate by a rotating actuator during the substrate being immersed into the electrolyte to be plated; controlling the rotating actuator to rotate N turns and then reversely rotate N turns, which are alternately applied for a number of cycles, wherein the N is equal to or less than 3.0.

[0011] As described above, the present invention discloses a unique way to agitate the electrolyte while the substrate being plated, that is making the substrate holding module together with the substrate vibrate, which can enhance mass transfer so as to raise plating rate as well as plating uniformity. Furthermore, since the vibration of the substrate holding module is back and forth and the vibration frequency is fast enough to make additives distribute uniformly in the pattern structures. The mass transfer boundary layer of the electrolyte will be much thinner, and the additives in the electrolyte which are absorbed into pattern structures are exchanged very fast and uniform, so the uniformity of the plated metal in the pattern structures is improved, overcoming the pillar or bump tilt issue, and meanwhile the plating rate can be higher too.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a schematic view illustrating a conventional plating apparatus.

[0013] FIGS. 2A-2C are schematic views illustrating plated metal pillars or bumps tilt while employing the conventional plating apparatus to perform metal deposition.

[0014] FIGS. 3A-3C are schematic views illustrating plated metal pillars or bumps tilt while employing the conventional plating apparatus to perform metal deposition.

[0015] FIG. 4 is a schematic view illustrating a plating apparatus according to an exemplary embodiment of the present invention.

[0016] FIG. 5A and FIG. 5B are schematic views illustrating a relative velocity being rapidly changed to realize electrolyte agitation.

[0017] FIG. 6 is a schematic view illustrating a plating apparatus according to another exemplary embodiment of the present invention.

[0018] FIGS. 7A-7B are schematic views illustrating a plating apparatus according to an exemplary embodiment of the present invention.

[0019] FIGS. 8A-8B and FIGS. 9A-9B are schematic views illustrating a substrate holding module of the plating apparatus horizontal vibration.

[0020] FIGS. 10A-10B and FIGS. 11A-11B are schematic views illustrating a plating apparatus according to another exemplary embodiment of the present invention.

[0021] FIGS. 12A-12B are schematic views illustrating a plating apparatus according to an exemplary embodiment of the present invention.

[0022] FIGS. 13A-13B and FIGS. 14A-14B are schematic views illustrating a substrate holding module of the plating apparatus vertical vibration.

[0023] FIGS. 15A-15B and FIGS. 16A-16B are schematic views illustrating a plating apparatus according to another exemplary embodiment of the present invention.

[0024] FIGS. 17A-17B are schematic views illustrating a plating apparatus according to yet another exemplary embodiment of the present invention.

[0025] FIGS. 18A-18C are schematic views illustrating a plating apparatus according to an exemplary embodiment of the present invention.

[0026] FIGS. 19A-19C and FIGS. 20A-20C are schematic views illustrating a substrate holding module of the plating apparatus horizontal vibration and vertical vibration simultaneously.

[0027] FIG. 21 is a model diagram of vibration.

[0028] FIG. 22 is a schematic view illustrating a plating apparatus according to an exemplary embodiment of the present invention.

[0029] FIG. 23 is a schematic view illustrating a plating apparatus according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0030] Please refer to FIG. 1 illustrating a conventional plating apparatus 100 for metal deposition. The plating apparatus 100 has a plating bath 110 for accommodating electrolyte, a substrate holding module 120 for holding a substrate 130 and electrically connecting with a conductive side of the substrate 130, a rotating actuator 140 connecting with the substrate holding module 120 for driving the substrate holding module 120 to rotate along the axis of the substrate holding module 120, an anode 150 being disposed in the plating bath 110 and facing the conductive side of the substrate 130, a power supply 160 electrically connecting with the substrate holding module 120 and the anode 150. The plating apparatus 100 further has a groove 170 which is disposed around the plating bath 110 for receiving the electrolyte overflowed from the plating bath 110. The plating apparatus 100 further has a tank 190. A pipeline 180 is connected to the groove 170 and the tank 190, and the tank 190 is connected to the plating bath 110 by another pipeline 180.

[0031] When the plating apparatus 100 is used for depositing metal on the substrate 130 with pattern structures 131, the rotating actuator 140 drives the substrate holding module 120 to rotate along the axis of the substrate holding module 120 and the electrolyte is supplied from the center of the plating bath 110 and flows through the center of the substrate 130 to the edge of the substrate 130. Generally, for depositing metal on the substrate 130, various additives such as leveler, accelerator, suppressor, etc. are added to the electrolyte. Thereinto, some additives are sensitive to the flow rate of electrolyte. For example, in the electrolyte of Cu plating, the leveler is easier to adhere on the substrate surface where the flow rate of electrolyte is stronger, so when the leveler plays a major role during plating, the leveler has more chance staying at one side of pattern structures 131 induced by the electrolyte flowing from center to edge of the substrate 130, which causes the leveler is distributed non-uniform in the pattern structures 131, resulting in uneven metal deposition in the pattern structures 131, causing metal pillars or bumps tilt, as shown in FIG. 2A to FIG. 2C. Another example, in the electrolyte for Cu plating, the accelerator is more sensitive to the flow rate of electrolyte. The accelerator is easier to adhere on the substrate surface where the flow rate of electrolyte is stronger. In another embodiment, when the accelerator plays a major role during plating, the accelerator has more chance staying at one side of pattern structures 131’ on a substrate 130’ induced by the electrolyte flowing from center to edge of the substrate 130’, which causes the accelerator is distributed non-uniform in the pattern structures 131’, resulting in uneven metal deposition in the pattern structures 131’, causing metal pillars or bumps tilt, as shown in FIG. 3A to FIG. 3C. The tilt will be bigger when the plating is high. In order to achieve better bump profile at high plating rate new technology is necessary.

[0032] In order to solve the problem and obtain uniform metal deposition in pattern structures on a substrate, the present invention discloses plating apparatuses and plating methods which can make additives, such as leveler, accelerator and suppressor, distribute uniformly in the pattern structures, no longer gathering in one place by driving a substrate holding module together with the substrate to vibrate during the substrate being immersed into electrolyte to be plated, so as to reduce the tilt of plated metal pillars or bumps and obtain uniform metal deposition in the pattern structures. High frequency vibration can also reduce the electrolyte boundary layer thickness. The thinner boundary layer thickness can achieve higher mass transfer rate, and the metal depositing rate can be higher.

[0033] Referring to FIG. 4, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to an exemplary embodiment of the present invention. The plating apparatus 400 has a plating bath 401 configured to accommodate electrolyte, a substrate holding module 402 configured to hold a substrate 403 and electrically connecting with a conductive side of the substrate 403, a rotating actuator 404 configured to drive the substrate holding module 402 to rotate along the axis of the substrate holding module 402, at least one driving device 405 configured to drive the substrate holding module 402 to horizontally vibrate and/or vertically vibrate. The driving device 405 can be a motor, a cylinder or a vibrator. The plating apparatus 400 further includes at least one anode 406 being disposed in the plating bath 401 and facing the conductive side of the substrate 403, a power supply 407 electrically connecting with the substrate holding module 402 and the anode 406. A groove 408 is disposed around the plating bath 401 for receiving the electrolyte overflowed from the plating bath 401. The plating apparatus 400 further has a tank 410. A pipeline 409 is connected to the groove 408 and the tank 410, and the tank 410 is connected to the plating bath 401 by another pipeline 409.

[0034] Combining with FIG. 5A and FIG. 5B, the substrate 403 has pattern structures 4031. When the plating apparatus 400 is used for depositing metal in the pattern structures 4031, the substrate 403 is horizontally held by the substrate holding module 402, and then the substrate 403 is immersed into the electrolyte for plating, at the same time, the driving device 405 drives the substrate holding module 402 as well as the substrate 403 to perform reciprocating motion so as to agitate the electrolyte, including horizontal vibration and/or vertical vibration, which can enhance mass transfer so that the metal ions, the additives, such as leveler, accelerator, and suppressor can be distributed uniformly in the pattern structures 4031, no longer gathering in one place during the substrate 403 being immersed into the electrolyte to be plated, so as to reduce the tilt of plated metal pillars or bumps and obtain uniform metal deposition in the pattern structures 4031. Specifically, the rotating actuator 404 drives the substrate holding module 402 to rotate along the axis of the substrate holding module 402 while the substrate 403 being immersed into the electrolyte to be plated. The electrolyte is supplied from the center of the plating bath 401 and flows through the center of the substrate 403 to the edge of the substrate 403 with a flow rate V_2. The driving device 405 drives the substrate holding module 402 as well as the substrate 403 to horizontally vibrate with a vibration velocity V_1. The V_1 is no less than $0.2V_2$, and preferably, the V_1 is greater than the V_2, and more preferably, the V_1 is 2 times greater than the V_2. As shown in FIG. 5A, when the vibration direction is opposite to the flow direction of electrolyte, a relative velocity V is equal to $V_1 + V_2$. As shown in FIG. 5B, when the vibration direction is the same as the flow direction of electrolyte, a relative velocity V is equal to $V_1 - V_2$. The relative velocity V is rapidly changed due to the horizontal vibration of the substrate holding module 402, which realizes the agitation of electrolyte so as to enhance mass transfer, improve distribution uniformity of the additives in the pattern structures 4031 and further improve plating rate and plating uniformity.

[0035] Referring to FIG. 6, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to another exemplary embodiment of the present invention. The plating apparatus 600 has a plating bath 601 configured to accommodate electrolyte, a substrate holding module 602 configured to hold a substrate 603, at least one driving device 605 configured to drive the substrate holding module 602 to horizontally vibrate and/or vertically vibrate. The driving device 605 can be a motor, a cylinder or a vibrator. The plating apparatus 600 further has at least one anode 606 being disposed in the plating bath 601 and facing a conductive side of the substrate 603, a power supply 607 electrically connecting with the conductive side of the substrate 603 and the anode 606. A groove 608 is disposed around the plating bath 601 for receiving the electrolyte overflowed from the plating bath 601. The plating apparatus 600 further has a tank 610. A pipeline 609 is connected to the groove 608 and the tank 610, and the tank 610 is connected to the plating bath 601 by another pipeline 609.

[0036] In this embodiment, the substrate 603 with pattern structures is vertically held by the substrate holding module 602. The substrate holding module 602 and the substrate 603 are vertically immersed into the electrolyte for depositing metal in the pattern structures. During the plating, the driving device 605 drives the substrate holding module 602 as well as the substrate 603 to perform reciprocating motion to agitate the electrolyte, including horizontal vibration and/or vertical vibration, which can enhance mass transfer so that the additives, such as leveler, accelerator, suppressor can be distributed uniformly in the pattern structures, no longer gathering in one place during the substrate 603 being immersed into the electrolyte to be plated, so as to reduce the tilt of plated metal pillars or bumps and obtain uniform metal deposition in the pattern structures.

[0037] With reference to FIGS. 7A-9B, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to an exemplary embodiment of the present invention. The plating apparatus 700 includes a plating bath 701, a substrate holding module, a vibrating plate 715, a mounting plate 716, a supporting pedestal 717 and a driving device 705. The substrate holding module further includes a substrate holder 702, supporting columns 712, a fixing device 713, a bracket 714 and a rotating actuator 704.

[0038] The plating bath 701 is configured to accommodate electrolyte. The plating bath 701 can include an anode chamber and a cathode chamber for electroplating. The anode chamber and the cathode chamber are separated by a membrane positioned on a membrane frame. The anode chamber can be divided into multiple anode zones and each anode zone accommodates an anode which is connected to an independently controlled power supply. The anodes can be made of materials such as copper (Cu), Ti or Ti plate with Pt coating. At least one diffusion plate 711 having a plurality of small apertures is disposed in the cathode chamber for electric field uniform control and flow of electrolyte uniform control. A groove 708 is disposed around the cathode chamber for receiving the electrolyte overflowed from the cathode chamber.

[0039] The substrate holder 702 is configured to hold a substrate. The supporting columns 712 are connected to the substrate holder 702 and the fixing device 713. The bracket 714 is fixed at a side of the fixing device 713. The vibrating plate 715 is configured to support the substrate holding module. One end of the vibrating plate 715 is connected to the bracket 714, and the other end of the vibrating plate 715 is connected to the mounting plate 716. The mounting plate 716 is disposed on the supporting pedestal 717. The mounting plate 716 is capable of moving up and down along the supporting pedestal 717 driven by a vertical actuator so as to bring the vibrating plate 715 to move up and down. The vibrating plate 715 has a natural frequency. The rotating actuator 704 is disposed on the fixing device 713 and configured to drive the substrate holder 702 to rotate. The driving device 705 is disposed on the bracket 714 and configured to drive the substrate holding module to horizontally vibrate or resonate with the natural frequency of the vibrating plate 715. The driving device 705 can be a vibrator, such as an inertia vibrator.

[0040] As shown in FIGS. 8A-8B and FIGS. 9A-9B, the driving device 705 is capable of driving the substrate holder 702 to horizontally vibrate while the substrate is immersed into the electrolyte to be plated. The substrate holder 702 can perform a reciprocating motion by the driving of the driving device 705. A pair of limit stop members 718 is configured to limit the amplitude of the substrate holding module so as to prevent the bracket 714 from impacting the mounting plate 716. The pair of limit stop members 718 can be made of soft rubber. In one embodiment, the pair of limit stop members 718 is disposed on the bracket 714 and respectively located at both sides of the vibrating plate 715. In another embodiment, the pair of limit stop members 718 is disposed on the mounting plate 716 and respectively located at both sides of the vibrating plate 715.

[0041] The amplitude of the substrate holding module is related to the size of pattern structures. Preferably, the amplitude of the substrate holding module is larger than the size of the pattern structures so as to improve the vibration effect on the metal deposition in the pattern structures. The amplitude of the substrate holding module can be set from 25um to 2000um, and preferably from 100um to 500um.

[0042] The vibration frequency of the substrate holding module is related to the amplitude of the substrate holding module and the vibration velocity of the substrate holding module. Further, the vibration velocity of the substrate holding module is related to the flow rate of electrolyte. Preferably, the vibration velocity of the substrate holding module is larger than the flow velocity from center to edge of the electrolyte. Normally the flow velocity of electrolyte is set from 0.01 m/s to 0.2 m/s, which depends on the initial flow rate of the electrolyte supply. The vibration frequency of the substrate holding module can be calculated by the calculation formula: $f = \frac{V1}{4A}$, wherein, f is the vibration frequency of the substrate holding module, V1 is the vibration velocity of the substrate holding module, A is the amplitude of the substrate holding module. For example, setting V1 is 0.02 m/s, A is 0.5 mm, f is calculated out to be 10 Hz. This frequency is a resonance frequency of the substrate holding module and the vibrating plate 715 which is more specifically a cantilever structure, and also is the natural frequency of the vibrating plate 715, and yet is the starting frequency of the driving device 705. The inertia vibrator working frequency can be set from 0.1Hz to 500Hz. And preferably it is set equal to the resonance frequency of the vibrating plate 715, which needs the least energy to drive it.

[0043] With reference to FIG. 21, a model diagram of vibration is shown. Combining with the model diagram and the following calculation formulas, the size of the vibrating plate 715 can be got.

[0044] $$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \quad (1)$$

[0045] $$k = m * (2\pi f)^2 \quad (2)$$

[0046] $$k = \frac{EHB^3}{4L^3} \quad (3)$$

[0047] $$B = \left(\frac{4kL^3}{EH}\right)^{\frac{1}{3}} \quad (4)$$

[0048] In the calculation formulas (1)-(4), f is the vibration frequency of the substrate holding module, m is the weight of the substrate holding module, k is the stiffness coefficient of the vibrating plate, E is the elastic modulus of material of the vibrating plate, H is the cross section width of the vibrating plate, B is the cross section height of the vibrating plate, L is the length of the vibrating plate.

[0049] Based on the calculation formulas (1)-(4), the size of the vibrating plate 715 can be got. Some examples are given in the following table.

