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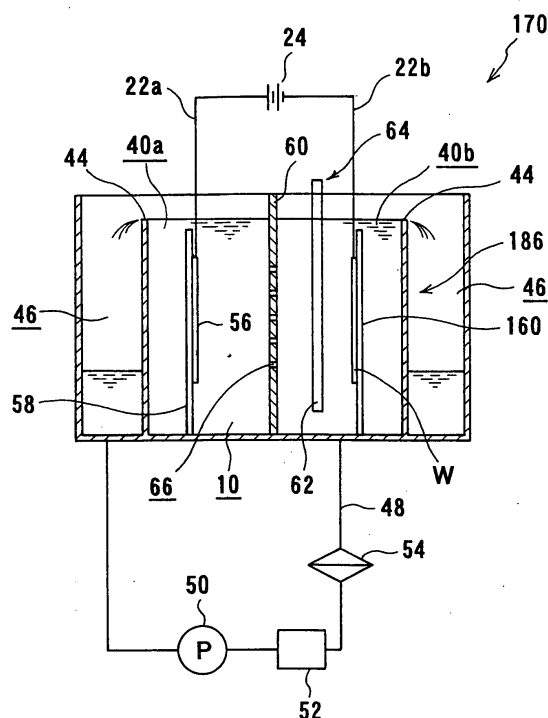
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(54) **PLATING DEVICE**

(57) A plating apparatus according to the present invention has a plating tank (40) for holding a plating solution (10), an anode (56) disposed so as to be immersed in the plating solution (10) in the plating tank (40), a regulation plate (60) disposed between the anode (56) and a plating workpiece (W) disposed so as to face the anode (56), and a plating power supply (24) for supply a current between the anode (56) and the plating workpiece (W) to carry out plating. The regulation plate (60) is disposed so as to separate the plating solution (10) held in the plating tank (40) into a plating solution on the anode side and a plating solution on the plating workpiece side, and a through-hole group (66) having a large number of through-holes (66) is formed in the regulation plate (60).

FIG. 3



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Description

Technical Field

[0001] The present invention relates to a plating apparatus for carrying out plating of a surface of a plating workpiece to be plated, such as a substrate, and more particularly to a plating apparatus for forming a plated film in fine interconnect trenches or holes, via holes, through-holes, or resist openings formed in a surface of a semiconductor wafer or the like, or for forming a bump (protruding electrode), which provides electrical connection with an electrode of a package or the like, on a surface of a semiconductor wafer.

Background Art

[0002] In TAB (Tape Automated Bonding) or FC (Flip Chip), for example, it has widely been practiced to form protruding connecting electrodes (bumps) of gold, copper, solder, lead-free solder, or nickel, or a multi-layer laminate of these metals at predetermined portions (electrodes) on a surface of a semiconductor chip having interconnects formed therein, and to electrically connect the interconnects via the bumps with electrodes of a package or with TAB electrodes. Methods of forming bumps include various methods, such as electroplating, vapor deposition, printing, and ball bumping. With a recent increase in the number of I/O in a semiconductor chip and a trend toward finer pitches, electroplating has more frequently been employed because it can cope with fine processing and has relatively stable performance.

[0003] With an electroplating method, a metal film (plated film) having a high purity can readily be obtained. Further, an electroplating method has a relatively high deposition rate of a metal film, and control of thickness of the metal film can be performed relatively easily.

[0004] FIG 37 shows an example of a conventional plating apparatus which employs a so-called face-down method. The plating apparatus has an upwardly opened plating tank 12 for holding a plating solution 10 therein and a vertically movable substrate holder 14 for detachably holding a substrate W in a state such that a front face (surface to be plated) of the substrate W faces downward (face-down). An anode 16 is disposed horizontally at a bottom of the plating tank 12. Overflow tanks 18 are provided around an upper portion of the plating tank 12. Further, a plating solution supply nozzle 20 is connected to the bottom of the plating tank 12.

[0005] In operation, a substrate W held horizontally by the substrate holder 14 is located at a position such as to close an opening at an upper end of the plating tank 12. In this state, the plating solution 10 is supplied from the plating solution supply nozzle 20 into the plating solution tank 12 and allowed to overflow the upper portion of the plating tank 12, thereby bringing the plating solution 10 into contact with a surface of the substrate

W held by the substrate holder 14. Simultaneously, the anode 16 is connected via a conductor 22a to an anode of a plating power supply 24, and the substrate W is connected via a conductor 22b to a cathode of the plating power supply 24. Thus, due to a potential difference between the substrate W and the anode 16, metal ions in the plating solution 10 receive electrons from the surface of the substrate W, so that metal is deposited on the surface of the substrate W so as to form a metal film.

[0006] According to the plating apparatus, uniformity of the thickness of the metal film formed on the surface of the substrate W can be adjusted to a certain extent by adjusting the size of the anode 16, an interpolar distance and potential difference between the anode 16 and the substrate W, a supply rate of the plating solution 10 supplied from the plating solution supply nozzle 20, and the like.

[0007] FIG 38 shows an example of a conventional plating apparatus which employs a so-called dipping method. The plating apparatus has a plating tank 12a for holding a plating solution 12a therein and a vertically movable substrate holder 14a for detachably holding a substrate W in a state such that a front face (surface to be plated) is exposed while a peripheral portion of the substrate W is water-tightly sealed. An anode 16a is held by an anode holder 26 and disposed vertically within the plating tank 12. Further, a regulation plate 28 made of a dielectric material having a central hole 28a is disposed in the plating tank 12 so as to be positioned between the anode 16a and the substrate W when the substrate W held by the substrate holder 14a is disposed at a position facing the anode 16a.

[0008] In operation, the anode 16a, the substrate W, and the regulation plate 28 are immersed in the plating solution in the plating tank 12a. Simultaneously, the anode 16a is connected via a conductor 22a to an anode of a plating power supply 24, and the substrate W is connected via a conductor 22b to a cathode of the plating power supply 24. Accordingly, metal is deposited onto the surface of the substrate W so as to form a metal film in the same manner as described above.

[0009] According to the plating apparatus, distribution of thickness of the metal film formed on the surface of the substrate W can be adjusted to a certain extent by disposing the regulation plate 28 having the central hole 28a between the anode 16a and the substrate W disposed at a position facing the anode 16a, and adjusting a potential distribution on the plating bath 12a with the regulation plate 28.

[0010] FIG 39 shows another example of a conventional plating apparatus which employs a so-called dipping method. The plating apparatus differs from the apparatus shown in FIG 38 in that a ring-shaped dummy cathode (dummy electrode) 30 is provided instead of a regulation plate, that a substrate W is held by a substrate holder 14a in a state such that the dummy cathode 30 is disposed around the substrate W, and that the dummy cathode 30 is connected to a cathode of a plating power

supply 24 during plating.

[0011] According to the plating apparatus, uniformity of thickness of a plated film formed on the surface of the substrate W can be improved by adjusting an electric potential of the dummy cathode 30.

[0012] On the other hand, for example, when a metal film (plated film) for interconnects or bumps is formed on a surface of a semiconductor substrate (wafer), the metal film formed is required to be uniform in surface profile and in film thickness over the entire surface of the substrate. There are increasing demands for a high degree of uniformity in recent high-density packaging technologies such as SOC and WL-CSP. However, with the above conventional plating apparatuses, it is quite difficult to form a metal film that meets a high degree of uniformity requirement.

[0013] Specifically, when a substrate is plated by the plating apparatus shown in FIG 37, a metal film is formed under a strong influence of a flow of the plating solution. If the plating solution flows fast, as shown in FIG 40A, the thickness of the metal film P tends to be thicker in a central portion of the substrate W, to which metal ions are sufficiently supplied, than in a peripheral portion of the substrate W. If the flow of the plating the solution is made considerably weak in order to prevent the above phenomenon, as shown in FIG 40B, the thickness of the metal film P tends to be thicker in a peripheral portion of the substrate W than in a central portion. When a substrate W is plated by the plating apparatus shown in FIG 38, a potential distribution can be improved by the regulation plate having the central hole, so that the uniformity of the film thickness distribution of a metal film can be improved to a certain extent over the entire surface of the substrate. However, as shown in FIG 40C, the metal film P tends to have an undulate thickness distribution, in which the film thickness is thicker in a central portion and a peripheral portion of the substrate W. Further, when a substrate is plated by the plating apparatus shown in FIG 39, it is difficult to adjust a voltage applied to the dummy electrode (dummy cathode). In addition, it becomes necessary to remove a metal film attached to a surface of the dummy electrode, and the removal necessitates a troublesome operation.

[0014] In the conventional plating apparatuses, there is a general tendency that due to a surface potential distribution produced over a surface of a substrate, the film thickness of a plated film is larger in a peripheral portion of the substrate, which serves as an electrically receiving portion, causing a U-shaped film thickness distribution over the substrate surface (see FIG 40B). This is one of the main factors that impair the uniformity of film thickness. In order to suppress this phenomenon, a regulation plate or a dummy electrode is employed in a method of regulating supply of metal ions to a surface of a substrate, i.e. regulating a flow of a plating solution, and a method of controlling or regulating a potential distribution on a surface of a substrate and an electric field

in a plating tank.

[0015] The regulating method of a flow of a plating solution and the regulating method using a regulation plate are intended to concentrate metal ions or an electric field to a central portion of a substrate to raise a plated film at the central portion of the substrate, thereby adjusting a film thickness distribution of the plated film over the entire substrate surface so as to be a W-shaped distribution and minimizing a film thickness variation from an average film thickness (see FIG 40C). Accordingly, the uniformity of the film thickness is greatly influenced by regulation of the flow of the plating solution and by selection and fine control of the position of the regulation plate and the size of the central hole. Thus, the uniformity of the film thickness is greatly influenced by the degree of adjustment (tuning).

[0016] On the other hand, the method using a dummy electrode is intended to broaden a range of a potential distribution from a substrate surface to a region including the dummy electrode around the substrate, thereby shifting the raised portion of the plated film in the electrically receiving portion to the dummy electrode and obtaining an extremely uniform film thickness on the substrate surface. As an equivalent method to the method employing a dummy electrode, there has also been known a method which uses a pattern in a peripheral portion of a substrate as a "discarded chip" so as to serve as a dummy electrode. In such methods that employ a dummy electrode, the uniformity of the film thickness is influenced by adjustment of a voltage. Further, it is necessary to periodically remove a metal film (plated film) attached to the dummy electrode, which necessitates a troublesome operation. When a pattern in a peripheral portion of a substrate is used as a "discarded chip" so as to serve as a dummy electrode, the number of effective chips per substrate is inevitably reduced to thereby cause a lowered productivity.

[0017] All of the above-described methods eventually adjust a film thickness distribution to obtain a uniform film thickness distribution. Thus, none of the above-described methods are intended to positively control or regulate an electric field in a plating tank, which is produced between an anode and a plating workpiece as a cathode, so as to control and improve a potential distribution on a surface of the plating workpiece, thereby equalizing and improving the film thickness distribution of the plated film which would otherwise become a U-shaped distribution.

Disclosure of Invention

[0018] The present invention has been made in view of the above drawback. It is, therefore, an object of the present invention to provide a plating apparatus which can form a metal film (plated film) having a uniform thickness over an entire plating workpiece with a relatively simple arrangement and without needs for a complicated operation and setting.

[0019] In order to achieve the above object, the present invention provides a plating apparatus characterized by comprising a plating tank for holding a plating solution; an anode disposed so as to be immersed in the plating solution in the plating tank; a regulation plate disposed between the anode and a plating workpiece disposed so as to face the anode; and a plating power supply for supply a current between the anode and the plating workpiece to carry out plating, wherein the regulation plate is disposed so as to separate the plating solution held in the plating tank into a plating solution on the anode side and a plating solution on the plating workpiece side, and a through-hole group having a large number of through-holes is formed in the regulation plate.

[0020] According to the present invention, an electric field leaks through a large number of through-holes formed in the regulation plate disposed in the plating tank, and the leaked electric field spreads uniformly. Accordingly, a potential distribution can be made more uniform over an entire surface of the plating workpiece, and a within wafer uniformity of a metal film formed on the surface of the plating workpiece can be enhanced. Further, the plating solution is prevented from passing through a large number of through-holes formed in the regulation plate provided in the plating tank. Accordingly, non-uniform film thickness is prevented from being caused to a metal film formed on the surface of the plating workpiece due to influence of a flow of the plating solution.

[0021] According to a preferred aspect of the present invention, the through-hole group is formed by a plurality of slit-like elongated holes extending linearly in one direction or extending in an arc. The use of slit-like elongated holes as the through-holes can promote leakage of electric field while preventing the plating solution from passing through the through-holes. For example, the widths of the elongated holes are set to be about 0.5 to 20 mm, preferably about 1 to 15 mm. The lengths of the elongated holes are determined depending upon the shape of the plating workpiece.

[0022] According to a preferred aspect of the present invention, the through-hole group is formed by a plurality of cross holes extending crosswise in vertical and horizontal directions.

[0023] According to a preferred aspect of the present invention, the through-hole group is formed by a combination of a plurality of fine holes, a plurality of holes having different diameters, and slit-like elongated holes. The use of a combination of a plurality of fine holes, a plurality of holes having different diameters, and slit-like elongated holes as the through-hole group can increase the productivity. For example, the diameters of the fine holes or small holes (peripheral holes) are set to be about 1 to 20 mm, preferably about 2 to 10 mm. For example, the diameters of large holes (central holes) are set to be about 50 to 300 mm, preferably about 30 to 100 mm.

[0024] It is desirable that the through-hole group be formed in the regulation plate substantially over an entire area facing the plating workpiece, and formed in an area substantially similar to a shape of the plating workpiece. With such a through-hole group, it is possible to form a metal film having a good film thickness uniformity in all directions on the plating workpiece.