M(kg)=	30	30	30	30	30	30
f1(Hz)=	10	10	20	30	40	50
K1(N/m)=	118435.2528	118435.2528	473741.0113	1065917.275	1894964.045	2960881.32
π=	3.141592654	3.141592654	3.141592654	3.141592654	3.141592654	3.141592654
E(Pa)=	20600000000	20600000000	20600000000	20600000000	20600000000	20600000000
H(m)=	0.05	0.1	0.1	0.1	0.1	0.1
L(m)=	0.024	0.024	0.024	0.024	0.024	0.024
B1(m)=	0.001852589	0.001470401	0.002334116	0.003058558	0.003705179	0.004299479

[0050] Referring to FIGS. 10A-11B, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to another exemplary embodiment of the present invention. Comparing to the plating apparatus shown in FIGS. 7A-9B, in this embodiment, a driving device 705' can be a pair of motors or cylinders to drive the substrate holding module to horizontally vibrate in resonance with the vibrating plate 715. The pair of motors or cylinders can be disposed on the bracket 714 and respectively located at both sides of the vibrating plate 715. Or, the pair of motors or cylinders can be disposed on the mounting plate 716 and respectively located at both sides of the vibrating plate 715.

[0051] Referring to FIG. 12A to FIG. 14B, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to another embodiment of the present invention. The plating apparatus 1200 includes a plating bath 1201, a substrate holding module, a pair of vibrating plates 1215, a mounting plate 1216, a supporting pedestal 1217 and a driving device 1205. The substrate holding module further includes a substrate holder 1202, supporting columns 1212, a fixing device 1213, a bracket 1214, a rotating actuator 1204, a vertical connecting member 1219, a horizontal connecting member 1220, an elastic connecting member 1221 and a frame 1222.

[0052] The plating bath 1201 is configured to accommodate electrolyte. The plating bath 1201 can include an anode chamber and a cathode chamber for electroplating. The anode chamber and the cathode chamber are separated by a membrane positioned on a membrane frame. The anode chamber can be divided into multiple anode zones and each anode zone accommodates an anode which is connected to an independently controlled power supply. The anodes can be made of materials such as copper (Cu), Ti or Ti plate with Pt coating. At least one diffusion plate 1211 having a plurality of small apertures is disposed in the cathode chamber for electric field uniform control and flow of electrolyte uniform control. A groove 1208 is disposed around the cathode chamber for receiving the electrolyte overflowed from the cathode chamber.

[0053] The substrate holder 1202 is configured to hold a substrate. The supporting columns 1212 are connected to the substrate holder 1202 and the fixing device 1213. The bracket 1214 is substantially U-shaped and has a pair of arms and a base portion. The pair of arms of the bracket 1214 are disposed at both sides of the fixing device 1213 and respectively connected to the pair of vibrating plates 1215. The pair of vibrating plates 1215 are connected to the both sides of the fixing device 1213. The base portion of the bracket 1214 is connected to the mounting plate 1216. The mounting plate 1216 is disposed on the supporting pedestal 1217. The mounting plate 1216 is capable of moving up and down along the supporting pedestal 1217 under the driven by a vertical actuator so as to bring the substrate holding module to move up and down. To prevent the substrate holding module from sagging, the vertical connecting member 1219 is connected to the base portion of the bracket 1214 and the horizontal connecting member 1220, and the horizontal connecting member 1220 is connected to the elastic connecting member 1221, and the elastic connecting member 1221 is connected to the frame 1222 which is fixed on the fixing device 1213. The rotating actuator 1204 is disposed on the fixing device 1213 and configured to drive the substrate holder 1202 to rotate.

[0054] The driving device 1205 is disposed on the fixing device 1213 and configured to drive the substrate holding module to vertically vibrate or resonate with a natural frequency of the vibrating plates 1215 during the substrate being plated, as shown in FIGS. 13A-13B and FIGS. 14A-14B. The driving device 1205 can be a vibrator.

[0055] The substrate holder 1202 moving up and down at high frequency can generate strong agitation effect in the space between the substrate and the diffusion plate 1211. When the substrate holder 1202 moves down at high speed, the liquid pressure in the said space will be increased rapidly and the electrolyte will be driven into the pattern structures by the pressure. Then the micro-wised liquid flow speed at the pattern structures is very high, and the additives will penetrate into the pattern structures uniformly, which will help to overcome the bump tilt issue. And on another side, when the substrate holder 1202 moves up, said space will be bigger and will be increasing and the liquid pressure in said space will be decreased rapidly. The liquid in the micro pattern structures will be dragged out. In the high speed of up and down motion, the liquid pressure is changed rapidly. The mass transfer rate in the pattern structures will be enhanced.

[0056] Referring to FIGS. 15A-16B, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to another exemplary embodiment of the present invention. Comparing to the plating apparatus shown in FIGS. 12A-14B, in this embodiment, a driving device 1205' can be a motor or a cylinder to drive the substrate holding module to vertically vibrate in resonance with the vibrating plates 1215. The motor or cylinder can be disposed on the horizontal connecting member 1220.

[0057] Referring to FIGS. 17A-17B, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to another exemplary embodiment of the present invention. The plating apparatus 1700 includes a plating bath 1701, a substrate holding module, a vibrating plate 1715, a mounting plate 1716, a supporting pedestal 1717 and a vertical actuator. The substrate holding module further includes a substrate holder 1702, supporting columns 1712, a fixing device 1713 and a rotating actuator 1704.

[0058] The plating bath 1701 is configured to accommodate electrolyte. The plating bath 1701 can include an anode chamber and a cathode chamber for electroplating. The anode chamber and the cathode chamber are separated by a membrane positioned on a membrane frame. The anode chamber can be divided into multiple anode zones and each anode zone accommodates an anode which is connected to an independently controlled power supply. The anodes can be made of materials such as copper (Cu), Ti or Ti plate with Pt coating. At least one diffusion plate 1711 having a plurality of small apertures is disposed in the cathode chamber for electric field uniform control and flow of electrolyte uniform control. A groove 1708 is disposed around the cathode chamber for receiving the electrolyte overflowed from the cathode chamber.

[0059] The substrate holder 1702 is configured to hold a substrate. The supporting columns 1712 are connected to the substrate holder 1702 and the fixing device 1713. The vibrating plate 1715 is connected to a side of the fixing device 1713 and the mounting plate 1716. The mounting plate 1716 is disposed on the supporting pedestal 1717. The mounting plate 1716 is capable of moving up and down along the supporting pedestal 1717 under the driven by the vertical actuator so as to bring the substrate holding module to move up and down. The rotating actuator 1704 is disposed on the fixing device 1713 and configured to drive the substrate holder 1702 to rotate.

[0060] In this embodiment, the vertical actuator is acted as a driving device and configured to drive the substrate holding module to vertically vibrate or resonate with a natural frequency of the vibrating plate 1715 during the substrate being plated.

[0061] Referring to FIG. 18A to FIG. 20C, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to another exemplary embodiment of the present invention. The plating apparatus 1800 includes a plating bath 1801, a substrate holding module, a first vibrating plate 18151, a pair of second vibrating plates 18152, a mounting plate 1816, a supporting pedestal 1817 and a first driving device 1805. The substrate holding module further includes a substrate holder 1802, supporting columns 1812, a fixing device 1813, a bracket 1814 and a rotating actuator 1804.

[0062] The plating bath 1801 is configured to accommodate electrolyte. The plating bath 1801 can include an anode chamber and a cathode chamber for electroplating. The anode chamber and the cathode chamber are separated by a membrane positioned on a membrane frame. The anode chamber can be divided into multiple anode zones and each anode zone accommodates an anode which is connected to an independently controlled power supply. The anodes can be made of materials such as copper (Cu), Ti or Ti plate with Pt coating. At least one diffusion plate 1811 having a plurality of small apertures is disposed in the cathode chamber for electric field uniform control and flow of electrolyte uniform control. A groove 1808 is disposed around the cathode chamber for receiving the electrolyte overflowed from the cathode chamber.

[0063] The substrate holder 1802 is configured to hold a substrate. The supporting columns 1812 are connected to the substrate holder 1802 and the fixing device 1813. The bracket 1814 is substantially U-shaped and has a pair of arms and a base portion. The pair of arms of the bracket 1814 are disposed at both sides of the fixing device 1813 and respectively connected to the pair of second vibrating plates 18152. The pair of second vibrating plates 18152 are connected to the both sides of the fixing device 1813. The base portion of the bracket 1814 is connected to one end of the first vibrating plate 18151. The other end of the first vibrating plate 18151 is connected to the mounting plate 1816. The mounting plate 1816 is disposed on the supporting pedestal 1817. The mounting plate 1816 is capable of moving up and down along the supporting pedestal 1817 by a vertical actuator so as to bring the substrate holding module to move up and down. The rotating actuator 1804 is disposed on the fixing device 1813 and configured to drive the substrate holder 1802 to rotate.

[0064] The first driving device 1805 is disposed on the base portion of the bracket 1814 and configured to drive the substrate holding module to horizontally vibrate or resonate with a natural frequency of the first vibrating plate 18151. The vertical actuator is acted as a second driving device and configured to drive the substrate holding module to vertically vibrate or resonate with a natural frequency of the pair of second vibrating plates 18152. In this embodiment, the substrate holding module can be driven to horizontally vibrate and vertically vibrate simultaneously by the first driving device 1805 and the vertical actuator during the substrate being plated.

[0065] Referring to FIG. 22, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to another exemplary embodiment of the present invention. The plating apparatus 2200 includes a plating bath 2201, a substrate holding module, a mounting plate 2216, a supporting pedestal 2217 and a driving device 2205. The substrate holding module further includes a substrate holder 2202, supporting columns 2212, a connecting plate 2225, a fixing device 2213, a bracket 2214, a rotating actuator 2204, a shaft 2223, a bearing 2224 and a pair of elastic members 2226.

[0066] The plating bath 2201 is configured to accommodate electrolyte. The plating bath 2201 can include an anode chamber and a cathode chamber for electroplating. The anode chamber and the cathode chamber are separated by a membrane positioned on a membrane frame. The anode chamber can be divided into multiple anode zones and each anode zone accommodates an anode which is connected to an independently controlled power supply. The anodes can be made of materials such as copper (Cu), Ti or Ti plate with Pt coating. At least one diffusion plate 2211 having a plurality of small apertures is disposed in the cathode chamber for electric field uniform control and flow of electrolyte uniform control. A groove 2208 is disposed around the cathode chamber for receiving the electrolyte overflowed from the cathode chamber.

[0067] The substrate holder 2202 is configured to hold a substrate. The supporting columns 2212 are connected to the substrate holder 2202 and the connecting plate 2225. The rotating actuator 2204 is disposed on the fixing device 2213. The shaft 2223 passes through the fixing device 2213. One end of the shaft 2223 is connected to the rotating actuator 2204 and the other end of the shaft 2223 is connected to the connecting plate 2225 by the bearing 2224. The pair of elastic members 2226 are connected to the shaft 2223 and the connecting plate 2225. The bracket 2214 is fixed at a side of the fixing device 2213 and connected to the mounting plate 2216. The mounting plate 2216 is disposed on the supporting pedestal 2217. The mounting plate 2216 is capable of moving up and down along the supporting pedestal 2217 by a vertical actuator so as to bring the substrate holding module to move up and down. The driving device 2205 is disposed on the connecting plate 2225.

[0068] While plating, the rotating actuator 2204 drives the shaft 2223 to rotate at a rotation speed w1. Because the pair of elastic members 2226 are connected to the shaft 2223 and the connecting plate 2225, the substrate holder 2202 as well as the supporting columns 2212 and the connecting plate 2225 rotates along with the shaft 2223 at the rotation speed w1. While the substrate holder 2202 rotates for plating, the driving device 2205 drives the substrate holder 2202 as well as the supporting columns 2212 and the connecting plate 2225 to clockwise rotate and counterclockwise rotate at a rotation speed w2, preferably, the w2 is larger than the w1, so that the rotation speed of the substrate holder 2202 can be rapidly changed to realize the agitation of electrolyte. Therefore, the plating uniformity and the plating rate can be improved.

[0069] As described above, the present invention employs at least one driving device to drive the substrate to vibrate during the substrate being immersed into the electrolyte to be plated, which makes the additives in the microstructures distribute uniformly so that the uniformity of plated metal in the microstructures is improved. Furthermore, comparing to using a paddle to agitate electrolyte in the prior art, since the present invention has no shelter such as paddles being set between the substrate and the diffusion plate, so the electric field distribution is more uniform, and there is no “shadow” problem in the present invention.

[0070] The present invention also provides a plating method for metal deposition on a substrate with pattern structures, comprising the steps:

[0071] loading a substrate in a substrate holding module to be held by the substrate holding module;

[0072] making the substrate immerse into electrolyte accommodated in a plating bath;

[0073] driving the substrate holding module together with the substrate to horizontally vibrate and/or vertically vibrate during the substrate being immersed into the electrolyte to be plated.

[0074] In an embodiment, the substrate is horizontally held by the substrate holding module.

[0075] In an embodiment, the substrate is vertically held by the substrate holding module, and the substrate holding module and the substrate are vertically immersed into the electrolyte.

[0076] In an embodiment, the electrolyte has a flow rate V_2, the substrate holding module as well as the substrate is driven to vibrate with a vibration velocity V_1, the V_1 is no less than $0.2V_2$.

[0077] In an embodiment, the vibration frequency of the substrate holding module is set from 0.1Hz to 500Hz.

[0078] In an embodiment, the amplitude of the substrate holding module is larger than the size of the pattern structures.

[0079] In an embodiment, the amplitude of the substrate holding module is set from 25um to 2000um.

[0080] In an embodiment, further comprising driving the substrate holding module together with the substrate to rotate during the substrate being immersed into the electrolyte to be plated.

[0081] Referring to FIG. 23, a plating apparatus for metal deposition on a substrate with pattern structures is illustrated according to an exemplary embodiment of the present invention. The plating apparatus 2300 has a plating bath 2301 configured to accommodate electrolyte, a substrate holding module 2302 configured to hold a substrate 2303 and electrically connecting with a conductive side of the substrate 2303, a rotating actuator 2304 configured to drive the substrate holding module 2302 to rotate along the axis of the substrate holding module 2302. The plating apparatus 2300 further includes a controller 2330 connecting to the rotating actuator 2304 and configured to control the rotating actuator 2304 to rotate N turns and then reverse rotate N turns, which are alternately applied for a number of cycles. The N is equal to or less than 3.0. Preferably, the N is 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0. The controller 2330 controls the rotation speed of the rotating actuator 2304 being below 120 rpm. The plating apparatus 2300 further has at least one anode 2306 being disposed in the plating bath 2301 and facing the conductive side of the substrate 2303, a power supply 2307 electrically connecting with the substrate holding module 2302 and the anode 2306. A groove 2308 is disposed around the plating bath 2301 for receiving the electrolyte overflowed from the plating bath 2301. The plating apparatus 2300 further has a tank 2310. A pipeline 2309 is connected to the groove 2308 and the tank 2310, and the tank 2310 is connected to the plating bath 2301 by another pipeline 2309.

[0082] In this embodiment, during plating, the present invention employs the controller 2330 to control the rotating actuator 2304 to rotate N turns and then reverse rotate N turns, which are alternately applied for a number of cycles, wherein the N is equal to or less than 3.0, improving the uniformity of plated metal in the pattern structures. The high frequency of the oscillation movement of the substrate, during the rotation direction changing the electrolyte at the substrate surface will be changed dramatically. The dramatically changing of the rotating actuator from clockwise to anticlockwise can generate the liquid motion in a turbulent status which enhances the agitation like a strong striation at substrate surface. The rotating actuator is controlled at point to point position control mode.

[0083] The present invention further provides a plating method for metal deposition on a substrate with pattern structures, comprising:

[0084] loading a substrate in a substrate holding module to be held by the substrate holding module;

[0085] making the substrate immerse into electrolyte accommodated in a plating bath;

[0086] driving the substrate holding module together with the substrate to rotate by a rotating actuator during the substrate being immersed into the electrolyte to be plated;

[0087] controlling the rotating actuator to rotate N turns and then reverse rotate N turns, which are alternately applied for a number of cycles, wherein the N is equal to or less than 3.0.

[0088] In an embodiment, the N is 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0. When N equals to 0.5, the substrate holding module will rotate from 0 degree to 180 degrees, and then rotate back again. The rotation speed is the same, and the frequency is very high. If the substrate holding module rotates less than 180 degrees, there will be non-symmetric plating rate on the substrate surface. So the rotation cycles needs to be 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0. If N is bigger than 3.0, taking 60 rpm rotation speed as an example, it will take 3s to rotate clockwise then another 3s anticlockwise. Then the one periodic cycle takes 6s. If N is bigger, the periodic cycle time will be more, and therefore the agitation by said dramatic changing is weakened.

[0089] In an embodiment, controlling the rotation speed of the rotating actuator to be below 120 rpm.

[0090] All the embodiments of the present invention described above are suitable for electroless plating to obtain uniform metal deposition in pattern structures on a substrate.

[0091] All the embodiments of the present invention described above are also suitable for electrical removing metal on a substrate to obtain uniform profile.

[0092] The foregoing description of the present invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teaching. Such modifications and variations that may be apparent to those skilled in the art are intended to be included within the scope of this invention as defined by the accompanying claims.

WHAT IS CLAIMED IS：

1. A plating apparatus for metal deposition on a substrate with pattern structures, comprising:
a plating bath, configured to accommodate electrolyte;
a substrate holding module, configured to hold a substrate; and
at least one driving device, configured to drive the substrate holding module together with the substrate to horizontally vibrate and/or vertically vibrate during the substrate being immersed into the electrolyte to be plated.

2. The plating apparatus as claimed in claim 1, wherein the at least one driving device is a motor, a cylinder or a vibrator.

3. The plating apparatus as claimed in claim 1, wherein the substrate holding module horizontally holds the substrate.

4. The plating apparatus as claimed in claim 1, wherein the substrate holding module vertically holds the substrate, and the substrate holding module and the substrate are vertically immersed into the electrolyte.

5. The plating apparatus as claimed in claim 1, wherein the electrolyte has a flow rate V_2, the at least one driving device drives the substrate holding module as well as the substrate to vibrate with a vibration velocity V_1, the V_1 is no less than $0.2V_2$.

6. The plating apparatus as claimed in claim 1, further comprising at least one vibrating plate, the at least one driving device is configured to drive the substrate holding module to vibrate or resonate with a natural frequency of the at least one vibrating plate.

7. The plating apparatus as claimed in claim 6, further comprising a mounting plate, a supporting pedestal, the substrate holding module further comprising a bracket, one end of the vibrating plate being connected to the bracket, and the other end of the vibrating plate being connected to the mounting plate, the mounting plate being disposed on the supporting pedestal.

8. The plating apparatus as claimed in claim 7, wherein the mounting plate is capable of moving up and down along the supporting pedestal.

9. The plating apparatus as claimed in claim 7, wherein the driving device is disposed on the bracket and the driving device is a vibrator.

10. The plating apparatus as claimed in claim 7, further comprising a pair of limit stop members being configured to limit the amplitude of the substrate holding module while the substrate holding module is driven to vibrate.

11. The plating apparatus as claimed in claim 10, wherein the pair of limit stop members are disposed on the bracket and respectively located at both sides of the vibrating plate, or the pair of limit stop members are disposed on the mounting plate and respectively located at both sides of the vibrating plate.

12. The plating apparatus as claimed in claim 7, wherein the driving device is a pair of motors or cylinders, the pair of motors or cylinders are disposed on the bracket and respectively located at both sides of the vibrating plate, or the pair of motors or cylinders are disposed on the mounting plate and respectively located at both sides of the vibrating plate.

13. The plating apparatus as claimed in claim 6, further comprising a mounting plate, a supporting pedestal, the substrate holding module further comprising a fixing device, a bracket, the at least one vibrating plate comprising a pair of vibrating plates, the bracket having a pair of arms and a base portion, the pair of arms of the bracket being disposed at both sides of the fixing device and respectively connected to the pair of vibrating plates, the pair of vibrating plates being connected to the both sides of the fixing device, the base portion of the bracket being connected to the mounting plate, the mounting plate being disposed on the supporting pedestal.

14. The plating apparatus as claimed in claim 13, wherein the mounting plate is capable of moving up and down along the supporting pedestal.

15. The plating apparatus as claimed in claim 13, wherein the substrate holding module

further comprises a vertical connecting member, a horizontal connecting member, an elastic connecting member and a frame, the vertical connecting member is connected to the base portion of the bracket and the horizontal connecting member, the horizontal connecting member is connected to the elastic connecting member, the elastic connecting member is connected to the frame, and the frame is fixed on the fixing device.

16. The plating apparatus as claimed in claim 13, wherein the driving device is disposed on the fixing device, the driving device is a vibrator.

17. The plating apparatus as claimed in claim 15, wherein the driving device is disposed on the horizontal connecting member, the driving device is a motor or a cylinder.

18. The plating apparatus as claimed in claim 6, further comprising a mounting plate, a supporting pedestal, the substrate holding module further comprising a fixing device, the vibrating plate being connected to a side of the fixing device and the mounting plate, the mounting plate being disposed on the supporting pedestal, wherein the driving device is a vertical actuator which drives the mounting plate to move up and down along the supporting pedestal to make the substrate holding module vertically vibrate.

19. The plating apparatus as claimed in claim 6, wherein the at least one vibrating plate comprises a first vibrating plate and a pair of second vibrating plates, the at least one driving device comprises a first driving device and a second driving device, the first driving device is configured to drive the substrate holding module to horizontally vibrate or resonate with a natural frequency of the first vibrating plate, the second driving device is configured to drive the substrate holding module to vertically vibrate or resonate with a natural frequency of the pair of second vibrating plates.

20. The plating apparatus as claimed in claim 19, wherein the second driving device is a vertical actuator.

21. The plating apparatus as claimed in claim 6, further comprising a rotating actuator being configured to drive the substrate to rotate.

22. The plating apparatus as claimed in claim 1, wherein the substrate holding module

further comprises a substrate holder fixed to a connecting plate, a rotating actuator, a shaft, a bearing and a pair of elastic members, wherein the substrate holder is configured to hold a substrate, one end of the shaft is connected to the rotating actuator and the other end of the shaft is connected to the connecting plate by the bearing, the pair of elastic members are connected to the shaft and the connecting plate, the rotating actuator drives the shaft to rotate to bring the substrate holder to rotate at a rotation speed w1, while the substrate holder rotates for plating, the driving device drives the substrate holder to clockwise rotate and counterclockwise rotate at a rotation speed w2.

23. The plating apparatus as claimed in claim 22, wherein the w2>w1.

24. The plating apparatus as claimed in claim 1, wherein the vibration frequency of the substrate holding module is set from 0.1Hz to 500Hz.

25. The plating apparatus as claimed in claim 1, wherein the amplitude of the substrate holding module is larger than the size of the pattern structures on the substrate.

26. The plating apparatus as claimed in claim 1, wherein the amplitude of the substrate holding module is set from 25um to 2000um.

27. A plating method for metal deposition on a substrate with pattern structures, comprising:
loading a substrate in a substrate holding module to be held by the substrate holding module;
making the substrate immerse into electrolyte accommodated in a plating bath;
driving the substrate holding module together with the substrate to horizontally vibrate and/or vertically vibrate during the substrate being immersed into the electrolyte to be plated.

28. The plating method as claimed in claim 27, wherein the substrate is horizontally held by the substrate holding module.

29. The plating method as claimed in claim 27, wherein the substrate is vertically held by the substrate holding module, and the substrate holding module and the substrate are

vertically immersed into the electrolyte.

30. The plating method as claimed in claim 27, wherein the electrolyte has a flow rate V2, the substrate holding module as well as the substrate is driven to vibrate with a vibration velocity V1, the V1 is no less than 0.2V2.

31. The plating method as claimed in claim 27, wherein the vibration frequency of the substrate holding module is set from 0.1Hz to 500Hz.

32. The plating method as claimed in claim 27, wherein the amplitude of the substrate holding module is larger than the size of the pattern structures on the substrate.

33. The plating method as claimed in claim 27, wherein the amplitude of the substrate holding module is set from 25um to 2000um.

34. The plating method as claimed in claim 27, further comprising driving the substrate to rotate during the substrate being immersed into the electrolyte to be plated.

35. A plating apparatus for metal deposition on a substrate with pattern structures, comprising:
a plating bath, configured to accommodate electrolyte;
a substrate holding module, configured to hold a substrate;
a rotating actuator, configured to drive the substrate holding module together with the substrate to rotate; and
a controller, configured to control the rotating actuator to rotate N turns and then reversely rotate N turns, which are alternately applied for a number of cycles, the N is equal to or less than 3.0.

36. The plating apparatus as claimed in claim 35, wherein the N is 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0.

37. The plating apparatus as claimed in claim 35, wherein the rotation speed of the rotating actuator is below 120 rpm.

38. A plating method for metal deposition on a substrate with pattern structures, comprising:
loading a substrate in a substrate holding module to be held by the substrate holding module;
making the substrate immerse into electrolyte accommodated in a plating bath;
driving the substrate holding module together with the substrate to rotate by a rotating actuator during the substrate being immersed into the electrolyte to be plated;
controlling the rotating actuator to rotate N turns and then reversely rotate N turns, which are alternately applied for a number of cycles, wherein the N is equal to or less than 3.0.