[0025] Preferably, the plating apparatus comprises an agitating mechanism provided between the plating workpiece and the regulation plate for stirring the plating solution held in the plating tank. By agitating the plating solution between the plating workpiece and the regulation plate by the agitating mechanism during plating, sufficient ions can be supplied more uniformly to the plating workpiece. Therefore, a metal film having a more uniform thickness can be formed more rapidly.

[0026] Preferably, the agitating mechanism should comprise a paddle-type agitating mechanism having a paddle which reciprocates parallel to the plating workpiece. By reciprocating a paddle parallel to the plating workpiece during plating to agitate the plating solution by the paddle, the directionality of the flow of the plating solution can be eliminated, and simultaneously sufficient ions can be supplied more uniformly to the surface of the plating workpiece.

[0027] According to a preferred aspect of the present invention, the anode and the regulation plate are provided in a vertical direction. This arrangement provides a plating apparatus with a small installation space and having excellent maintainability.

[0028] The present invention also provides another plating apparatus characterized by comprising a plating tank for holding a plating solution; an anode disposed so as to be immersed in the plating solution in the plating tank; a regulation plate disposed between the anode and a plating workpiece disposed so as to face the anode; and a plating power supply for supply a current between the anode and the plating workpiece to carry out plating, wherein the regulation plate is disposed so as to separate the plating solution held in the plating tank into a plating solution on the anode side and a plating solution on the plating workpiece side, and a plating solution passage is formed in the regulation plate for allowing an electric field to uniformly pass therethrough and allowing the plating solution to pass therethrough.

[0029] By thus allowing the electric field produced between the anode and the plating workpiece in the plating tank to pass uniformly through the plating solution passage without leaking out of the plating solution passage, distortion or deviation of the electric field can be adjusted and corrected so as to equalize a potential distribution over an entire surface of the plating workpiece, thereby enhancing a within wafer uniformity of a metal film formed on the plating workpiece.

[0030] The length of the plating solution passage is properly determined depending upon the shape of the plating tank, the distance between the anode and the plating workpiece, and the like. However, the length is

generally 10 to 90 mm, preferably 20 to 75 mm, more preferably 30 to 60 mm.

[0031] Preferably, the plating solution passage is defined by an inner circumferential surface of a cylindrical member or a rectangular block. This arrangement can simplify the structure.

[0032] It is desirable that a large number of through-holes having a size such as to prevent leakage of an electric field be formed in a circumferential wall of the cylindrical member. With this arrangement, the plating solution is allowed to pass through the through-holes formed in the circumferential wall of the cylindrical member while preventing leakage of the electric field. Accordingly, the concentration of the plating solution is prevented from being different between the inside and outside of the cylindrical member. With respect to the shape of the through-holes, for example, fine holes, slit-like elongated holes, cross holes extending vertically and horizontally, and a combination thereof may be exemplified.

[0033] According to a preferred aspect of the present invention, the plating apparatus comprises an agitating mechanism provided in at least one of a space between the plating workpiece and the regulation plate and a space between the anode and the regulation plate for agitating the plating solution held in the plating tank. By agitating the plating solution during plating, the concentration of the plating solution containing metal ions and various additives can be made uniform in the plating tank, and the plating solution having a uniform concentration can be supplied to the plating workpiece. Accordingly, a metal film having a more uniform thickness can be formed more rapidly.

[0034] The agitating mechanism is preferably a paddle-type agitating mechanism having a paddle which reciprocates parallel to the plating workpiece.

[0035] The agitating mechanism may comprise a plating solution injection type agitating mechanism having a plurality of plating solution injection nozzles for ejecting the plating solution toward the plating workpiece. By injecting the plating solution from the plurality of plating solution injection nozzles toward the plating workpiece, the plating solution in the plating tank can be agitated so as to uniformize the plating solution concentration and, simultaneously, to sufficiently supply components of the plating solution to the plating workpiece. Thus, a metal film having a more uniform thickness can be formed more rapidly.

[0036] The plating solution passage may be formed in the regulation plate integrally with the regulation plate. A thick regulation plate may be used, and a through-hole may be formed in the regulation plate so as to serve as a plating solution passage.

[0037] The present invention provides yet another plating apparatus comprising a plating tank for holding a plating solution; an anode disposed so as to be immersed in the plating solution in the plating tank; a regulation plate disposed between the anode and a plating

workpiece disposed so as to face the anode for separating the plating solution held in the plating tank into a plating solution on the anode side and a plating solution on the plating workpiece side, the regulation plate having a plating solution passage for allowing an electric field to uniformly pass therethrough and allowing the plating solution to pass therethrough; a plating power supply for supply a current between the anode and the plating workpiece to carry out plating; and an electric field adjustment ring disposed at an end of the plating solution passage on the plating workpiece side for adjusting an electric field at a peripheral portion of the plating workpiece.

[0038] By adjusting an electric field at a peripheral portion of the plating workpiece by the electric field adjustment ring, an electric field produced between the anode and the plating workpiece can be uniformized over an entire surface of the plating workpiece, including an edge portion of the plating workpiece, which serves as an electrically receiving portion. Therefore, a within wafer uniformity of a metal film formed on the plating workpiece can be further enhanced.

[0039] The shape of the electric field adjustment ring may be properly determined depending upon the shape of the plating tank, the shape of the plating workpiece, the distance between the anode and the plating workpiece, and the like. The width of the ring is generally set to be in a range of 1 to 20 mm, preferably 3 to 17 mm, more preferably 5 to 15 mm.

[0040] A gap between the electric field adjustment ring and the plating workpiece is generally set to be in a range of 0.5 to 30 mm, preferably 1 to 15 mm, more preferably 1.5 to 6 mm.

[0041] According to a preferred aspect of the present invention, the plating solution passage is defined by an inner circumferential surface of a cylindrical member, and the electric field adjustment ring is connected to an end of the cylindrical member on the plating workpiece side.

[0042] Alternatively, the plating solution passage may be defined by an inner circumferential surface of a cylindrical member, and the electric field adjustment ring may be disposed at an end of the cylindrical member on the plating workpiece side so as to be separated from the cylindrical member. With such a separated plating solution passage, the cylindrical member and the electric field adjustment ring can be separated so as to offer a broader choice.

[0043] Alternatively, the plating solution passage may be defined by an inner circumferential surface of a cylindrical member, and the electric field adjustment ring may be formed on an end surface of the plating workpiece side. With this arrangement, the number of parts can be reduced.

Brief Description of Drawings

[0044]

FIG 1 is an overall layout of a plating facility having a plating apparatus according to an embodiment of the present invention;

FIG 2 is a schematic view of a transfer robot provided in a plating space of a plating processing apparatus shown in FIG 1;

FIG 3 is a schematic cross-sectional view of a plating apparatus provided in the plating processing apparatus shown in FIG 1;

FIG 4 is a schematic perspective view of a main portion of the plating apparatus shown in FIG 3;

FIG 5 is a plan view of a regulation plate provided in the plating apparatus shown in FIG 3;

FIG 6 is a schematic diagram illustrating a state of a metal film (plated film) formed by the plating apparatus shown in FIG 3;

FIGS. 7A through 7E are cross-sectional diagrams sequentially illustrating a process of forming a bump (protruding electrode) on a substrate;

FIG 8 is a plan view showing another example of a regulation plate;

FIG 9 is a plan view showing still another example of a regulation plate;

FIG 10 is a plan view showing yet another example of a regulation plate;

FIG 11 is a plan view showing yet another example of a regulation plate;

FIG 12 is a plan view showing yet another example of a regulation plate;

FIG 13 is a plan view showing yet another example of a regulation plate;

FIG 14 is a plan view showing yet another example of a regulation plate;

FIG 15 is a plan view showing yet another example of a regulation plate;

FIG 16 is a plan view showing yet another example of a regulation plate;

FIG 17 is a plan view showing yet another example of a regulation plate;

FIG 18 is a plan view showing yet another example of a regulation plate;

FIG 19 is a plan view showing yet another example of a regulation plate;

FIG 20 is a schematic cross-sectional view showing a plating apparatus according to another embodiment of the present invention;

FIG 21A is a perspective view showing a regulation plate and a cylindrical member provided in the plating apparatus shown in FIG 20;

FIG 21B is a front view of FIG 21A;

FIG 22 is a schematic diagram illustrating a state of a metal film (plated film) formed by the plating apparatus shown in FIG 20;

FIG 23 is a schematic cross-sectional view showing

a plating apparatus according to still another embodiment of the present invention;

FIG 24A is a perspective view showing another example of a regulation plate and a cylindrical member;

FIG 24B is a front view of FIG 24A;

FIG 25A is a perspective view showing still another example of a regulation plate and a cylindrical member;

FIG 25B is a front view of FIG 25A;

FIG 26A is a perspective view showing yet another example of a regulation plate and a cylindrical member;

FIG 26B is a front view of FIG 26A;

FIG 27A is a perspective view showing yet another example of a regulation plate and a cylindrical member;

FIG 27B is a front view of FIG 27A;

FIG 28 is a schematic cross-sectional view showing a plating apparatus according to yet another embodiment of the present invention;

FIG 29A is a perspective view showing a regulation plate, a cylindrical member, and an electric field adjustment ring provided in the plating apparatus shown in FIG 28;

FIG 29B is a front view of FIG 29A;

FIG 30 is a schematic diagram illustrating a metal film (plated film) formed by the plating apparatus shown in FIG 28;

FIG 31 is a schematic cross-sectional view showing a plating apparatus according to yet another embodiment of the present invention;

FIG 32A is a perspective view showing another example of a regulation plate, a cylindrical member, and an electric field adjustment ring;

FIG 32B is a front view of FIG 32A;

FIG 33A is a perspective view showing still another example of a regulation plate, a cylindrical member, and an electric field adjustment ring;

FIG 33B is a front view of FIG 33A;

FIG 34A is a perspective view showing yet another example of a regulation plate, a cylindrical member, and an electric field adjustment ring;

FIG 34B is a front view of FIG 34A;

FIG 35A is a perspective view showing yet another example of a regulation plate, a cylindrical member, and an electric field adjustment ring;

FIG 35B is a front view of FIG 35A;

FIG 36 is a schematic cross-sectional view showing a plating apparatus according to yet another embodiment of the present invention;

FIG 37 is a schematic cross-sectional view showing an example of a conventional plating apparatus;

FIG 38 is a schematic perspective view showing another example of a conventional plating apparatus;

FIG 39 is a schematic perspective view showing still another example of a conventional plating apparatus; and

FIGS. 40A through 40C are schematic diagrams illustrating various states of metal films (plated films) formed by conventional plating apparatuses.

Best Mode for Carrying Out the Invention

[0045] Embodiments of the present invention will be described below with reference to the drawings. The following embodiments show examples in which a substrate such as a semiconductor wafer is used as a plating workpiece.

[0046] FIG 1 shows an overall layout of a plating facility having a plating apparatus according to an embodiment of the present invention. The plating facility is designed so as to automatically perform all the plating processes including pretreatment of a substrate, plating, and posttreatment of the plating, in a successive manner. The interior of an apparatus frame 110 having an armored panel attached thereto is divided by a partition plate 112 into a plating space 116 for performing a plating process of a substrate and treatments of the substrate to which a plating solution is attached, and a clean space 114 for performing other processes, i.e. processes not directly involving a plating solution. Two substrate holders 160 (see FIG 2) are arranged in parallel, and substrate attachment/detachment stages 162 to attach a substrate to and detach a substrate from each substrate holder 160 are provided as a substrate delivery section on a partition portion partitioned by the partition plate 112, which divides the plating space 116 from the clean space 114. Loading/unloading ports 120, on which substrate cassettes storing substrates are mounted, are connected to the clean space 114. Further, the apparatus frame 110 has a console panel 121 provided thereon.

[0047] In the clean space 114, there are disposed at four corners an aligner 122 for aligning an orientation flat or a notch of a substrate with a predetermined direction, two cleaning/drying devices 124 for cleaning a plated substrate and rotating the substrate at a high speed to spin-dry the substrate, and a pretreatment device 126 for carrying out a pretreatment of a substrate, e.g., according to the present embodiment, a rinsing pretreatment including injecting pure water toward a front face (surface to be plated) of a substrate to thereby clean the substrate surface with pure water and, at the same time, wet the substrate surface with pure water so as to enhance a hydrophilicity of the substrate surface. Further, a first transfer robot 128 is disposed substantially at the center of these processing devices, i.e. the aligner 122, the cleaning/drying devices 124, and the pretreatment device 126, to thereby transfer and deliver a substrate between the processing devices 122, 124, and 126, the substrate attachment/detachment stages 162, and the substrate cassettes mounted on the loading/unloading ports 120.

[0048] The aligner 122, the cleaning/drying devices 124, and the pretreatment device 126 disposed in the

clean space 114 are designed so as to hold and process a substrate in a horizontal state in which a front face of the substrate faces upward. The transfer robot 128 is designed so as to transfer and deliver a substrate in a horizontal state in which a front face of the substrate faces upward.

[0049] In the plating space 116, in the order from the partition plate 112, there are disposed a stocker 164 for storing or temporarily storing the substrate holders 160, an activation treatment device 166 for etching, for example, an oxide film, having a large electric resistance, on a seed layer formed on a surface of a substrate with a chemical liquid such as sulfuric acid or hydrochloric acid to remove the oxide film, a first rinsing device 168a for rinsing the surface of the substrate with pure water, a plating apparatus 170 for carrying out plating, a second rinsing device 168b, and a blowing device 172 for dewatering the plated substrate. Two second transfer robots 174a and 174b are disposed beside these devices so as to be movable along a rail 176. One of the second transfer robots 174a transfers the substrate holders 160 between the substrate attachment/detachment stages 162 and the stocker 164. The other of the second transfer robots 174b transfers the substrate holders 160 between the stocker 164, the activation treatment device 166, the first rinsing device 168a, the plating apparatus 170, the second rinsing device 168b, and the blowing device 172.

[0050] As shown in FIG 2, each of the second transfer robots 174a and 174b has a body 178 extending in a vertical direction and an arm 180 which is vertically movable along the body 178 and rotatable about its axis. The arm 180 has two substrate holder retaining portions 182 provided in parallel for detachably retaining the substrate holders 160. The substrate holder 160 is designed so as to hold a substrate W in a state in which a front face of the substrate is exposed while a peripheral portion of the substrate is sealed, and to be capable of attaching the substrate W to the substrate holder 160 and detaching the substrate W from the substrate holder 160.

[0051] The stocker 164, the activation treatment device 166, the rinsing devices 168a, 168b, and the plating apparatus 170 are designed so as to engage with outwardly projecting portions 160a provided at both ends of each substrate holder 160 to thus support the substrate holders 160 in a state such that the substrate holders 160 are suspended in a vertical direction. The activation treatment device 166 has two activation treatment tanks 183 for holding a chemical liquid therein. As shown in FIG 2, the arm 180 of the second transfer robot 174b holding the substrate holders 160, which are loaded with the substrates W, in a vertical state is lowered so as to engage the substrate holders 160 with upper ends of the activation treatment tanks 183 to support the substrate holders 160 in a suspended manner as needed. Thus, the activation treatment device 166 is designed so that the substrate holders 160 are immersed

together with the substrates W in the chemical liquid in the activation treatment tanks 183 to carry out an activation treatment.

[0052] Similarly, the rinsing devices 168a and 168b have two rinsing tanks 184a and two rinsing tanks 184b which hold pure water therein, respectively, and the plating apparatus 170 has a plurality of plating tanks 186 which hold a plating solution therein. The rinsing devices 168a, 168b and the plating apparatus 170 are designed so that the substrate holders 160 are immersed together with the substrates W in the pure water in the rinsing tanks 184a, 184b or the plating solution in the plating tanks 186 to carry out rinsing treatment or plating in the same manner as described above. The arm 180 of the second transfer robot 174b holding the substrate holders 160 with substrates W in a vertical state is lowered, and air or inert gas is injected toward the substrates W mounted on the substrate holders 160 to blow away a liquid attached to the substrate holders 160 and the substrates W and to dewater the substrates W. Thus, the blowing device 172 is designed so as to carry out blowing treatment.

[0053] As shown in FIGS. 3 and 4, each plating tank 186 in the plating apparatus 170 is designed so as to hold a plating solution 10 therein. Thus, the substrates W, which are held in a state such that the front faces (surfaces to be plated) are exposed while peripheral portions of the substrate holders 160 are water-tightly sealed, are immersed in the plating solution 10.

[0054] Overflow tanks 46 are provided at both sides of the plating tank 186 for receiving a plating solution 10 overflowing upper ends of overflow weirs 44 of the plating tank 186. The overflow tanks 46 and the plating tank 186 are connected through a circulation pipe 48. The circulation pipe 48 has a circulating pump 50, a thermostatic unit 52, and a filter 54 provided in the circulation pipe 48. A plating solution 10 supplied into the plating tank 186 by operation of the circulating pump 50 fills the plating tank 186, then overflows the overflow weirs 44, flows into the overflow tanks 46, and returns to the circulating pump 50. Thus, the plating solution 10 is circulated.

[0055] An anode 56 having a circular shape corresponding to the shape of the substrate W is held by an anode holder 58 and provided vertically in the plating tank 186. Thus, when the plating solution 10 is filled in the plating tank 186, the anode 56 is immersed in the plating solution 10. Further, a regulation plate 60 is provided between the anode 56 and the substrate holder 160 to partition the interior of the plating tank 186 into an anode side chamber 40a and a substrate side chamber 40b and to separate the plating solution 10 held in the plating tank 186 into an anode side plating solution and a substrate side plating solution.

[0056] A paddle-type agitating mechanism 64 having a plurality of paddles 62 extending vertically downward is disposed between the substrate holder 160 and the regulation plate 60. The paddles 62 are reciprocated

within the plating solution in the substrate side chamber 40b in parallel to the substrate W held by the substrate holder 160, thereby stirring the plating solution in the substrate side chamber 40b.

[0057] The regulation plate 60 has a thickness of, for example, about 0.5 to 10 mm and is made of a dielectric material including PVC, PP, PEEK, PES, HT-PVC, PFA, PTFE, and other resin materials. A through-hole group 68 including a large number of through-holes 66 is provided in a predetermined area of the regulation plate 60, which is substantially the entire area facing the surface of the substrate W when the substrate W is held by the substrate holder 160 and located at a predetermined plating position in the plating tank 186, and which is a circular area similar to the shape of the substrate W.

[0058] According to the present embodiment, as particularly shown in FIG 5, the through-holes 66 are formed by slit-like elongated holes extending linearly in a horizontal direction. The through-holes (elongated holes) 66 are lineally arranged in parallel within a circular area corresponding to the shape of the substrate W so as to form the through-hole group 68. The through-holes (elongated holes) 66 generally have a width of about 0.5 to 20 mm, preferably about 1 to 15 mm. The length of the through-hole 66 is determined depending upon the size (diameter) of the substrate W.

[0059] Thus, the through-hole group 68 including a large number of through-holes 66 is provided in the regulation plate 60 so that an electric field leaks through the respective through-holes 66 at the time of plating, and that the leaked electric field spreads uniformly. Accordingly, a potential distribution can be made more uniform over the entire surface (surface to be plated) of the substrate W, and a within wafer uniformity of a metal film formed on the surface of the substrate W can be enhanced. Further, the plating solution 10 is prevented from passing through a large number of through-holes 66 formed in the regulation plate 60 provided in the plating tank 186. Accordingly, non-uniform film thickness is prevented from being caused to a metal film formed on the surface of the substrate W due to influence of a flow of the plating solution 10 (return flow of the plating solution).

[0060] Particularly, the use of slit-like elongated holes as the through-holes 66 can prevent the plating solution 10 from passing through the through-holes (elongated holes) 66 and simultaneously promote leakage of the electric field. Further, by forming the through-hole group 68, including a large number of through-holes 66, substantially in the entire area facing the surface of the substrate W which is a circular area similar to the shape of the substrate W, a metal film having a good film thickness uniformity can be formed in all directions on the surface of the substrate W.

[0061] With the plating apparatus 170, a plating solution 10 is first filled in the plating tank 186 and circulated as described above. In this state, the substrate holder 160 holding the substrate W is lowered to locate the sub-

strate W at a predetermined position within the plating tank 186 at which the substrate W is immersed in the plating solution 10. The anode 56 is connected via a conductor 22a to an anode of a plating power supply 24, and the substrate W is connected via a conductor 22b to a cathode of the plating power supply 24. At the same time, the paddle-type agitating mechanism 64 is operated so as to reciprocate the paddles 62 along the surface of the substrate W to thereby agitate the plating solution 10 in the substrate side chamber 40b. As a result, a metal is deposited on the surface of the substrate W so as to form a metal film on the surface of the substrate W.

[0062] At that time, as described above, an electric field leaks through a large number of through-holes 66 formed in the regulation plate 60, and the leaked electric field spreads uniformly. Accordingly, a potential distribution can be made more uniform over the entire front face (surface to be plated) of the substrate W, and a metal film P having an enhanced within wafer uniformity can be formed on the surface of the substrate W as shown in FIG 6. Further, by agitating the plating solution 10 between the substrate W and the regulation plate 60 with the paddles 62 during plating, the directionality of the flow of the plating solution can be eliminated, and simultaneously sufficient ions can be supplied more uniformly to the surface of the substrate W. Therefore, a metal film having a more uniform thickness can be formed more rapidly.

[0063] After completion of the plating, the plating power supply 24 is disconnected from the substrate W and the anode 56, and the substrate holder 160 is pulled up together with the substrate W. After necessary treatments such as water-cleaning and rinsing of the substrate W, the plated substrate W is transferred to a subsequent process.

[0064] A series of bump plating processes in the plating facility thus constructed will be described below with reference to FIGS. 7A through 7E. First, as shown in FIG 7A, a seed layer 500 is deposited as a feeding layer on a surface of a substrate W, and a resist 502 having a height H of, for example, about 20 to 120 μm is applied onto the entire surface of the seed layer 500. Thereafter, an opening 502a having a diameter D_1 of, for example, about 20 to 200 μm is formed at a predetermined position of the resist 502. Substrates W thus prepared are housed in a substrate cassette in a state such that front faces (surfaces to be plated) of the substrates face upward. The substrate cassette is mounted on the loading/unloading port 120.

[0065] One of the substrates W is taken out of the substrate cassette mounted on the loading/unloading port 120 by the first transfer robot 128 and placed on the aligner 122 to align an orientation flat or a notch of the substrate with a predetermined direction. The substrate W thus aligned is transferred to the pretreatment device 126 by the first transfer robot 128. In the pretreatment device 126, a pretreatment (rinsing pretreatment) using

pure water as a pretreatment liquid is carried out. On the other hand, two substrate holders 160 which have been stored in a vertical state in the stocker 164 are taken out by the second transfer robot 174a, rotated through 90° so that the substrate holders 160 are brought into a horizontal state, and then placed in parallel on the substrate attachment/detachment stages 162.

[0066] Then, the substrates W which have been subjected to the aforementioned pretreatment (rinsing pretreatment) are loaded into the substrate holders 160 placed on the substrate attachment/detachment stages 162 in a state such that peripheral portions of the substrates are sealed. The two substrate holders 160 which have been loaded with the substrates W are simultaneously retained, lifted, and then transferred to the stocker 164 by the second transfer robot 174a. The substrate holders 160 are rotated through 90° into a vertical state and lowered so that the two substrate holders 160 are held (temporarily stored) in the stocker 164 in a suspended manner. The above operation is carried out repeatedly in a sequential manner, so that substrates are sequentially loaded into the substrate holders 160, which are stored in the stocker 164, and are sequentially held (temporarily stored) in the stocker 164 at predetermined positions in a suspended manner.

[0067] On the other hand, the two substrate holders 160 which have been loaded with the substrates and temporarily stored in the stocker 164 are simultaneously retained, lifted, and then transferred to the activation treatment device 166 by the second transfer robot 174b. Each substrate is immersed in a chemical liquid such as sulfuric acid or hydrochloric acid held in the activation treatment tank 183 to thereby etch an oxide film, having a large electric resistance, formed on the surface of the seed layer so as to expose a clean metal surface. The substrate holders 160 which have been loaded with the substrates are transferred to the first rinsing device 168a in the same manner as described above to rinse the surfaces of the substrates with pure water held in the rinsing tanks 184a.

[0068] The substrate holders 160 which have been loaded with the rinsed substrates are transferred to the plating apparatus 170 in the same manner as described above. Each substrate W is supported in a suspended manner by the plating tank 186 in a state such that the substrate W is immersed in the plating solution 10 in the plating tank 186 to thus carry out plating on the surface of the substrate W. After a predetermined period of time has elapsed, the substrate holders 160 which have been loaded with the substrates are retained again and pulled up from the plating tank 186 by the second transfer robot 174b. Thus, the plating process is completed.

[0069] Thereafter, the substrate holders 160 are transferred to the second rinsing device 168b in the same manner as described above. The substrate holders 160 are immersed in pure water in the rinsing tanks 184b to clean the surfaces of the substrates with pure

water. Then, the substrate holders 160 which have been loaded with the substrates are transferred to the blowing device 172 in the same manner as described above. In the blowing device 172, inert gas or air is injected toward the substrates to blow away a plating solution and water droplets attached to the substrate holders 160. Thereafter, the substrate holders 160 which have been loaded with the substrates are returned to predetermined positions in the stocker 164 and held in a suspended state in the same manner as described above.

[0070] The second transfer robot 174b sequentially performs the above operation repeatedly so that the substrate holders 160 which have been loaded with the plated substrates are sequentially returned to predetermined positions in the stocker 164 and held in a suspended manner.

[0071] On the other hand, the two substrate holders 160 which have been loaded with the plated substrates are simultaneously retained and placed on the substrate attachment/detachment stages 162 by the second transfer robot 174a in the same manner as described above.

[0072] The first transfer robot 128 disposed in the clean space 114 takes the substrate out of the substrate holders 160 placed on the substrate attachment/detachment stages 162 and transfers the substrate to either one of the cleaning/drying devices 124. In the cleaning/drying device 124, the substrate held in a horizontal state such that the front face of the substrate faces upward is cleaned with pure water or the like and rotated at a high speed to spin-dry the substrate. Thereafter, the substrate is then returned to the substrate cassette mounted on the loading/unloading port 120 by the first transfer robot 128. Thus, a series of plating processes is completed. As a result, as shown in FIG 7B, a substrate W having a plated film 504 grown in the opening 502a formed in the resist 502 can be obtained.

[0073] The spin-dried substrate W as described above is immersed in a solvent such as acetone at a temperature of, for example, 50 to 60°C to remove the resist 502 from the substrate W as shown in FIG 7C. Further, as shown in FIG 7D, an unnecessary seed layer 502, which is exposed after plating, is removed. Next, the plated film 504 formed on the substrate W is reflowed to form a bump 506 having a round shape due to surface tension. The substrate W is then annealed at a temperature of, for example, 100°C or more to remove residual stress in the bump 506.