39. The plating method as claimed in claim 38, wherein the N is 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0.

40. The plating method as claimed in claim 38, wherein the rotation speed of the rotating actuator is below 120 rpm.

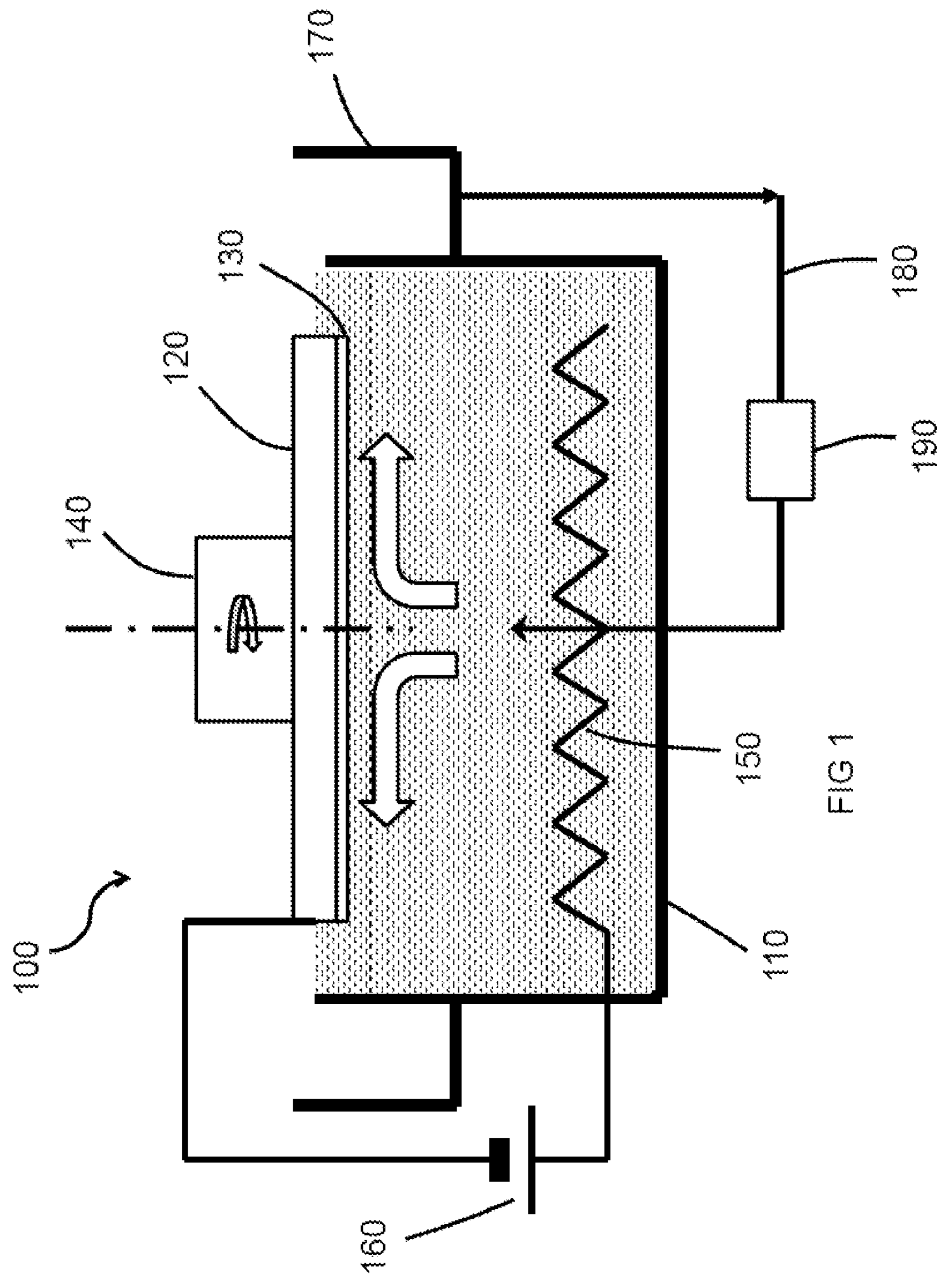

FIG 1

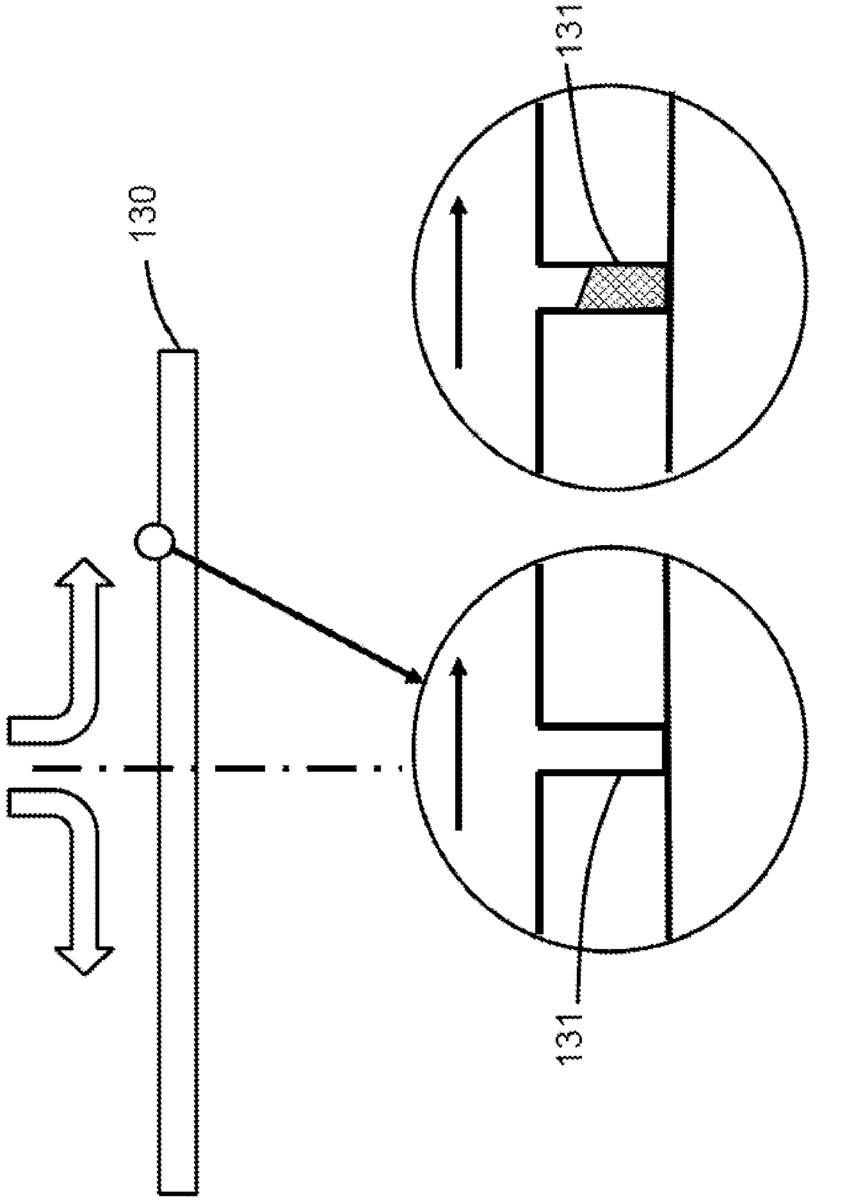

FIG 2A

FIG 2B

FIG 2C

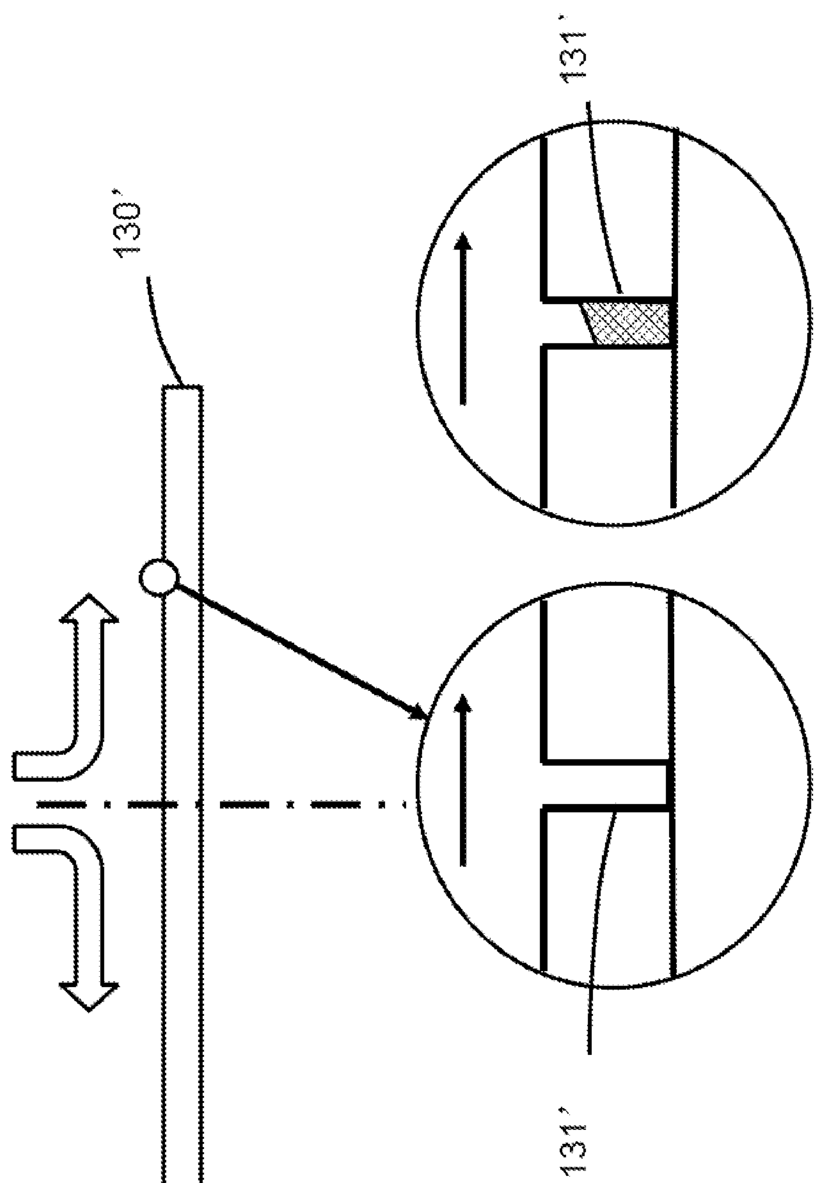

FIG 3A

FIG 3B

FIG 3C

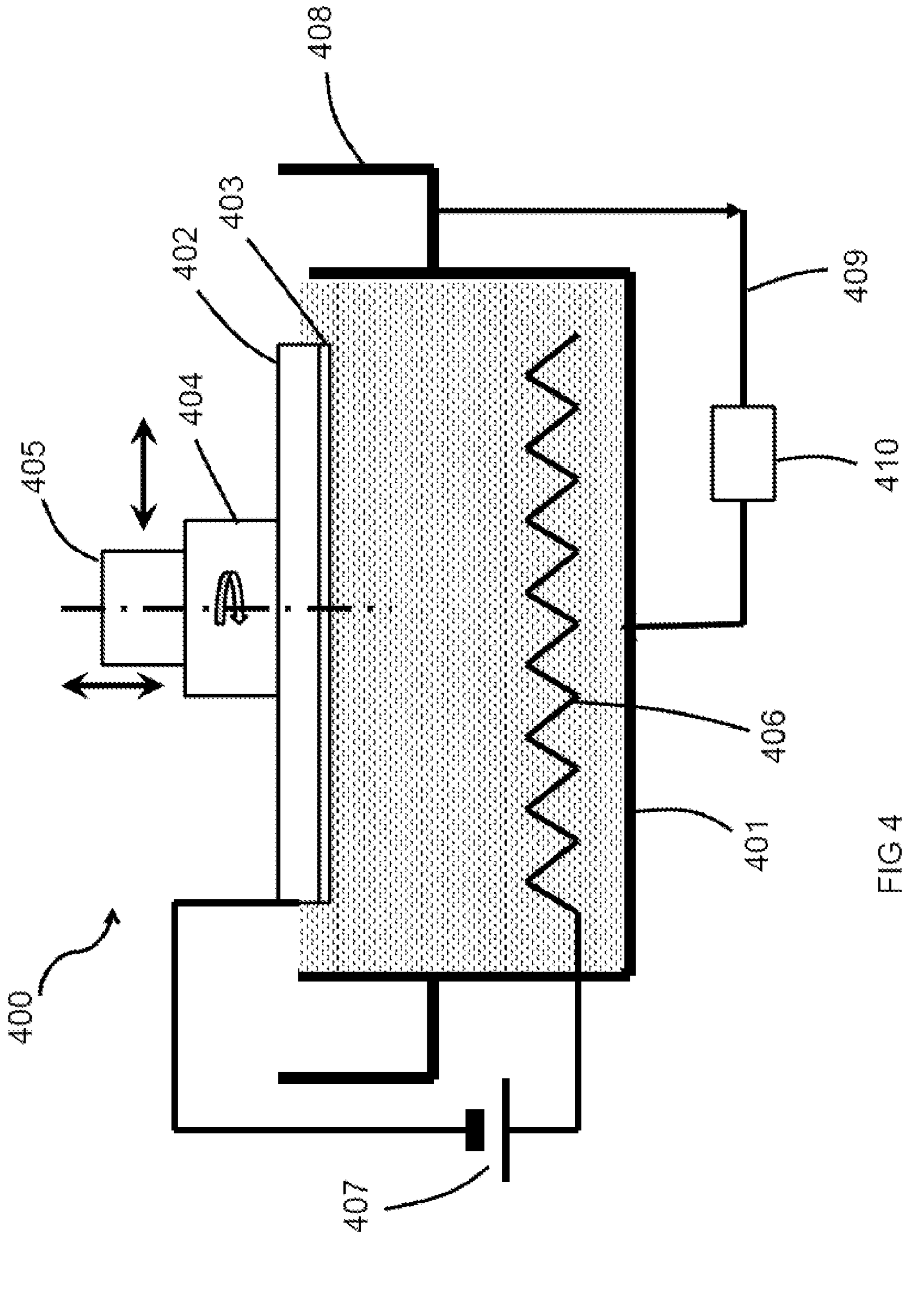

FIG 4

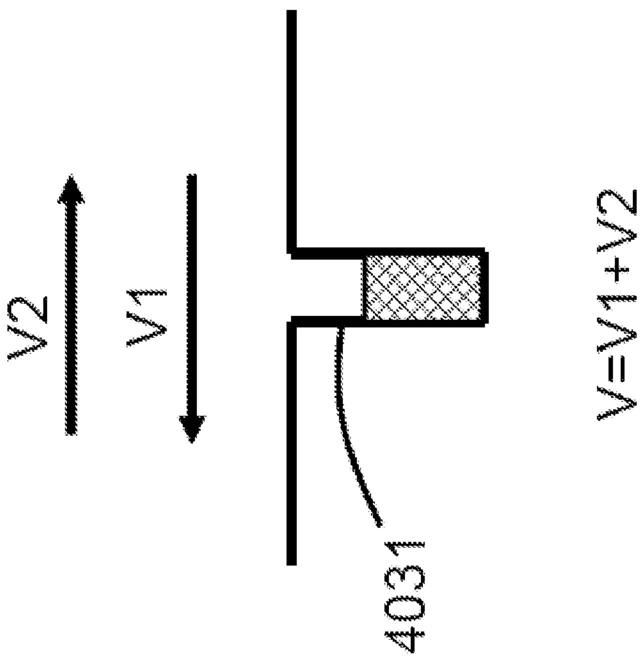

FIG 5A

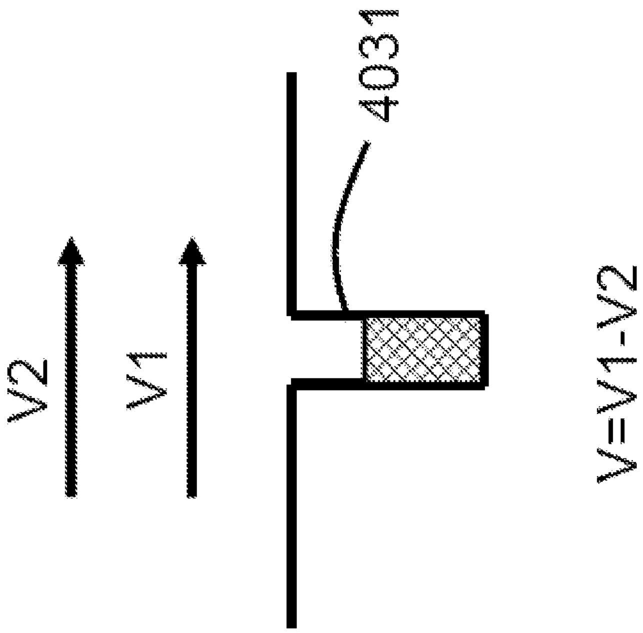

FIG 5B

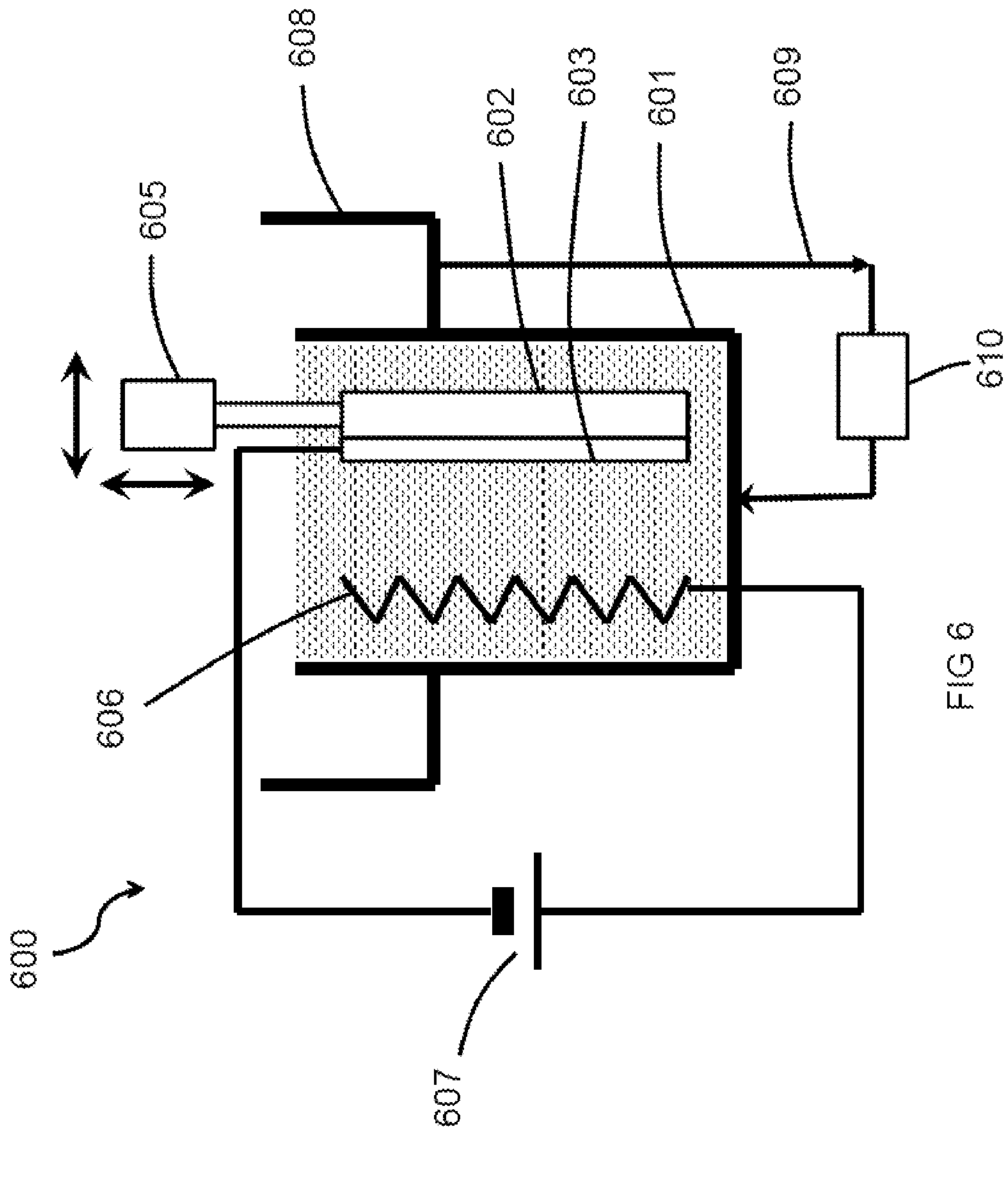

FIG 6

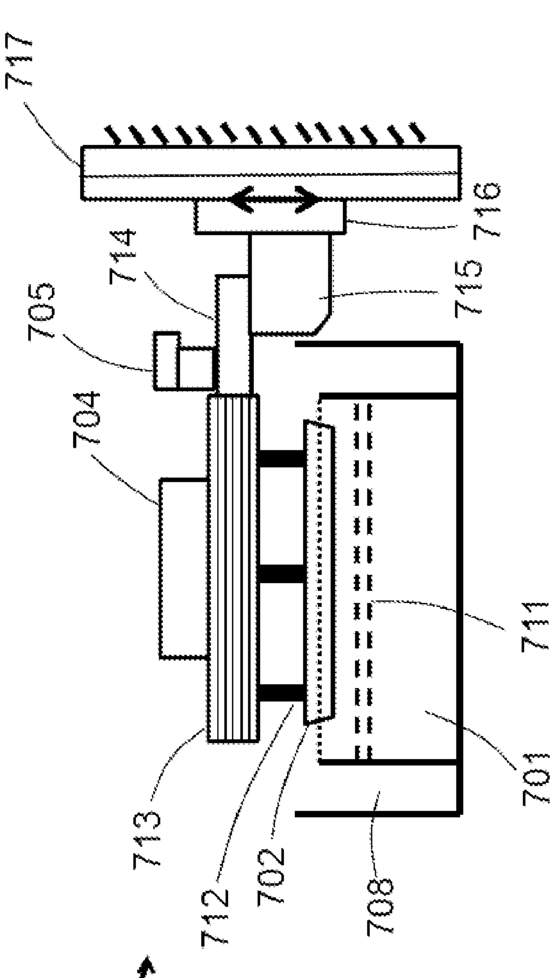
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FIG 7A