[0074] According to this embodiment, delivery of substrates in the plating space 116 is performed by the second transfer robots 174a and 174b disposed in the plating space 116, whereas delivery of substrates in the clean space 114 is performed by the first transfer robot 128 disposed in the clean space 114. Accordingly, it is possible to improve the cleanliness around a substrate in the plating processing apparatus which performs all the plating processes including pretreatment of a substrate, plating, and posttreatment of the plating, in a suc-

cessive manner, and to increase a throughput of the plating processing apparatus. Further, it is possible to reduce loads on facilities associated with the plating processing apparatus and to achieve downsizing of the plating processing apparatus.

[0075] According to the present embodiment, a plating tank 186 having a small footprint is used in the plating apparatus 170 for carrying out plating. Accordingly, it is possible to achieve further downsizing of the plating apparatus having a large number of plating tanks 186 and reduce loads on associated facilities in a plant. In FIG 1, one of the two cleaning/drying devices 124 may be replaced with a pretreatment device.

[0076] FIGS. 8 through 19 show various examples of a through-hole group including a large number of through-holes in a regulation plate 60. Specifically, FIG 8 shows an example in which through-holes 66a are formed by slit-like elongated holes extending linearly in a vertical direction, and the through-holes (elongated holes) 66a are arranged linearly in parallel in a circular area corresponding to the shape of a substrate W so as to form a through-hole group 68a. FIG 9 shows an example in which through-holes (elongated holes) 66b are arranged linearly in parallel in a rectangular area corresponding to the shape of a substrate W so as to form a through-hole group 68b, which is suitable for a rectangular substrate W.

[0077] FIG 10 shows an example in which a through-hole group 68c is formed by a plurality of through-holes (elongated holes) 66c which are slit-like elongated holes extending linearly substantially across the entire width of an area of a regulation plate 60 facing a surface of a substrate W. In this case, when a rectangular substrate W is used, as shown in FIG 11, through-holes (elongated holes) 66d may be arranged in parallel in a rectangular area corresponding to the shape of the substrate W so as to form a through-hole group 68d. Further, the through-holes 66d may be arranged so as to extend linearly in a vertical direction, which is not shown.

[0078] FIG 12 shows an example in which through-holes (cross holes) 66e which are cross holes extending crosswise in vertical and horizontal directions are arranged uniformly in a circular area so as to form a through-hole group 68e. In this case, when a rectangular substrate W is used, as shown in FIG 13, through-holes (cross holes) 66f may be arranged uniformly in a rectangular area corresponding to the shape of the substrate W so as to form a through-hole group 68f.

[0079] FIG 14 shows an example in which a plurality of through-holes (fine holes) 66g which are fine holes is distributed uniformly in a circular area so as to form a through-hole group 68g. In this illustrated example, the diameter of each through-hole (fine hole) 66g is set to be 2 mm, and 633 holes are provided in total. Although the diameters of the through-holes 66g as well as small holes (peripheral holes) 66h₂ through 66h₅ described below may be set arbitrarily within a range of, for example, 1 to 20 mm, they should preferably be in a range of

about 2 to 10 mm. When the through-hole group 68g is formed by the through-holes (fine holes) 66g, productivity of the regulation plate 60 can be increased.

[0080] FIG 15 shows an example in which a through-hole group 68h is formed by a plurality of through-holes 66h having different diameters, i.e. a large hole (central hole) 66h₁ having a large diameter and located at a central portion, and small holes (peripheral holes) 66h₂ through 66h₅ arranged outside of the large hole 66h₁ along a circumferential direction in a plurality of arrays (four arrays in FIG 15) having diameters gradually reduced in a radial direction. The diameter of the large hole (central hole) 66h₁ is set to be 84 mm in this example. Although the diameter of the large hole may be set arbitrarily within a range of, for example, 50 to 300 mm, it should preferably be in a range of about 30 to 100 mm. The diameters of the small holes (peripheral holes) 66h₂ through 66h₅ are set to be 10 mm, 8 mm, 7 mm, and 6 mm, respectively.

[0081] FIG 16 shows an example in which a through-hole group 68i is formed by a plurality of through-holes 66i including a central hole 66i₁ located at a central portion, and elongated holes 66i₂ through 66i₆ arranged outside of the central hole 66i₁ along a circumferential direction in a plurality of arrays (five arrays in FIG 16). In this example, the diameter of the central hole 66i₁ is set to be 34 mm, and the widths of the elongated holes 66i₂ through 66i₆ are set to be 27 mm, 18.5 mm, 7 mm, 7 mm, and 7 mm, respectively.

[0082] FIG 17 shows an example in which a through-hole group 68j is formed by a plurality of through-holes 66j including a large hole (central hole) 66j₁ having a large diameter and located at a central portion, elongated holes 66j₂ arranged outside of the central hole 66j₁ along a circumferential direction, and small holes (peripheral holes) 66j₃ through 66j₆ arranged outside of the elongated holes 66j₂ in a plurality of arrays (four arrays in FIG 17) having diameters gradually reduced in a radial direction. In this example, the diameter of the large hole (central hole) 66j₁ is set to be 67 mm, the width of the elongated hole 66j₂ is set to be 17 mm, and the diameters of the small holes (peripheral holes) 66j₃ through 66j₆ are set to be 9 mm, 8 mm, 7 mm, and 6 mm, respectively.

[0083] FIG 18 shows an example in which a through-hole group 68k is formed by a plurality of through-holes 66k including a large hole (central hole) 66k₁ having a large diameter and located at a central portion, elongated holes 66k₂, 66k₃ arranged outside of the central hole 66k₁ along a circumferential direction in a plurality of arrays (two arrays in FIG 18), and small holes (peripheral holes) 66k₄, 66k₅ arranged outside of the elongated holes 66k₃ in a plurality of arrays (two arrays in FIG 18) having diameters gradually reduced in a radial direction. In this example, the diameter of the large hole (central hole) 66k₁ is set to be 80 mm, the widths of the elongated holes 66k₂, 66k₃ are set to be 7 mm, and the diameters of the small holes (peripheral holes) 66k₄, 66k₅ are

set to be 6 mm and 4 mm, respectively.

[0084] FIG 19 shows an example in which a through-hole group 68l is formed by a plurality of through-holes 66l including a large hole (central hole) 66l₁ having a large diameter and located at a central portion, and a plurality of slit-like elongated holes 66l₂ arranged outside of the central hole 66l₁ at a predetermined pitch along a circumferential direction and extending linearly in a radial direction. The widths of the elongated holes 66l₂ are generally in a range of about 0.5 to 20 mm, preferably about 1 to 15 mm. The lengths of the elongated holes 66l₂ are set arbitrarily according to the shape of a plating workpiece.

[0085] Thus, a through-hole group is formed by combination of a plurality of through-holes having desired shapes, such as a plurality of fine holes, a plurality of holes having different diameters, and slit-like elongated holes. Accordingly, a through-hole group can meet various requirements regarding plating sites, plating conditions, and the like.

[0086] In the examples shown in FIGS. 14 through 19, through-holes are arranged in a circular area so as to form a through-hole group. However, as described above, when a rectangular substrate is used, through-holes may be arranged, as a matter of course, in a rectangular area corresponding to the shape of the substrate so as to form a through-hole group.

[0087] As described above, according to the present invention, an electric field leaks through a large number of through-holes formed in a regulation plate provided in the plating tank, and the leaked electric field spreads uniformly. Accordingly, a potential distribution can be made more uniform over the entire surface of a plating workpiece, and a within wafer uniformity of a metal film formed on the surface of the plating workpiece can be enhanced. Further, a plating solution is prevented from passing through a large number of through-holes formed in the regulation plate provided in the plating tank 186. Accordingly, non-uniform film thickness is prevented from being caused to a metal film formed on the surface of the plating workpiece due to influence of a flow of the plating solution.

[0088] FIG 20 shows a plating apparatus 170a according to another embodiment of the present invention, and FIGS. 21A and 21B show a regulation plate and a cylindrical member forming a plating solution passage which are used in the plating apparatus 170a. The plating apparatus 170a differs from the apparatus shown in FIGS. 3 through 5 in that the plating apparatus 170a employs a regulation plate 60 having a thickness of, for example, about 0.5 to 10 mm and having a central hole 60a at the center thereof which faces a substrate W held by a substrate holder 160 and has an inside diameter D corresponding to the outside diameter of the substrate W, and that a cylindrical member 200 having an inside diameter equal to the inside diameter D of the central hole 60a is concentrically connected to a surface of the regulation plate 60 on the substrate holder 160 side con-

tinuously with the central hole 60a so as to define a plating solution passage 200a inside an inner circumferential surface of the cylindrical member 200 for allowing an electric field to pass uniformly therethrough and allowing a plating solution 10 to pass therethrough. As with the regulation plate 60, the cylindrical member 200 is made of a dielectric material including PVC, PP, PEEK, PES, HT-PVC, PFA, PTFE, and other resin materials. Other constructions are the same as those shown in FIGS. 3 through 5.

[0089] The inside diameters D of the central hole of the regulation plate 60 and the cylindrical member 200 are generally set to be approximately in a range of ± 10 mm of an outside diameter (plated surface outside diameter) of a surface of a substrate W to be plated, preferably in a range of ± 5 mm of an outside diameter of a surface to be plated, more preferably in a range of ± 1 mm of an outside diameter of a surface to be plated. The length L of the cylindrical member 200 may properly be set depending upon the shape of the plating tank 186, the distance between the anode 56 and the substrate W, and the like. However, the length L is generally set to be in a range of 10 to 90 mm, preferably 20 to 75 mm, more preferably 30 to 60 mm.

[0090] Thus, an electric field produced between the anode 56 and the substrate W in the plating tank 186 passes along the plating solution passage 200a, i.e., passes uniformly through the cylindrical member 200 without leaking out of the cylindrical member 200. Accordingly, distortion and deviation of the electric field can be adjusted and corrected so as to equalize a potential distribution over the entire surface of the substrate W. As a result, as shown in FIG 22, a metal film P having an enhanced within wafer uniformity can be formed on the surface of the substrate W although it has a slightly thicker film at an edge portion of the substrate W.

[0091] Specifically, a regulation plate 60 generally is as thin as about 0.5 to 10 mm. Therefore, with a regulation plate 60 having only a central hole 60a formed therein, an electric field produced between the anode 56 and a substrate W in the plating tank 186 is not sufficiently regulated, and distortion or deviation of an electric field is caused. Accordingly, the substrate tends to be thicker at an edge portion, which serves as an electrically receiving portion. According to the present example, passing of an electric field is regulated over the length L of the cylindrical member 200, so that the above drawback is solved. Thus, a within wafer uniformity of a metal film can be enhanced.

[0092] In this example, as in the examples shown in FIGS. 3 through 5, a paddle-type agitating mechanism 64 having a plurality of paddles 62 extending vertically downward is disposed between the cylindrical member 200 and the substrate W held by the substrate holder 160. The paddle-type agitating mechanism 64 is operated during plating so as to reciprocate the paddles 62 along the surface of the substrate W, thereby agitating the plating solution 10 in a substrate side chamber 40b.

Accordingly, the directionality of the flow of the plating solution can be eliminated, and simultaneously sufficient ions can be supplied more uniformly to the surface of the substrate W. Therefore, a metal film having a more uniform thickness can be formed more rapidly.

[0093] FIG 23 shows a plating apparatus 170b according to still another embodiment of the present invention. The plating apparatus 170b differs from the apparatus shown in FIGS. 21 and 22 in that a plating solution injection type agitating mechanism 202 is disposed between the cylindrical member 200 and a substrate W held by the substrate holder 160 instead of the paddle-type agitating mechanism 64. Specifically, the plating solution injection type agitating mechanism 202 has a plating solution supply pipe 204, for example, in a ring shape, communicating with a circulation pipe 48 and immersed in the plating solution 10 in the plating tank 186, and a plurality of plating solution injection nozzles 206 attached to predetermined portions of the plating solution supply pipe 204 along a circumferential direction for ejecting the plating solution 10 toward the substrate W held by the substrate holder 160. A plating solution 10 fed by a pump 50 is supplied to the plating solution supply pipe 204 and injected from the plating solution injection nozzles 206 toward the substrate. Thus, the plating solution 10 is introduced into the plating tank 186, overflows upper ends of overflow weirs 44, and is circulated.

[0094] Thus, the plating solution 10 is injected from a plurality of plating solution injection nozzles 206 toward the substrate W. Accordingly, the plating solution 10 in the plating tank 186 can be agitated so as to uniformize the plating solution concentration and, simultaneously, to sufficiently supply components of the plating solution 10 to the substrate W. Thus, a metal film having a more uniform thickness can be formed more rapidly.

[0095] In this example, the cylindrical member 200 is coupled to a surface of the regulation plate 60 on the substrate W side. However, as shown in FIG 24B, an insertion hole 60b may be formed in the regulation plate 60, and a cylindrical member 200 having an inside diameter D, a length L, and a plating solution passage 200a inside an inner circumferential surface thereof may be inserted into the insertion hole 60b. In this manner, the cylindrical member 200 may be held at a predetermined position along a longitudinal direction of the cylindrical member 200. This arrangement ensures a sufficient length L as the cylindrical member 200 even if a distance between the regulation plate 60 and the paddles 62 (see FIG 20) or the plating solution supply pipe 204 (see FIG 23) is short.

[0096] Further, as shown in FIGS. 25A and 25B, the cylindrical member 200 may have a circumferential wall having a large number of through-holes 200b which have a size such as to prevent leakage of an electric field. With this arrangement, the plating solution 10 can pass through the through-holes 200b formed in the circumferential wall of the cylindrical member 200 while

preventing leakage of the electric field. Accordingly, the concentration of the plating solution is prevented from being different between the inside and outside of the cylindrical member 200. With respect to the shape of the through-holes, besides fine holes as in this example, slit-like elongated holes, cross holes extending vertically and horizontally, and a combination thereof may be exemplified.