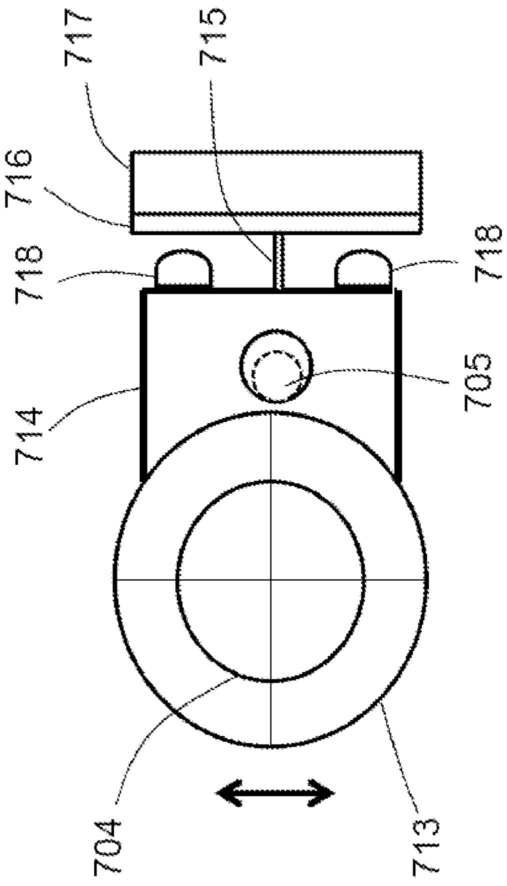
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FIG 7B

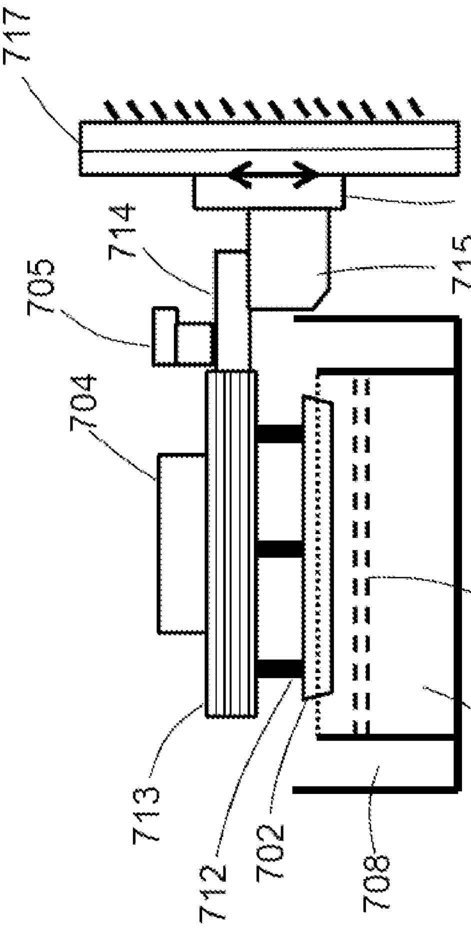
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FIG 8A

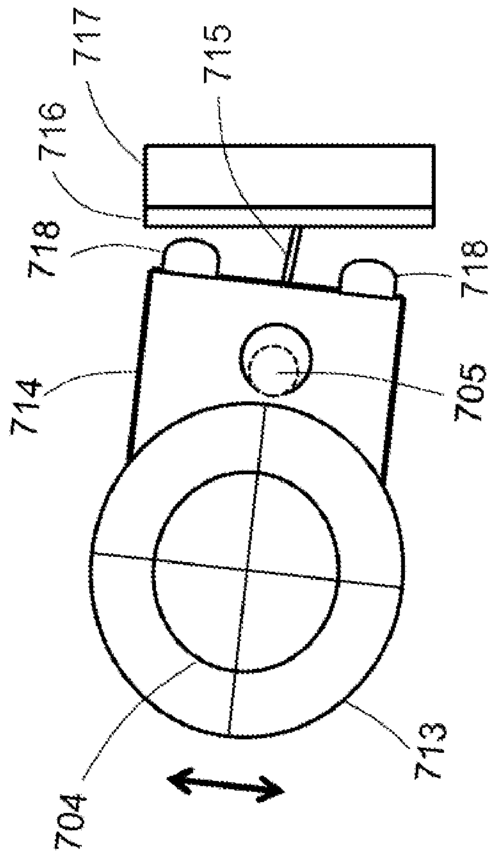
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FIG 8B

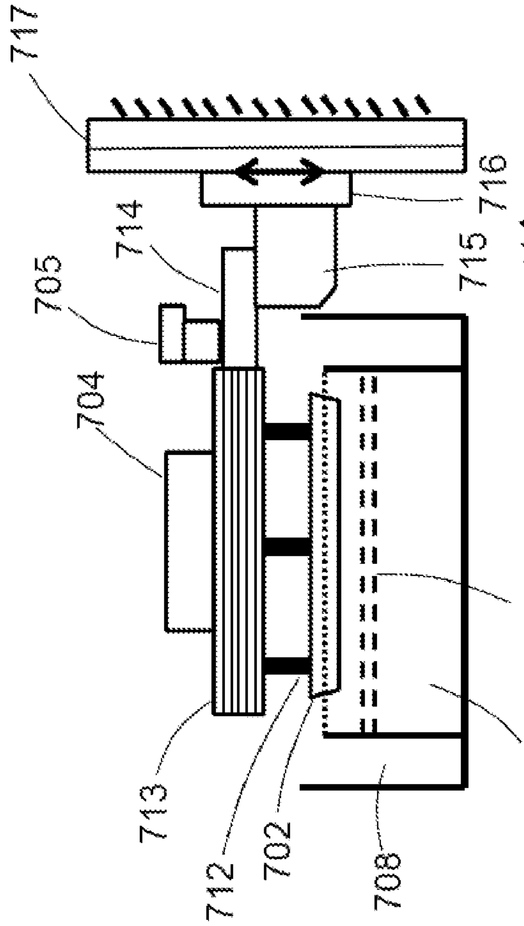
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FIG 9A

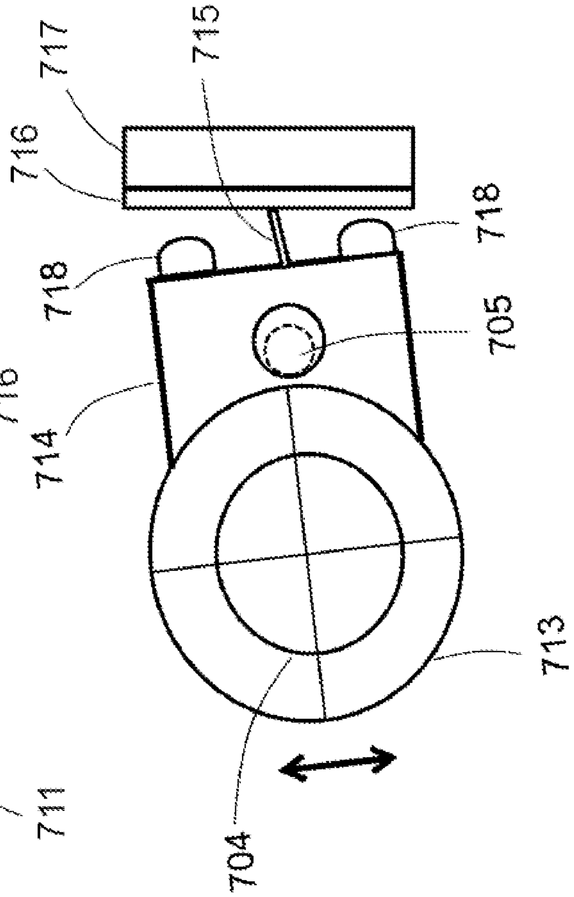
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FIG 9B