[0097] Further, as shown in FIGS. 26A and 26B, a regulation plate 210 may be formed by a plate having a sufficient thickness, and a through-hole having a predetermined inside diameter may be formed at a predetermined position in the regulation plate 210 so that the through-hole serves as a plating solution passage 210a having a predetermined inside diameter D and a predetermined length L. In such a case, the number of parts can be reduced.

[0098] Furthermore, as shown in FIGS. 27A and 27B, a rectangular block 212 having a sufficient thickness may be prepared so that a through-hole formed in the rectangular block 212 serves as a plating solution passage 210a having a predetermined inside diameter D and a predetermined length L, and the rectangular block 212 may be connected to a surface of a regulation plate 60 having a center hole 60a on the substrate W side.

[0099] FIG 28 shows a plating apparatus 170c according to yet another embodiment of the present invention, and FIGS. 29A and 29B shows a regulation plate, a cylindrical member forming a plating solution passage, and an electric field adjustment ring which are used in the plating apparatus 170c shown in FIG 28. The plating apparatus 170c differs from the apparatus shown in FIGS. 20 and 21 in the following points: An electric field adjustment ring 220 having the same inside diameter D as an inside diameter of the cylindrical member 200 and a width A is concentrically attached to a substrate W side end surface of the cylindrical member 200 having a plating solution passage 200a defined inside an inner circumferential surface thereof. The electric field adjustment ring 220 is disposed close to a substrate W with a gap G1. Further, the paddle-type agitating mechanism 64 having a plurality of paddles 62 extending vertically downward is disposed between the anode 56 and the regulation plate 60 in the anode side chamber 40a so as to reciprocate the paddles 62 in parallel to the substrate W held by the substrate holder 160, thereby agitating the plating solution. Thus, the paddle-type agitating mechanism 64 agitates the plating solution 10 in the anode side chamber 40a. Other constructions are the same as those shown in FIGS. 20 and 21.

[0100] As with the regulation plate 60 and the cylindrical member 200, the electric field adjustment ring 220 is made of a dielectric material including PVC, PP, PEEK, PES, HT-PVC, PFA, PTFE, and other resin materials. Other constructions are the same as those shown in FIGS. 3 through 5. The shape of the electric field adjustment ring 220 may properly be set depending upon the shapes of the plating tank 186 and the sub-

strate W, the distance between the anode 56 and the substrate W, and the like. However, the width A is generally set to be in a range of 1 to 20 mm, preferably 3 to 17 mm, more preferably 5 to 15 mm. A gap G1 between the electric field adjustment ring 220 and the substrate W is generally set to be in a range of 0.5 to 30 mm, preferably 1 to 15 mm, more preferably 1.5 to 6 mm.

[0101] The electric field adjustment ring 220 serves to adjust an electric field at a peripheral portion of the substrate W by covering a location near a peripheral portion of a substrate W over a predetermined width. Thus, an electric field is adjusted at a peripheral portion of the substrate W. Accordingly, an electric field produced between the anode 56 and the substrate W can be uniformized over the entire surface of the substrate W, including an edge portion of the substrate W, which serves as an electrically receiving portion. Therefore, as shown in FIG 30, a metal film P having an enhanced within wafer uniformity can be formed on the surface of the substrate W, including the edge portion of the substrate.

[0102] FIG 31 shows a plating apparatus 170d according to yet another embodiment of the present invention. The plating apparatus 170d has a plating solution injection type agitating mechanism 202, which is shown in FIG 23, disposed between the anode 56 and the regulation plate 60 in the anode side chamber 40a, instead of the paddle-type agitating mechanism 64 used in the plating apparatus shown in FIGS. 28 and 29. Specifically, in this example, a plating solution 10 fed by a pump 50 is supplied to the plating solution supply pipe 204 and injected from the plating solution injection nozzles 206 toward a plating solution passage 200a of the cylindrical member 200. Thus, the plating solution 10 is introduced into the plating tank 186, overflows upper ends of overflow weirs 44, and is circulated. Other constructions are the same as those shown in FIGS. 28 and 29.

[0103] Thus, the plating solution injection type agitating mechanism 202 is disposed in the anode side chamber 40a, and the plating solution is injected from the plating solution injection nozzles 206 toward the plating solution passage 200a of the cylindrical member 200. The plating solution can be supplied through the plating solution passage 200a to the substrate W held by the substrate holder 160 even if a gap G1 between an electric field adjustment ring 220 and the substrate W held by the substrate 160 is narrow.

[0104] As shown in FIGS. 32A and 32B, an insertion hole 60b may be formed in the regulation plate 60, and a cylindrical member 200 having an inside diameter D, a length L, a plating solution passage 200a inside an inner circumferential surface thereof, and an electric field adjustment ring 220 attached to an end surface thereof may be inserted into the insertion hole 60b substantially in the same manner as shown in FIGS. 24A and 24B. Thus, the cylindrical member 200 may be held at a predetermined position along a longitudinal direction of the cylindrical member 200.

[0105] As shown in FIGS. 33A and 33B, a large

number of through-holes 200b having a size such as to prevent leakage of an electric field may be formed in a circumferential wall of a cylindrical member 200 having an electric field adjustment ring 220 attached to an end surface thereof substantially in the same manner as shown in FIGS. 25A and 25B. Thus, the plating solution 10 can pass through the through-holes 200b formed in the circumferential wall of the cylindrical member 200 while preventing leakage of the electric field.

[0106] Further, as shown in FIGS. 34A and 34B, the electric field adjustment ring 220 may not be fixed to the end surface of the cylindrical member 200, but may be supported by a support 222 so as to have a gap G2 between the front of the substrate W side end surface of the cylindrical member 200 and the substrate W. As with the gap G1 between the electric field adjustment ring 220 and the substrate W, the gap G2 is generally set to be in a range of 0.5 to 30 mm, preferably 1 to 15 mm, more preferably 1.5 to 6 mm. With the plating solution passage 200a thus formed, the cylindrical member 200 and the electric field adjustment ring 220 can be separated so as to offer a broader choice.

[0107] As shown in FIGS. 35A and 35B, a plating solution passage 224a having a predetermined inside diameter D and a length L may be defined by an inner circumferential surface of a thick ring 224 having a sufficient thickness, and an electric field adjustment ring 224b having a predetermined width A may be formed by a substrate side end surface of the thick ring 224. In this case, the number of parts can be reduced.

[0108] Although the aforementioned examples show that the present invention is applied to a so-called dipping type plating apparatus, the present invention is also applicable to a face-down type plating apparatus or a face-up type plating apparatus.

[0109] FIG 36 shows an example in which the present invention is applied to a face-down type plating apparatus. In this example, the following structures are added to a conventional plating apparatus shown in FIG 37. Specifically, a regulation plate 230 having a central hole 230a formed therein is disposed at an upper position of the plating tank 12 so as to separate the interior of the plating tank 12 into an anode side chamber 12a and a substrate side chamber 12b. Further, a cylindrical member 232 having an inside diameter equal to the diameter of the central hole 230a and an inner circumferential surface forming a plating solution passage 232a is concentrically attached to an upper surface of the regulation plate 230 in a manner so as to project upward. With this arrangement, an electric field produced between the anode 16 and a substrate W in the plating tank 12 can pass along the plating solution passage 232a, i.e. uniformly through the cylindrical member 232 without leaking out of the cylindrical member 232. Accordingly, distortion and deviation of the electric field can be adjusted and corrected so as to equalize a potential distribution over the entire surface of the substrate W.

[0110] An electric field adjustment ring having an in-

side diameter equal to an inside diameter of the cylindrical member and a predetermined width may concentrically be attached to an upper end surface of the cylindrical member so as to cover a location near a peripheral portion of the substrate W over a predetermined width. Thus, an electric field can be adjusted at the peripheral portion of the substrate W. Accordingly, an electric field produced between the anode 56 and the substrate can be uniformized over the entire surface of the substrate, including an edge portion of the substrate, which serves as an electrically receiving portion. Therefore, a metal film having an enhanced within wafer uniformity can be formed on the surface of the substrate, including the edge portion of the substrate.

Claims

1. A plating apparatus **characterized by** comprising:

a plating tank for holding a plating solution;
an anode disposed so as to be immersed in the plating solution in said plating tank;
a regulation plate disposed between said anode and a plating workpiece disposed so as to face said anode; and
a plating power supply for supply a current between said anode and the plating workpiece to carry out plating,

wherein said regulation plate is disposed so as to separate the plating solution held in said plating tank into a plating solution on said anode side and a plating solution on the plating workpiece side, and a through-hole group having a large number of through-holes is formed in said regulation plate.

2. The plating apparatus according to claim 1, **characterized in that** said through-hole group is formed by a plurality of slit-like elongated holes extending linearly in one direction or extending in an arc.

3. The plating apparatus according to claim 1, **characterized in that** said through-hole group is formed by a plurality of cross holes extending crosswise in vertical and horizontal directions.

4. The plating apparatus according to claim 1, **characterized in that** said through-hole group is formed by a combination of a plurality of fine holes, a plurality of holes having different diameters, and slit-like elongated holes.

5. The plating apparatus according to claim 1, **characterized in that** said through-hole group is formed in said regulation plate substantially over an entire area facing the plating workpiece, and formed in an area substantially similar to a shape of the plating

workpiece.

6. The plating apparatus according to claim 1, **characterized by** comprising an agitating mechanism provided between the plating workpiece and said regulation plate for agitating the plating solution held in said plating tank.

7. The plating apparatus according to claim 6, **characterized in that** said agitating mechanism comprises a paddle-type agitating mechanism having a paddle which reciprocates parallel to the plating workpiece.

8. The plating apparatus according to claim 1, **characterized in that** said anode and said regulation plate are provided in a vertical direction.

9. A plating apparatus **characterized by** comprising:

a plating tank for holding a plating solution;
an anode disposed so as to be immersed in the plating solution in said plating tank;
a regulation plate disposed between said anode and a plating workpiece disposed so as to face said anode; and
a plating power supply for supply a current between said anode and the plating workpiece to carry out plating,

wherein said regulation plate is disposed so as to separate the plating solution held in said plating tank into a plating solution on said anode side and a plating solution on the plating workpiece side, and a plating solution passage is formed in said regulation plate for allowing an electric field to uniformly pass therethrough and allowing the plating solution to pass therethrough.

10. The plating apparatus according to claim 9, **characterized in that** a length of said plating solution passage is set to be in a range of 10 to 90 mm.

11. The plating apparatus according to claim 9, **characterized in that** said plating solution passage is defined by an inner circumferential surface of a cylindrical member or a rectangular block.

12. The plating apparatus according to claim 11, **characterized in that** a large number of through-holes having a size such as to prevent leakage of an electric field are formed in a circumferential wall of said cylindrical member.

13. The plating apparatus according to claim 9, **characterized by** comprising an agitating mechanism provided in at least one of a space between the plating workpiece and said regulation plate and a space

between said anode and said regulation plate for agitating the plating solution held in said plating tank.

14. The plating apparatus according to claim 13, **characterized in that** said agitating mechanism comprises a paddle-type agitating mechanism having a paddle which reciprocates parallel to the plating workpiece.

15. The plating apparatus according to claim 13, **characterized in that** said agitating mechanism comprises a plating solution injection type agitating mechanism having a plurality of plating solution injection nozzles for injecting the plating solution toward the plating workpiece.

16. The plating apparatus according to claim 13, **characterized in that** said plating solution passage is formed in said regulation plate integrally with said regulation plate.

17. A plating apparatus **characterized by** comprising:

a plating tank for holding a plating solution;
an anode disposed so as to be immersed in the plating solution in said plating tank;
a regulation plate disposed between said anode and a plating workpiece disposed so as to face said anode for separating the plating solution held in said plating tank into a plating solution on said anode side and a plating solution on the plating workpiece side, said regulation plate having a plating solution passage for allowing an electric field to uniformly pass therethrough and allowing the plating solution to pass therethrough;
a plating power supply for supply a current between said anode and the plating workpiece to carry out plating; and
an electric field adjustment ring disposed at an end of said plating solution passage on the plating workpiece side for adjusting an electric field at a peripheral portion of the plating workpiece.

18. The plating apparatus according to claim 17, **characterized in that** a width of said electric field adjustment ring is set to be in a range of 1 to 20 mm.

19. The plating apparatus according to claim 17, **characterized in that** a gap between said electric field adjustment ring and the plating workpiece is set to be in a range of 0.5 to 30 mm.

20. The plating apparatus according to claim 17, **characterized in that** said plating solution passage is defined by an inner circumferential surface of a cylindrical member, and said electric field adjustment

ring is connected to an end of said cylindrical member on the plating workpiece side.

21. The plating apparatus according to claim 20, **characterized in that** a large number of through-holes having a size such as to prevent leakage of an electric field are formed in a circumferential wall of said cylindrical member. 5
22. The plating apparatus according to claim 17, **characterized in that** said plating solution passage is defined by an inner circumferential surface of a cylindrical member, and said electric field adjustment ring is disposed at an end of said cylindrical member on the plating workpiece side so as to be separated from said cylindrical member. 10 15
23. The plating apparatus according to claim 17, **characterized in that** said plating solution passage is defined by an inner circumferential surface of a cylindrical member, and said electric field adjustment ring is formed on an end surface of the plating workpiece side. 20
24. The plating apparatus according to claim 17, **characterized by** comprising an agitating mechanism provided in at least one of a space between the plating workpiece and said regulation plate and a space between said anode and said regulation plate for agitating the plating solution held in said plating tank. 25 30
25. The plating apparatus according to claim 24, **characterized in that** said agitating mechanism comprises a paddle-type agitating mechanism having a paddle which reciprocates parallel to the plating workpiece. 35
26. The plating apparatus according to claim 24, **characterized in that** said agitating mechanism comprises a plating solution injection type agitating mechanism having a plurality of plating solution injection nozzles for injecting the plating solution toward the plating workpiece. 40 45

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FIG. 1

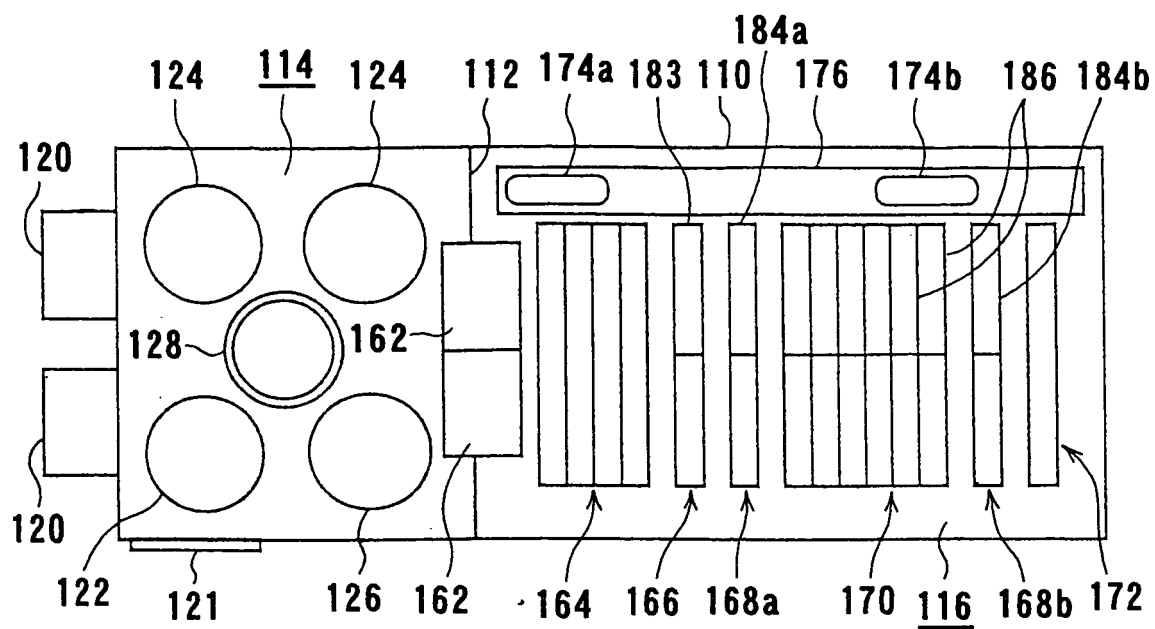
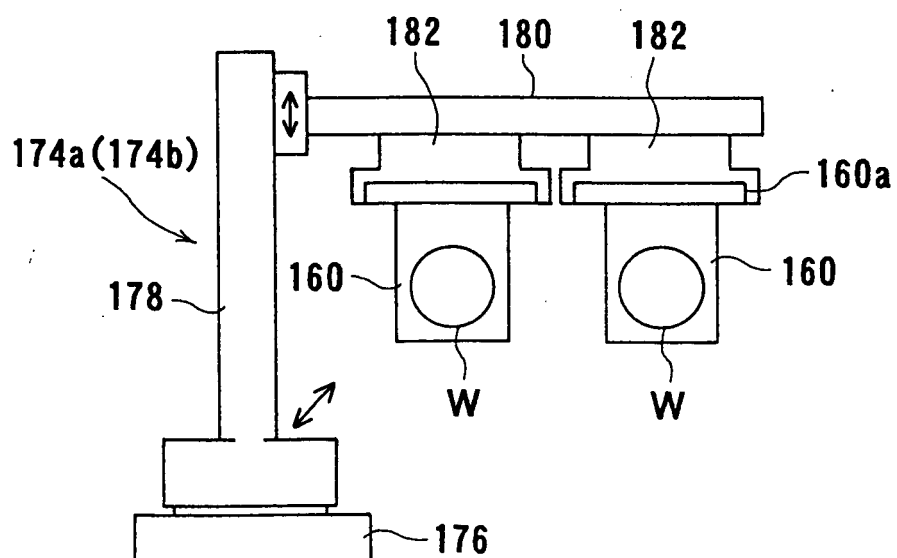