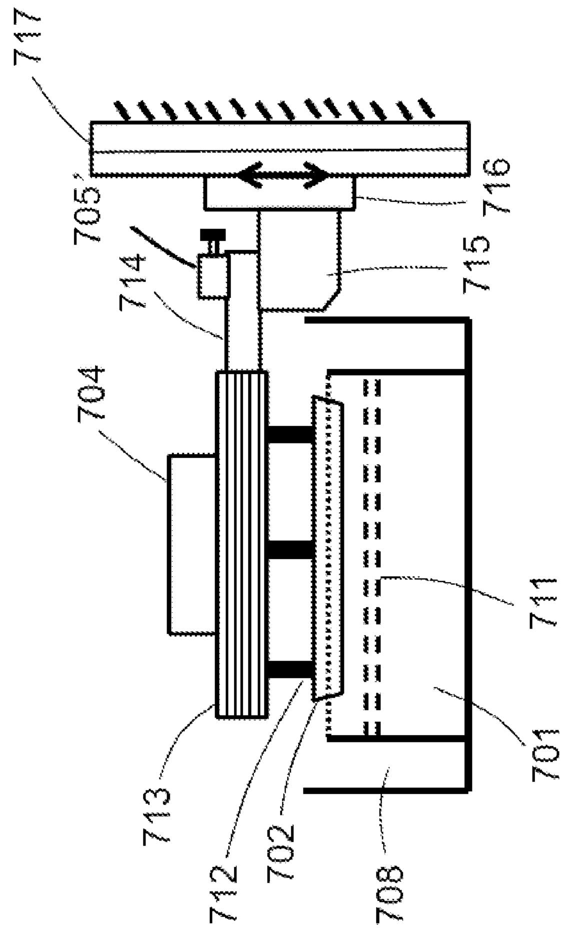


FIG 10A

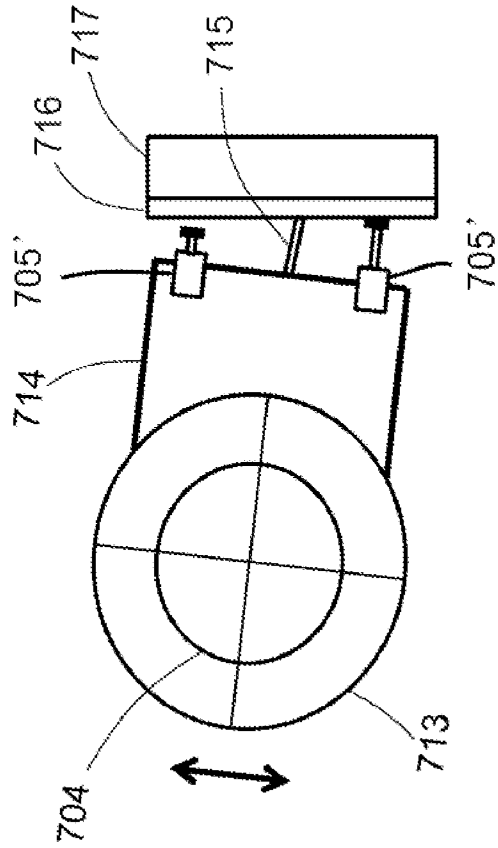


FIG 10B

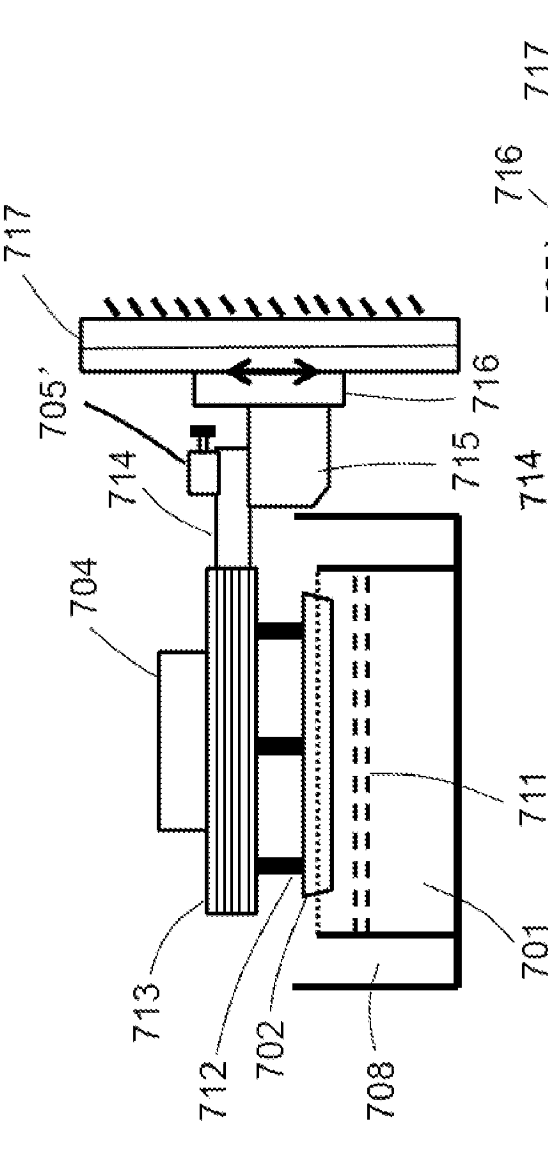


FIG 11A

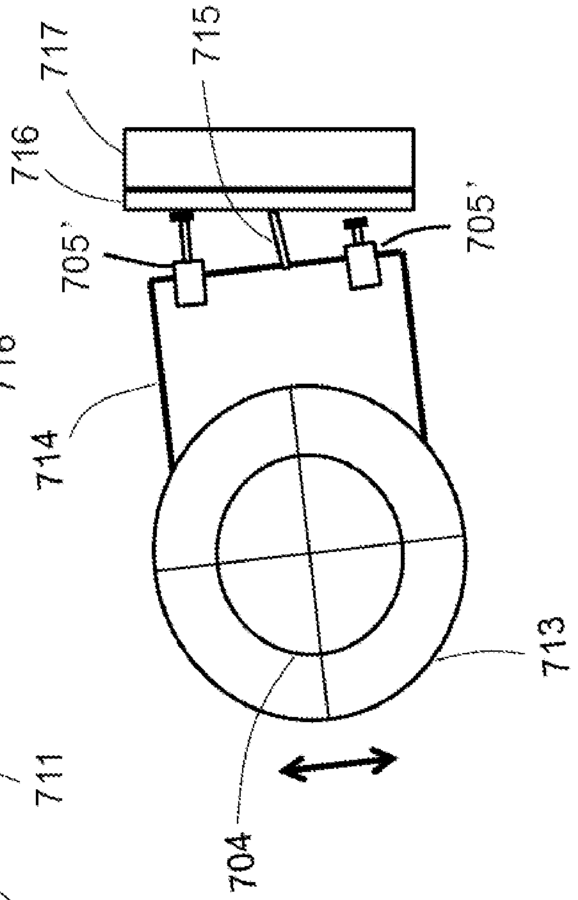


FIG 11B

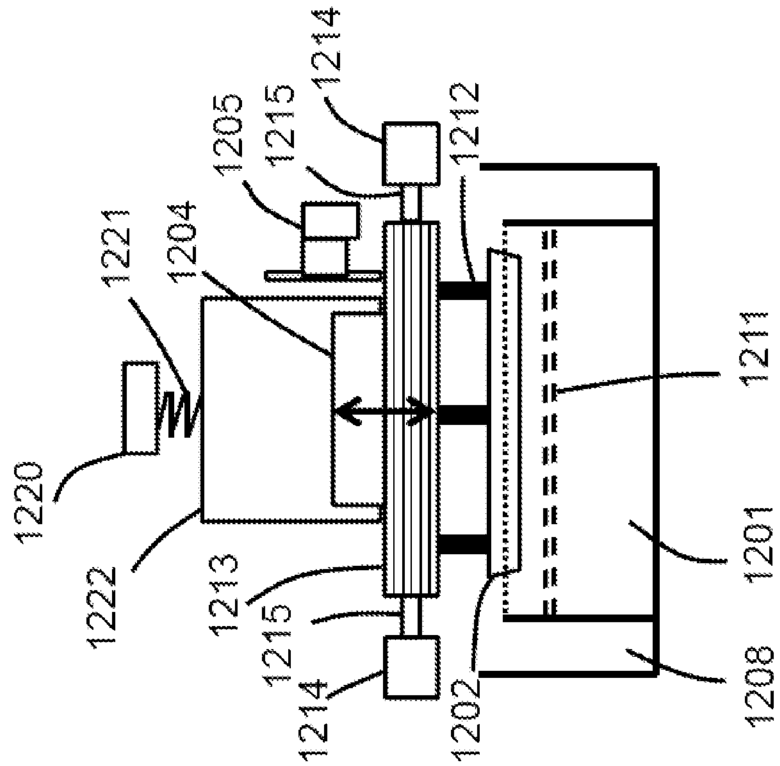


FIG 12B

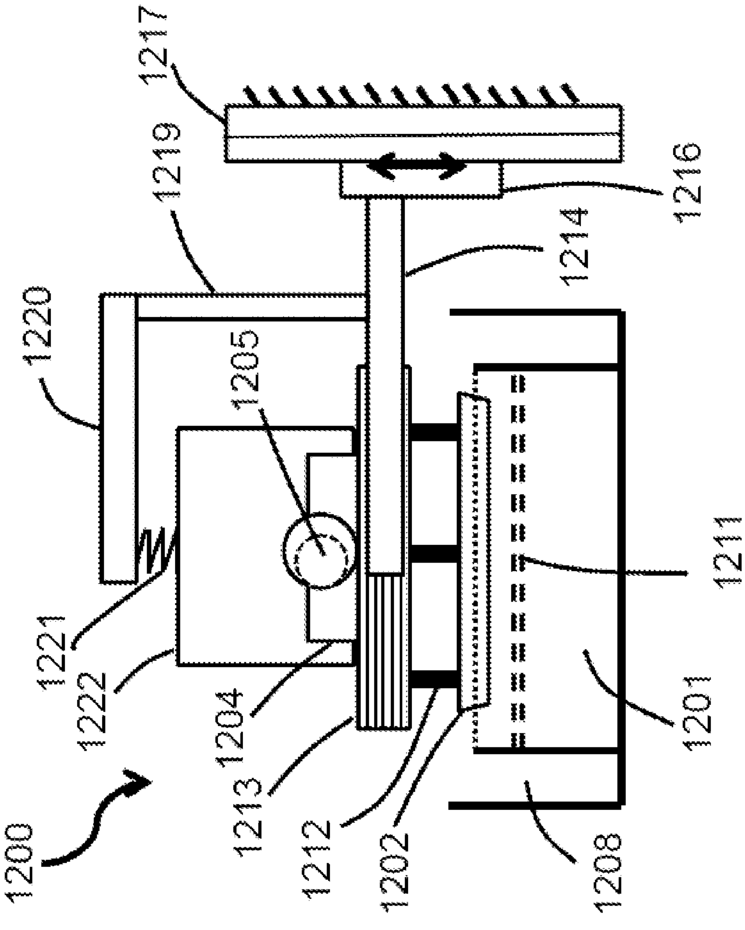


FIG 12A

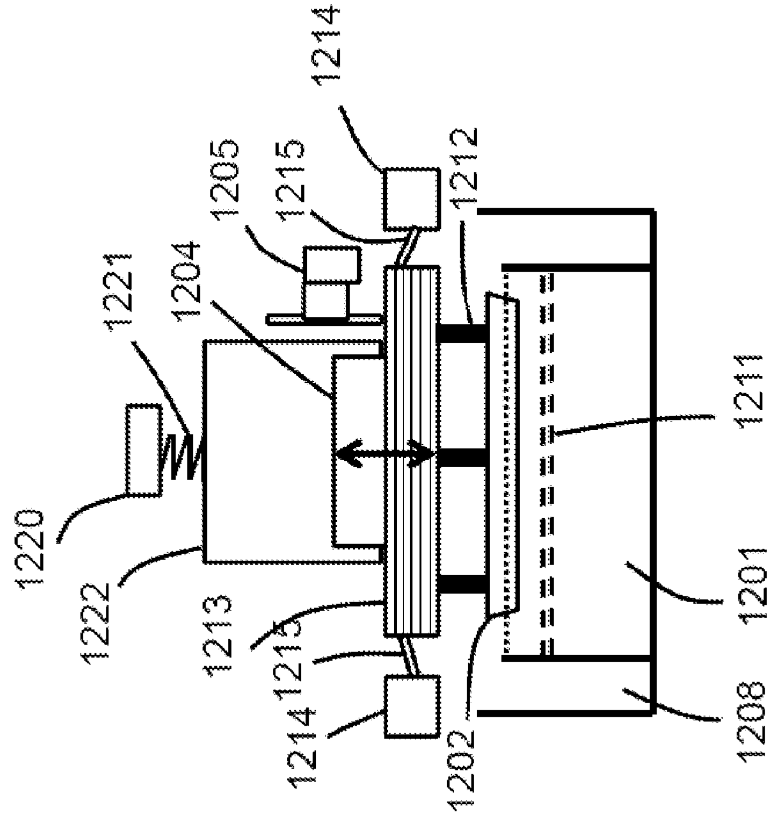


FIG 13B

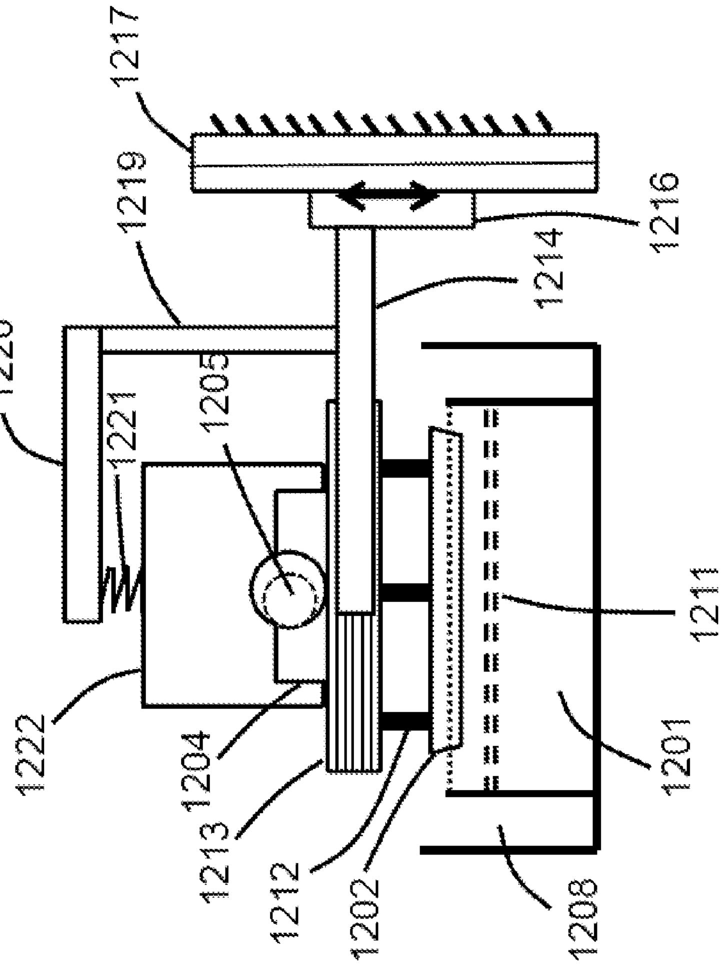


FIG 13A

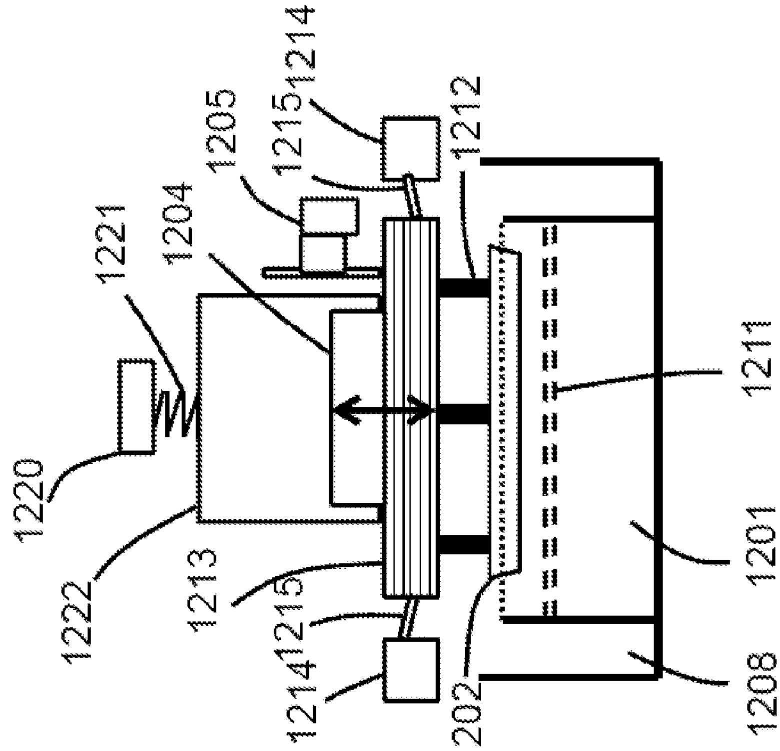


FIG 14B

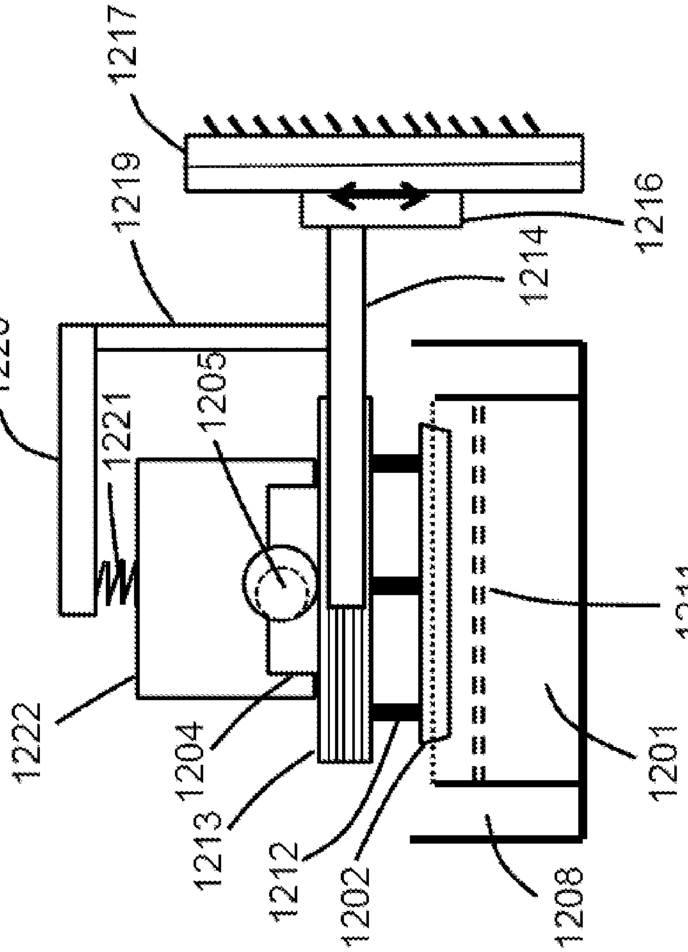


FIG 14A

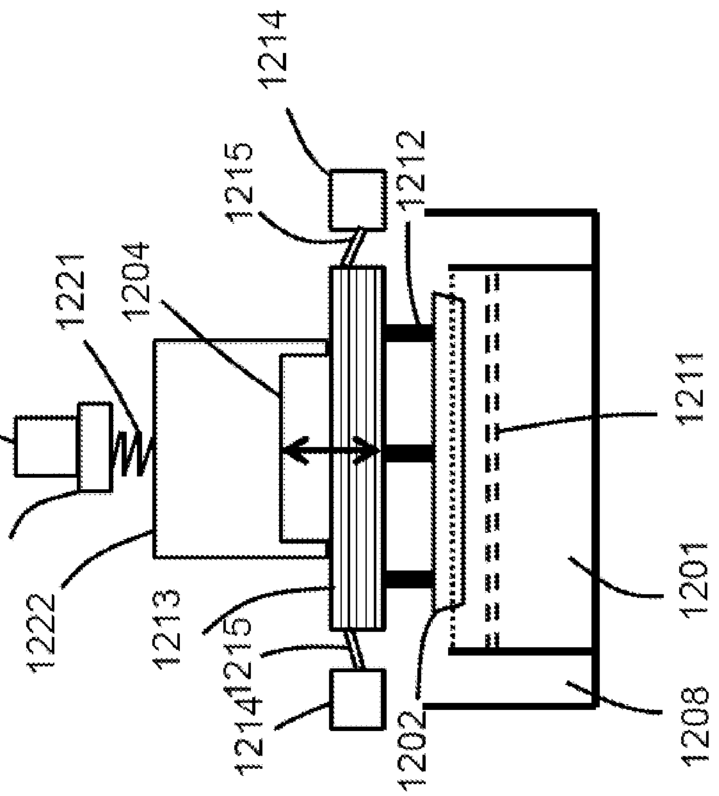


FIG 15B

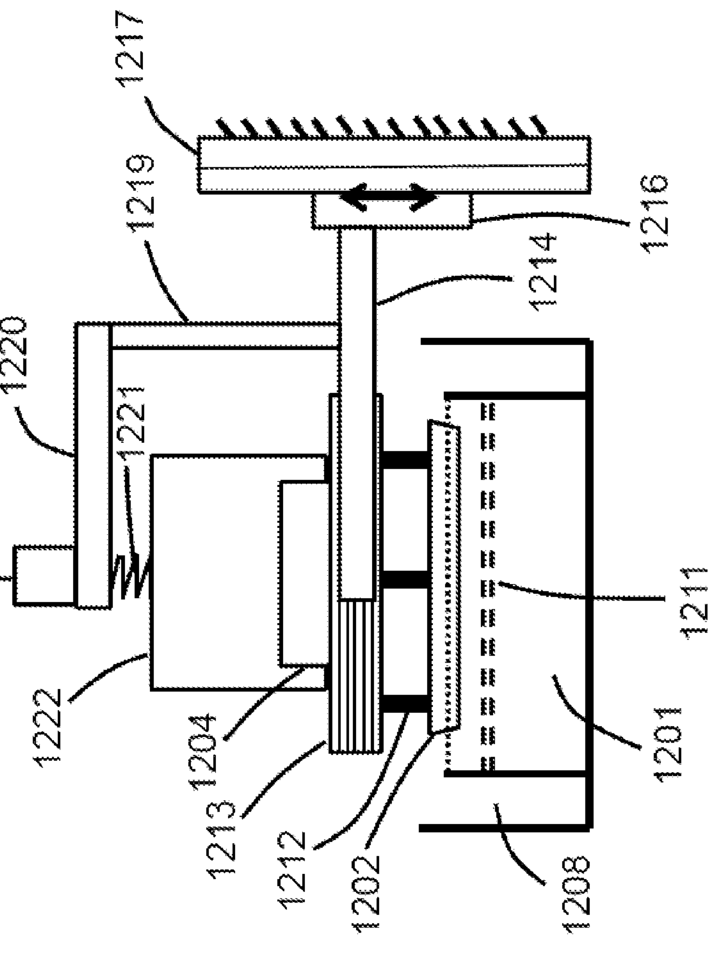


FIG 15A

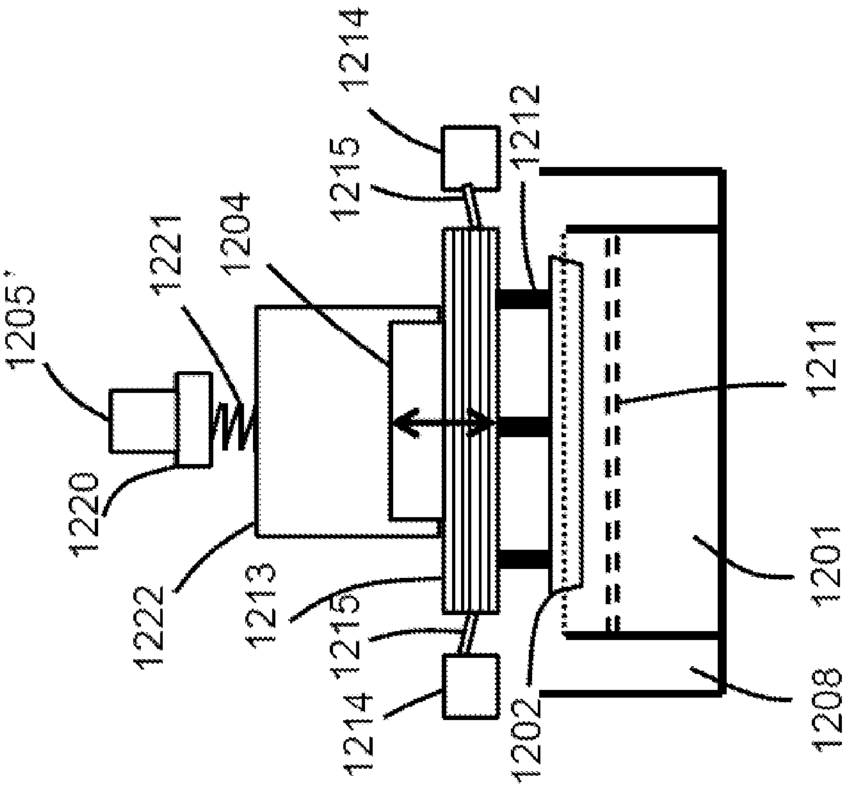


FIG 16B

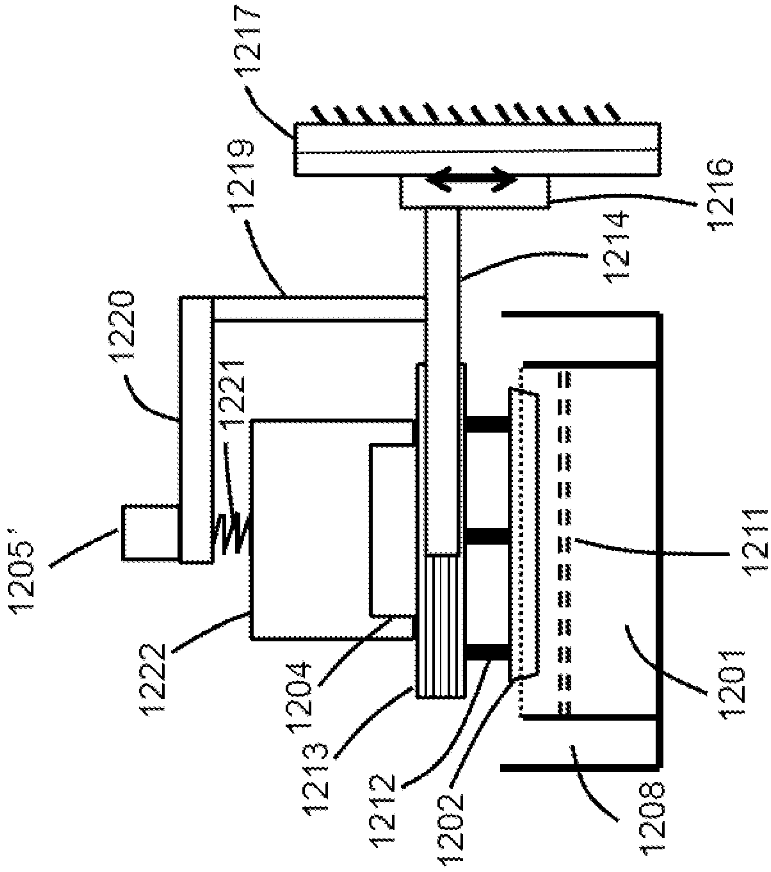
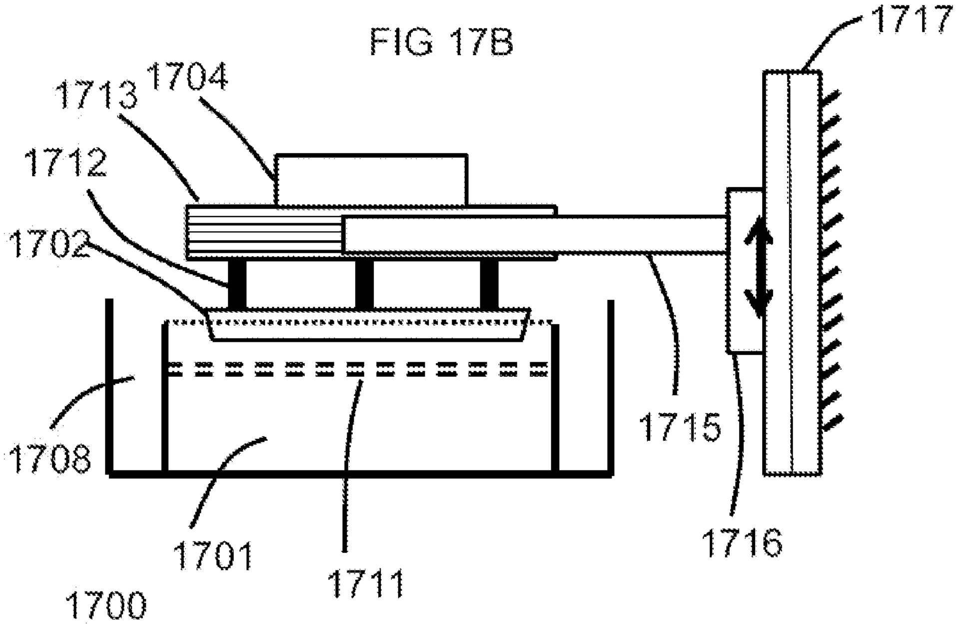