FIG. 2



F / G. 3

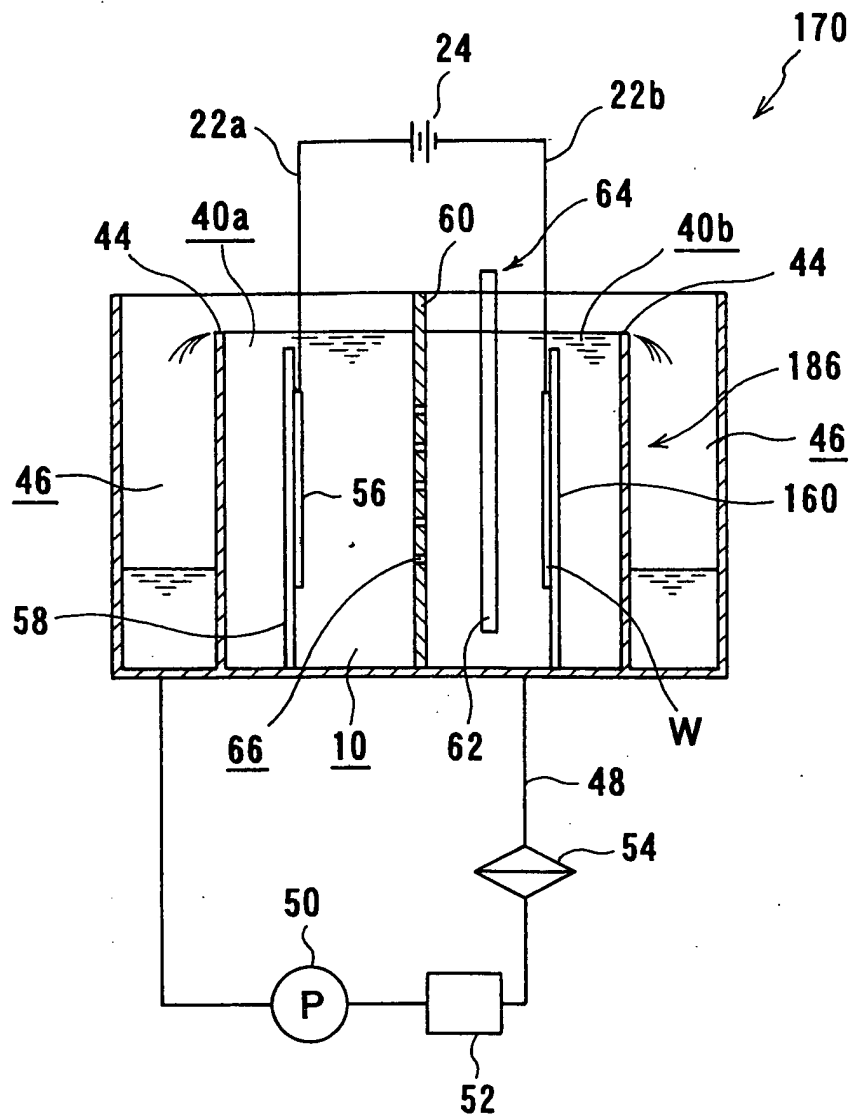


FIG. 4

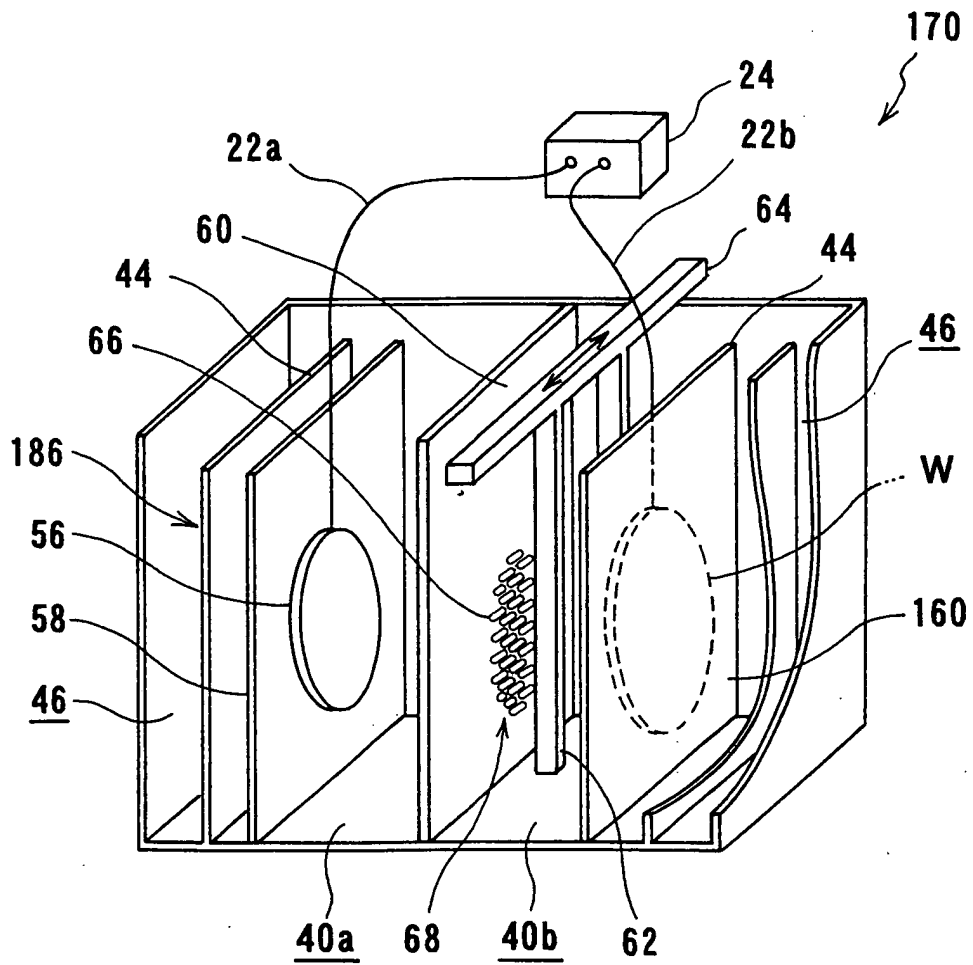


FIG. 5

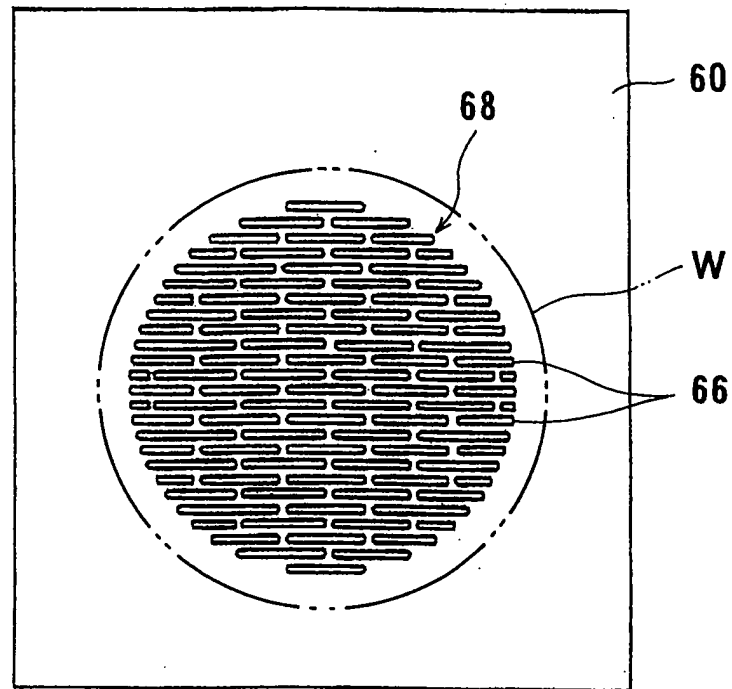


FIG. 6

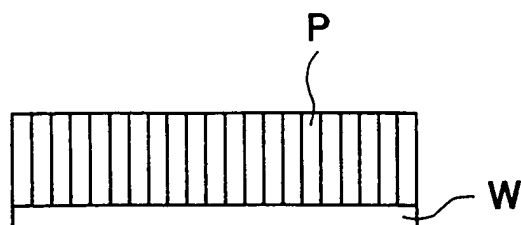


FIG. 7A

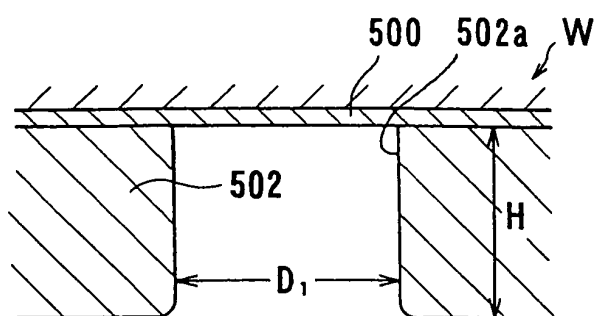


FIG. 7B

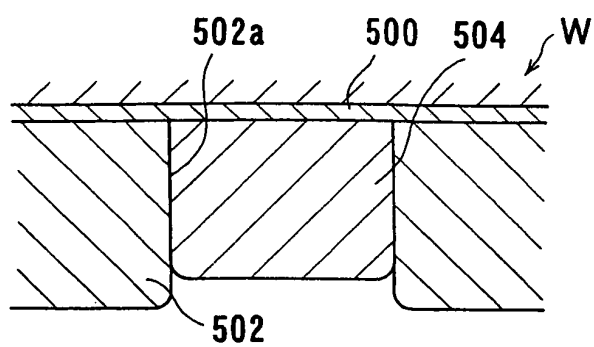


FIG. 7C

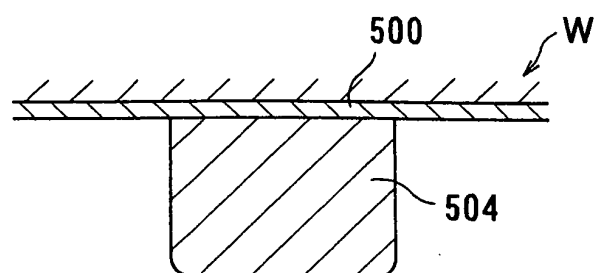


FIG. 7D

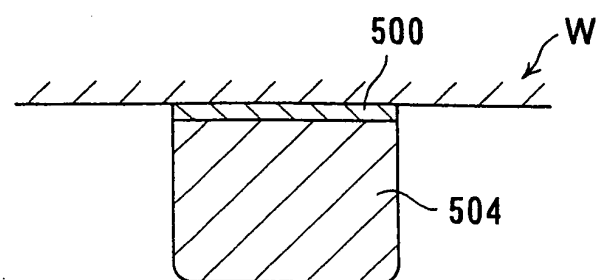


FIG. 7E

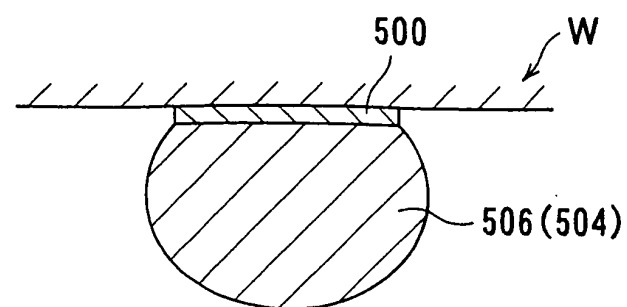


FIG. 8

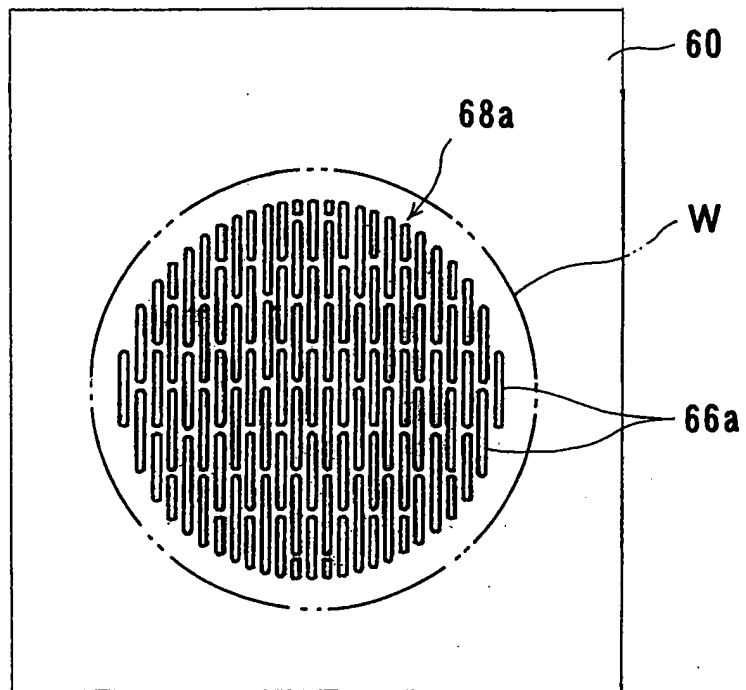


FIG. 9

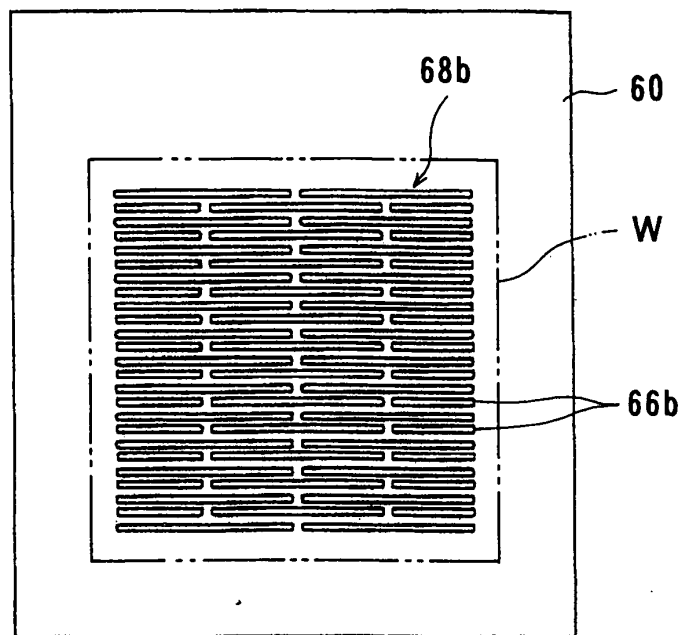