FIG 16A

FIG 17B



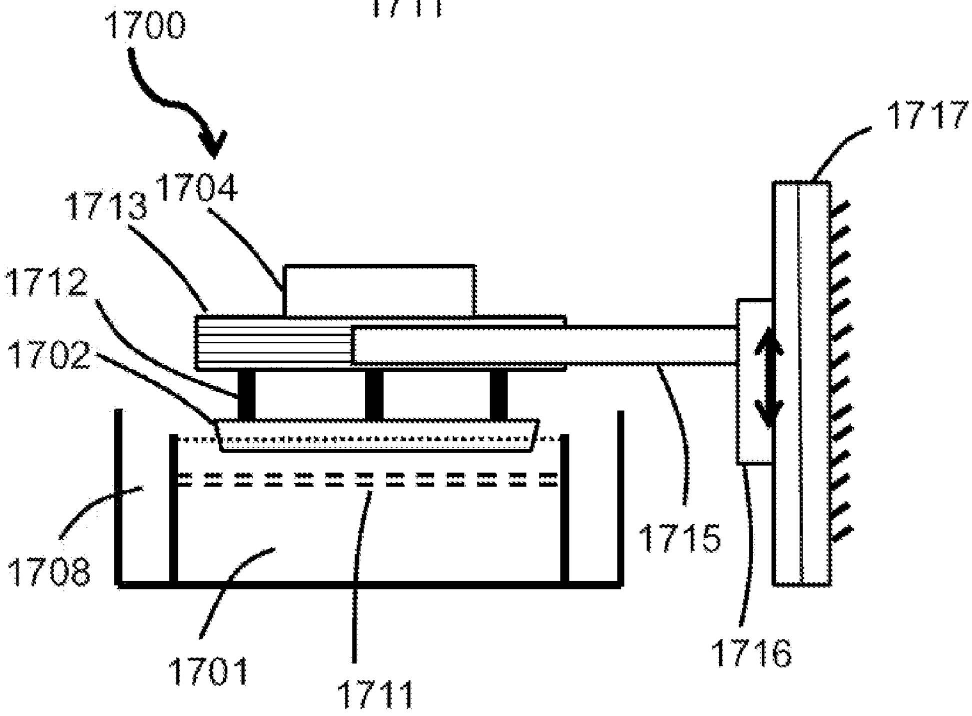


FIG 17A

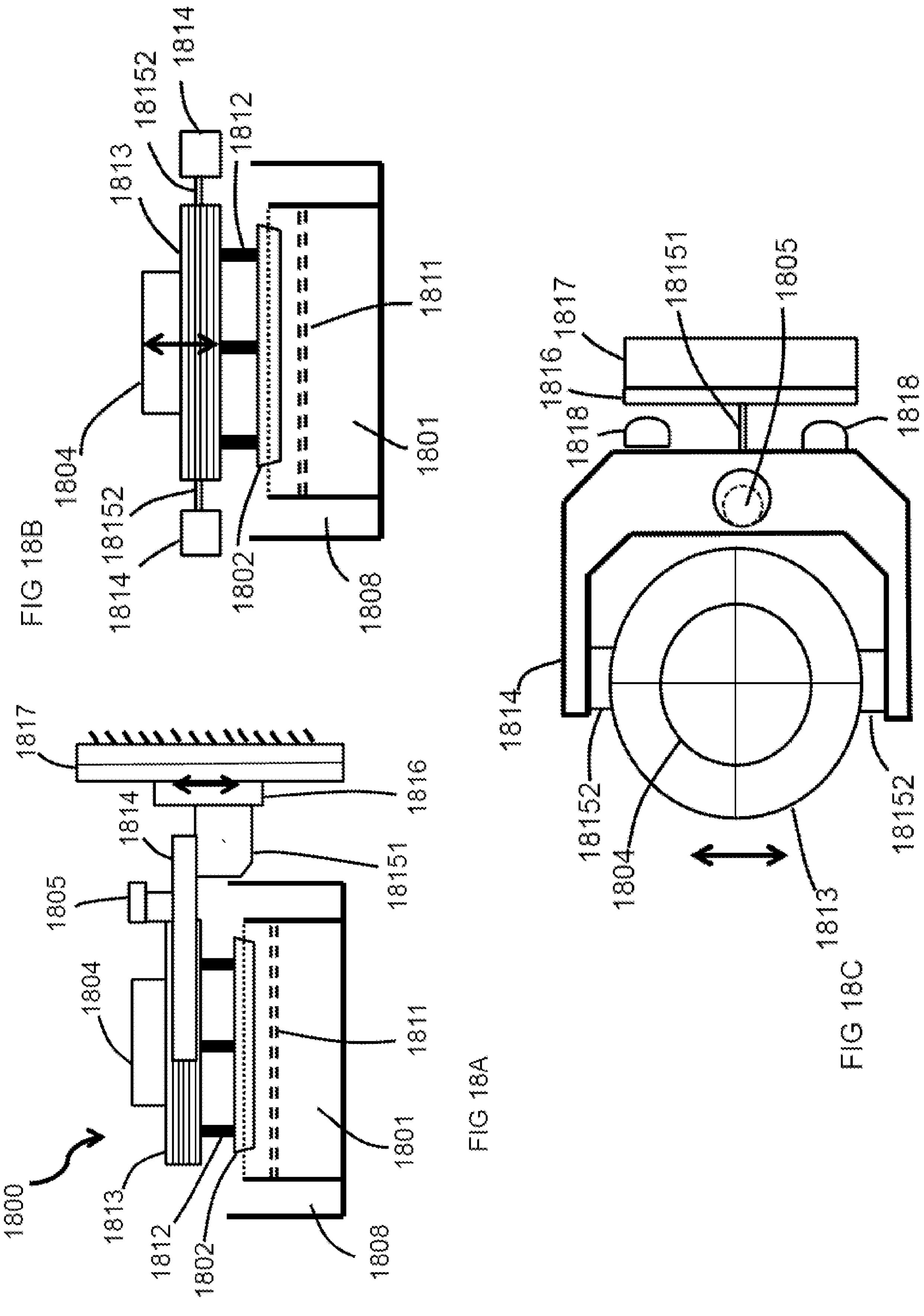


FIG 18B

FIG 18C

FIG 18A

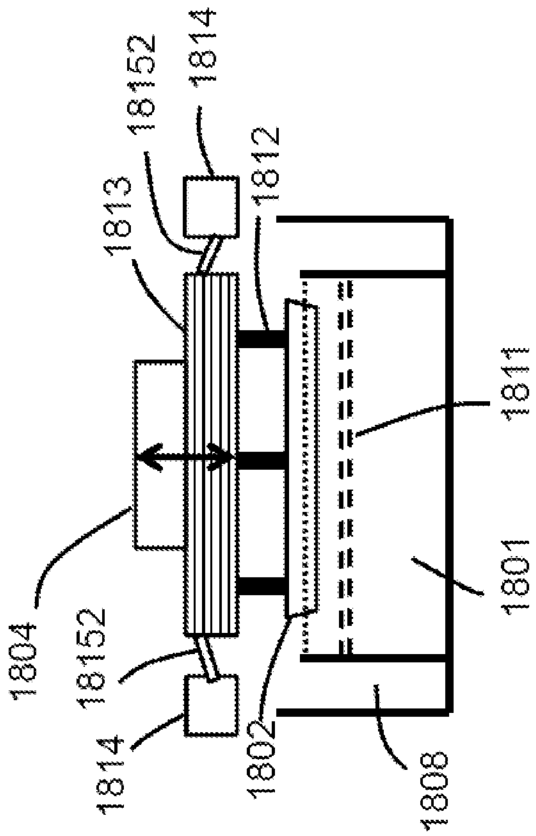


FIG 19B

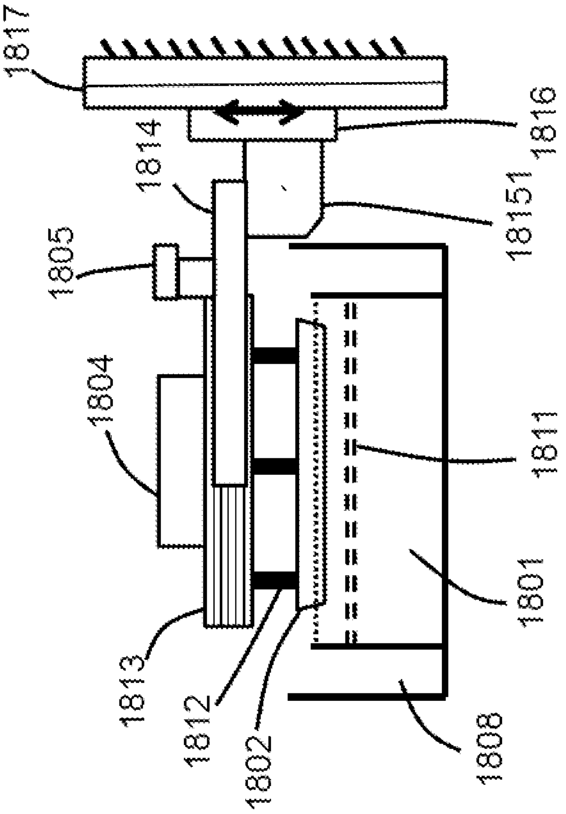


FIG 19A

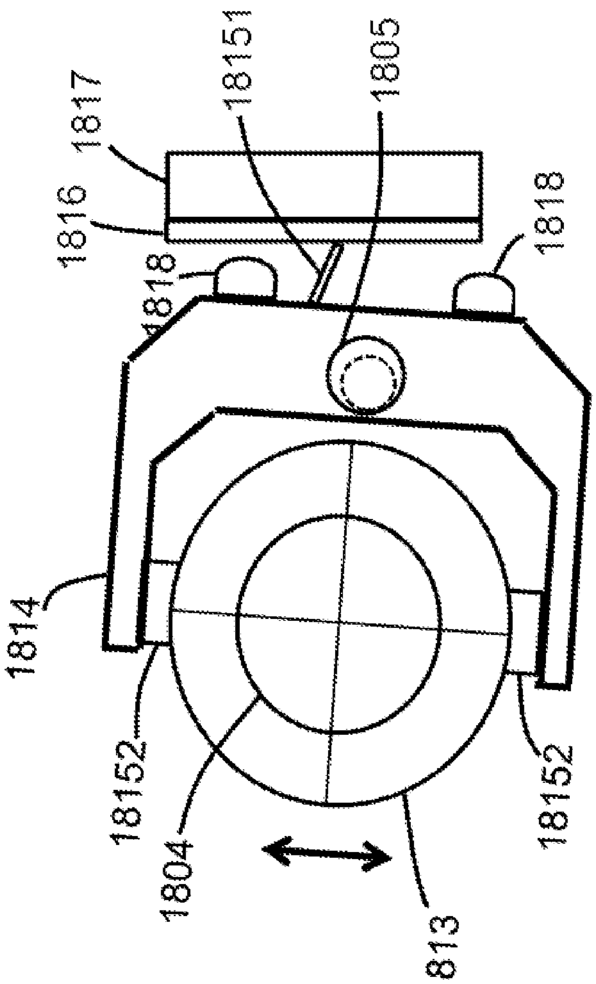


FIG 19C

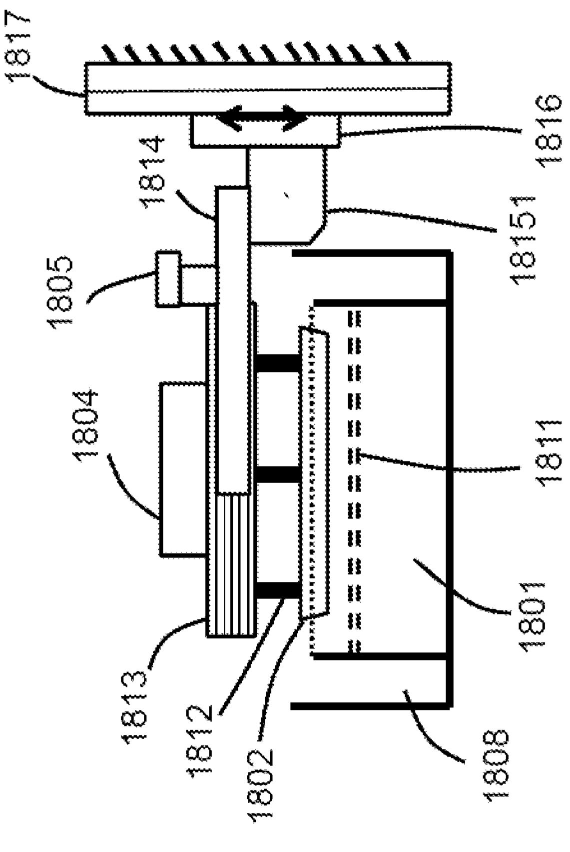


FIG 20A

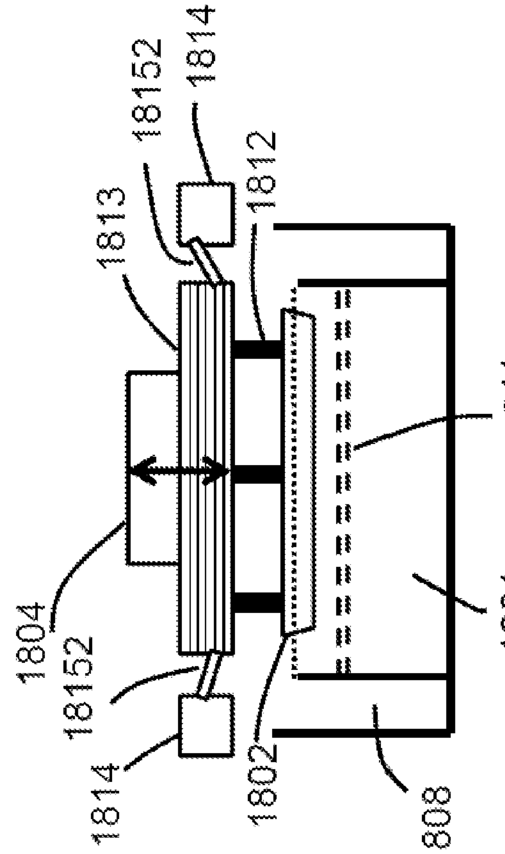


FIG 20B

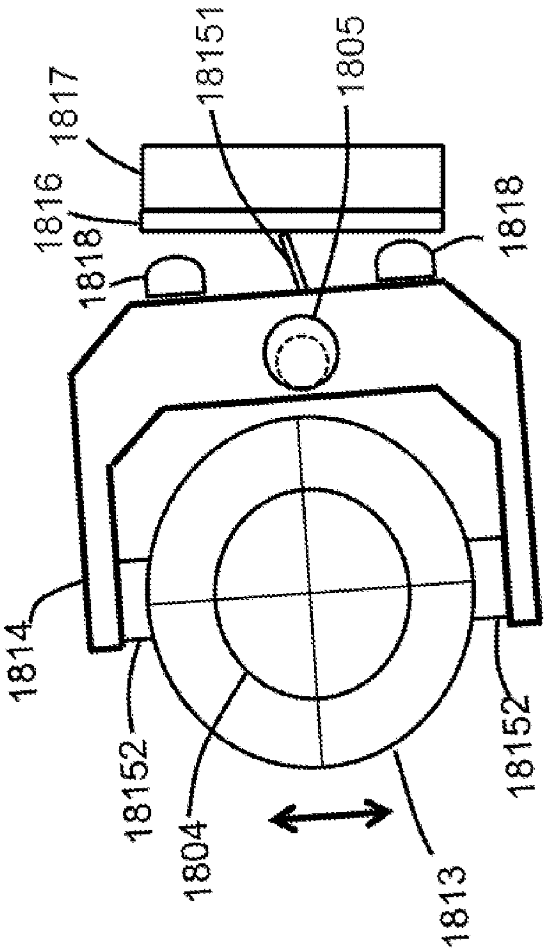


FIG 20C

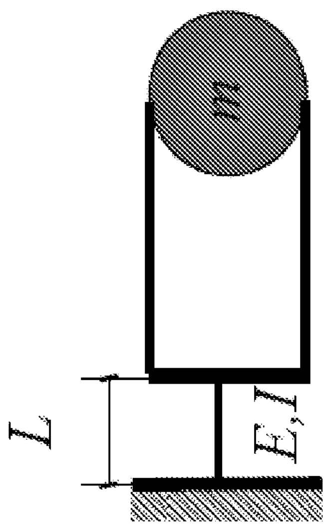


FIG 21

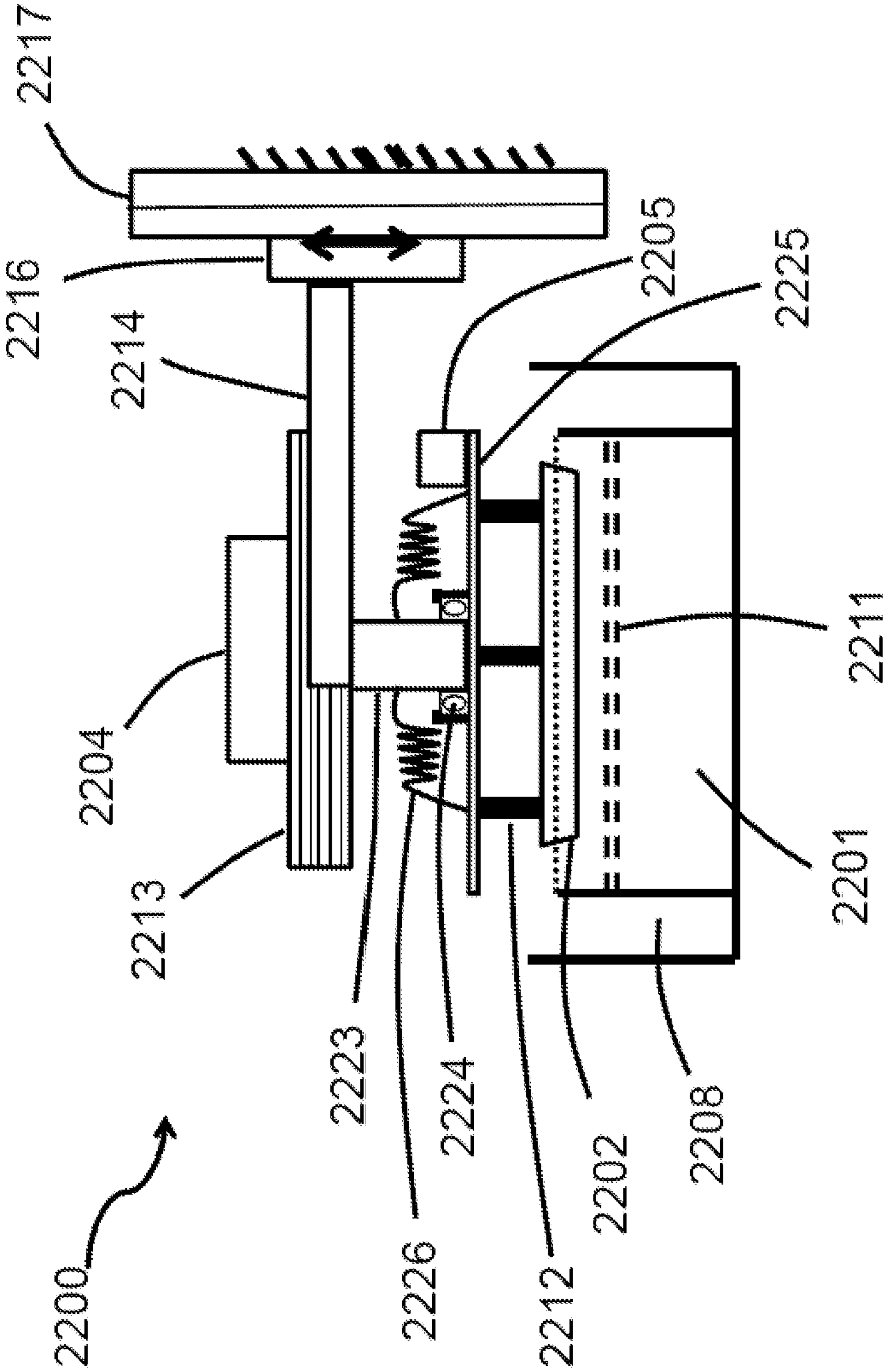

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FIG 22

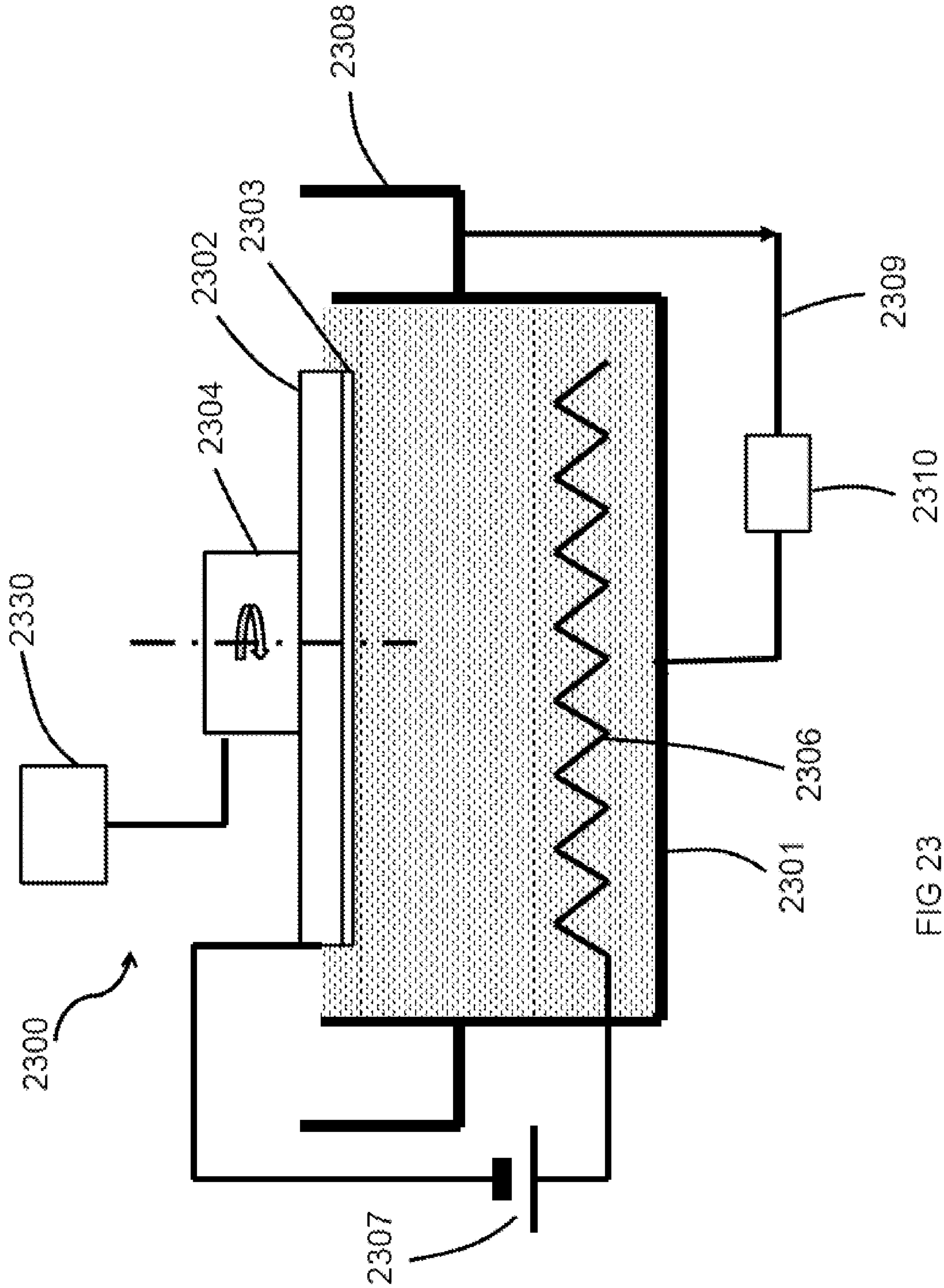

FIG 23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/080622

A. CLASSIFICATION OF SUBJECT MATTER

C25D 17/00(2006.01)i; C25D 17/06(2006.01)i; C25D 7/12(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C25D17,C25D7

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

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

DWPI,SIPOABS,CNABS,CNTXT, CNKI: ACM,electroplat+,electrodeposit+, deposit+,metalli+, horizontal+, vertical+, agitat+, oscillat+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012174732 A1 (ACM RES SHANGHAI INCet al.) 27 December 2012 (2012-12-27) see claims 6-8, paragraph [0037]-[0038], figures 8-9	1-4, 6-9, 12-14, 16, 18, 21, 24-34
A	WO 2012174732 A1 (ACM RES SHANGHAI INCet al.) 27 December 2012 (2012-12-27) see claims 6-8, paragraph [0037]-[0038], figures 8-9	5, 10-11, 15, 17, 19-20, 22-23, 35-40
X	WO 9954527 A2 (APPLIED MATERIALS INC) 28 October 1999 (1999-10-28) see claim 37	1, 27
X	CN 105986290 A (ACM RES SHANGHAI INC) 05 October 2016 (2016-10-05) see paragraph [0043], figure 3	1-3, 24, 27-28, 31
X	CN 105190859 A (ACM RES SHANGHAI INC) 23 December 2015 (2015-12-23) see paragraphs [0033]-[0034], figures 2A-3	1-3, 24, 27-28, 31

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

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"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 November 2020	**27 November 2020**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China	**CAO,Dongfang**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(010)-62084555**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/080622

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				WO	2014172837	A1	30 October 2014
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				US	10113244	B2	30 October 2018
				US	2016068985	A1	10 March 2016