FIG. 10

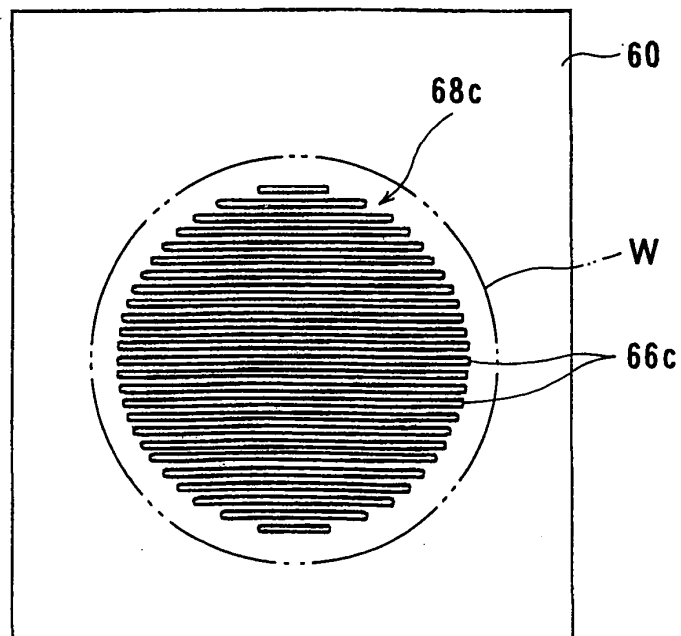


FIG. 11

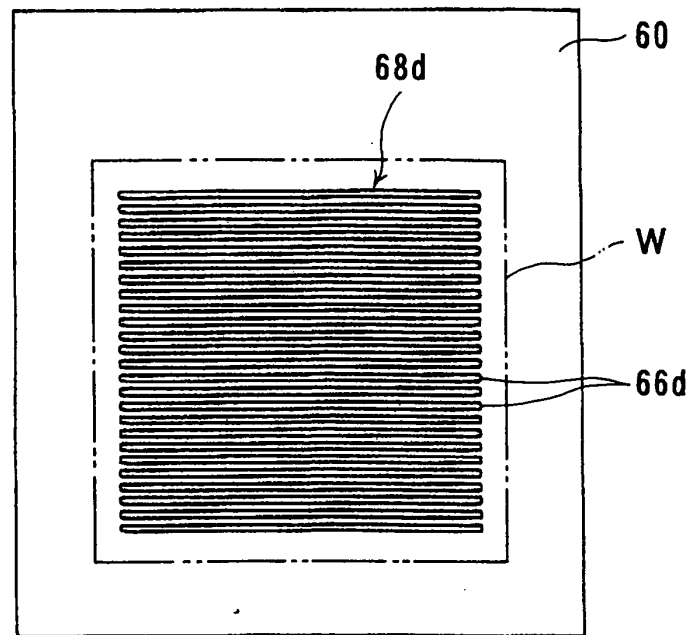


FIG. 12

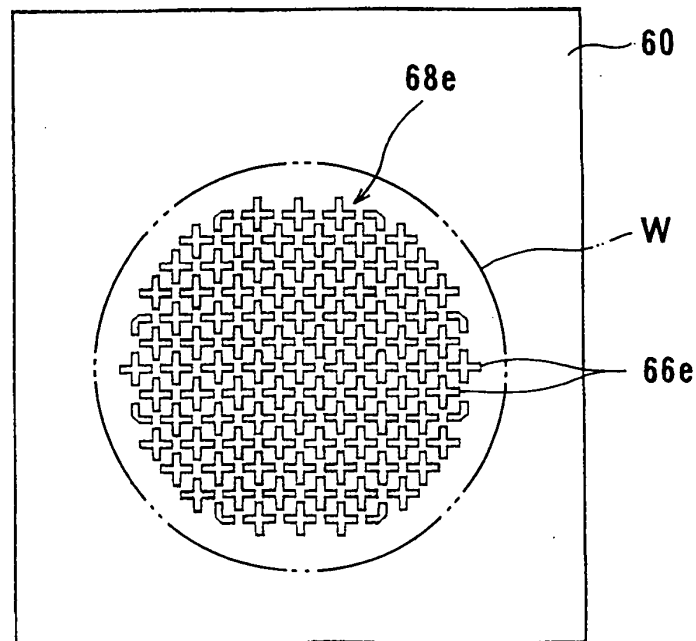


FIG. 13

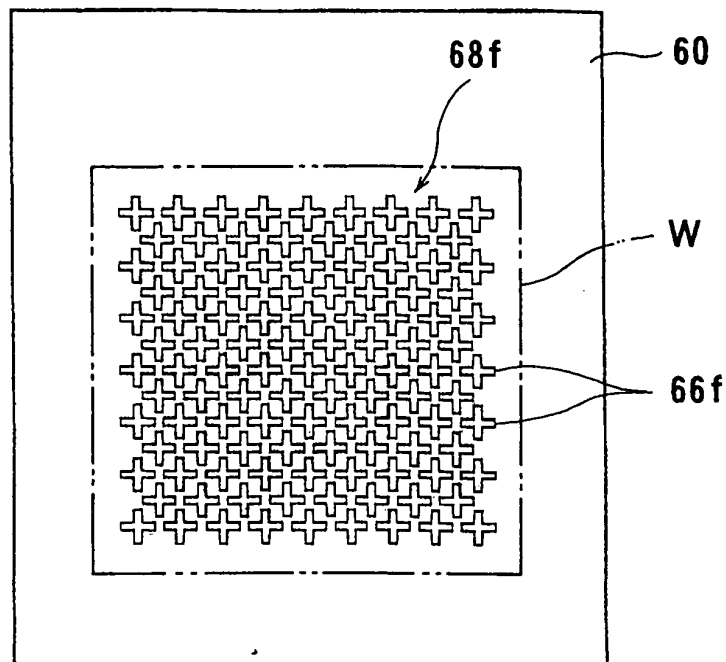


FIG. 14

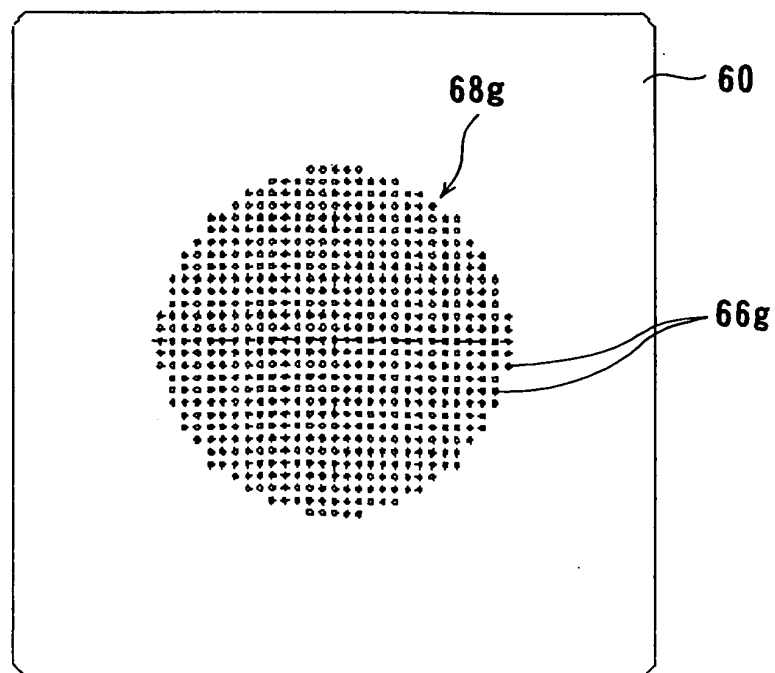


FIG. 15

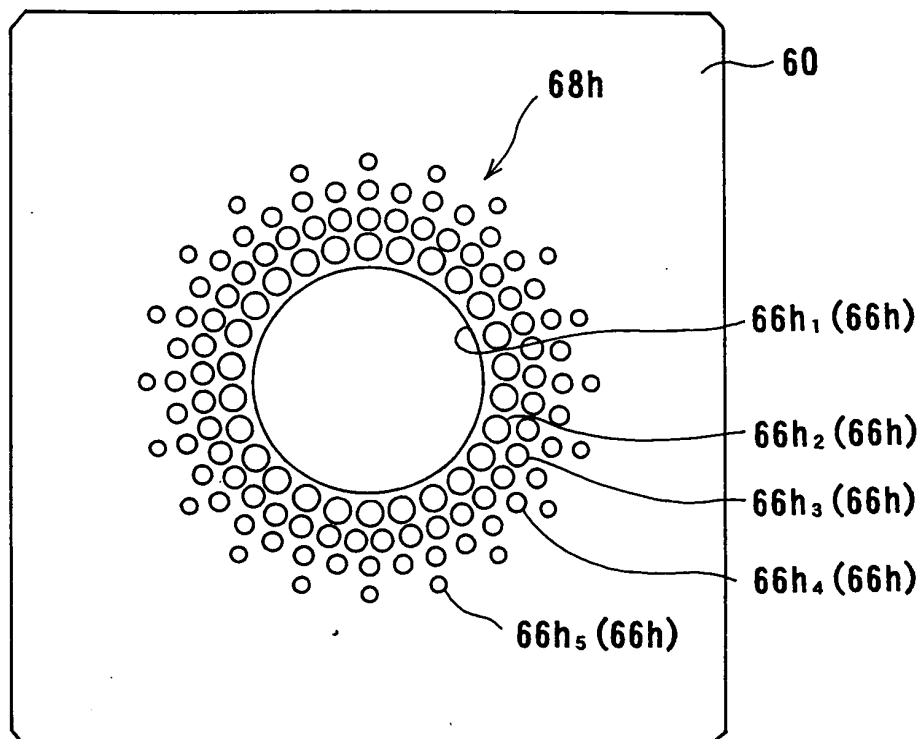


FIG. 16

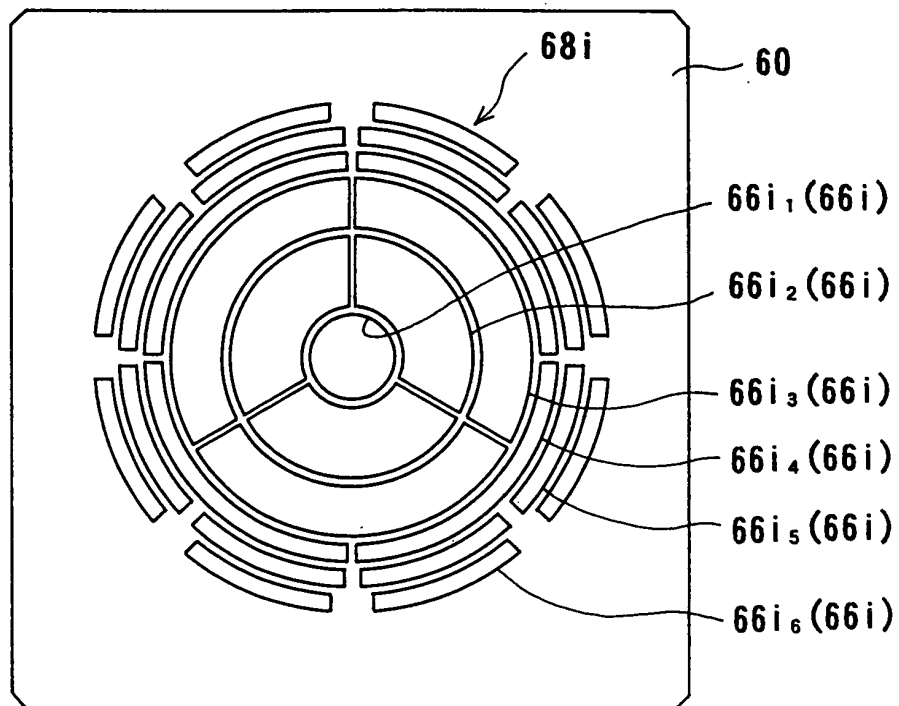


FIG. 17

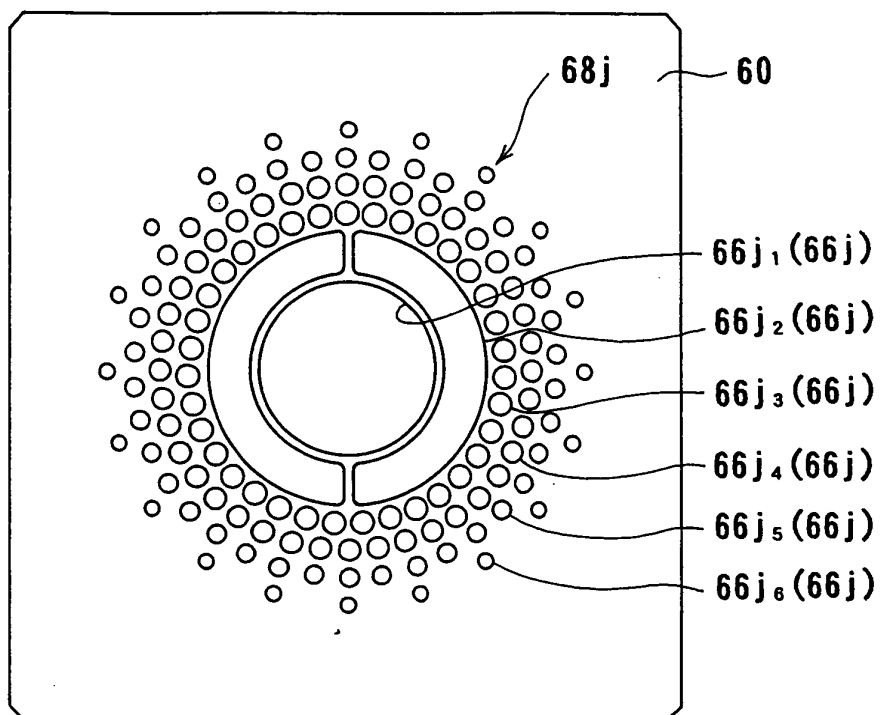


FIG. 18

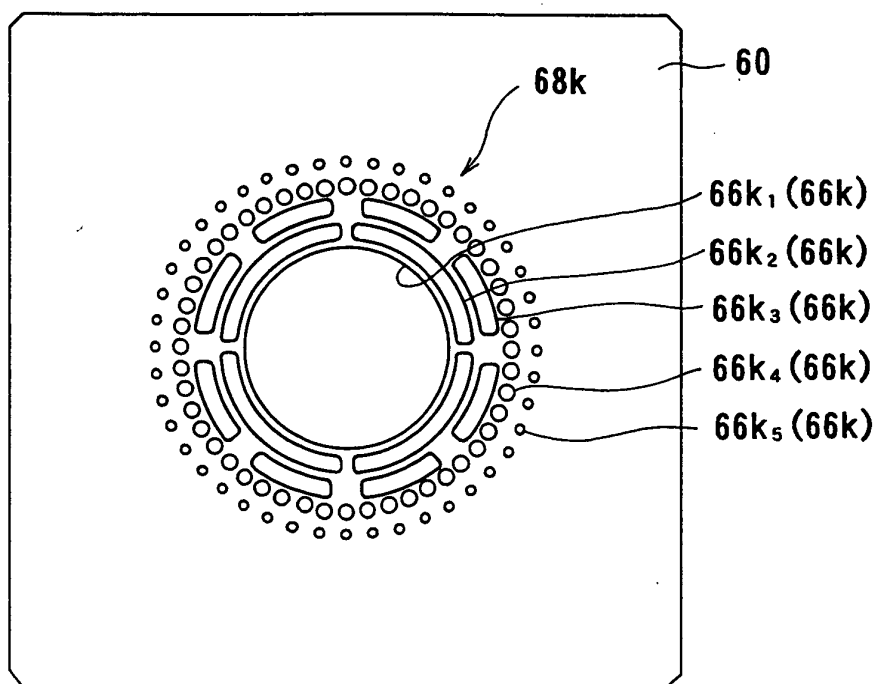


FIG. 19

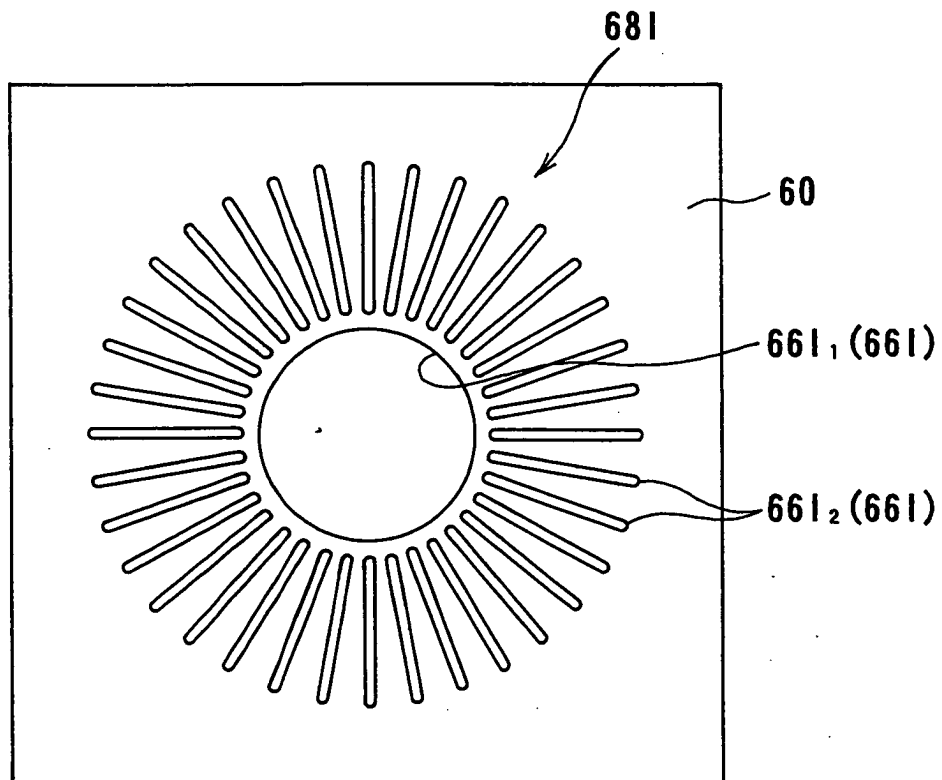


FIG. 20

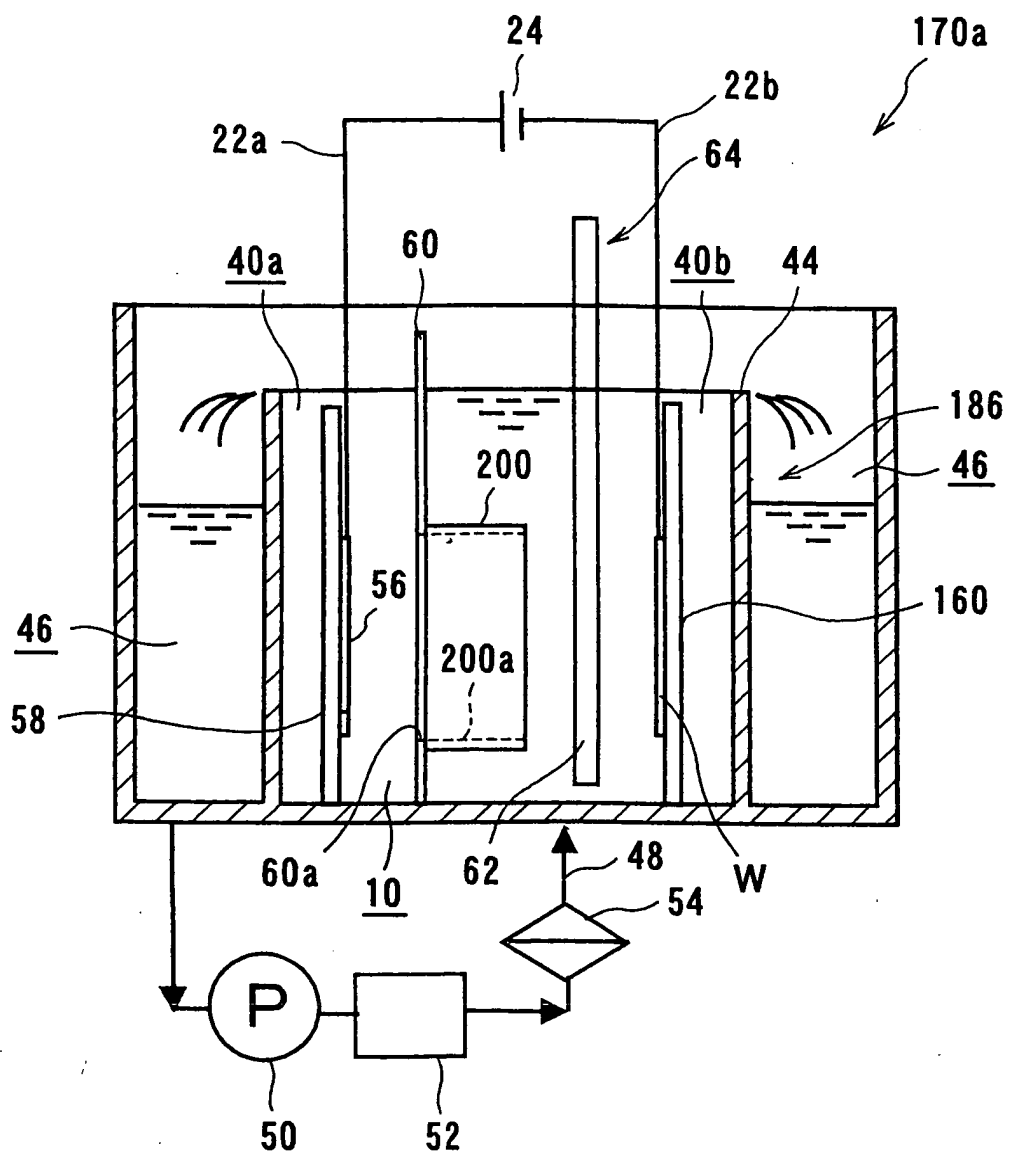


FIG. 21A

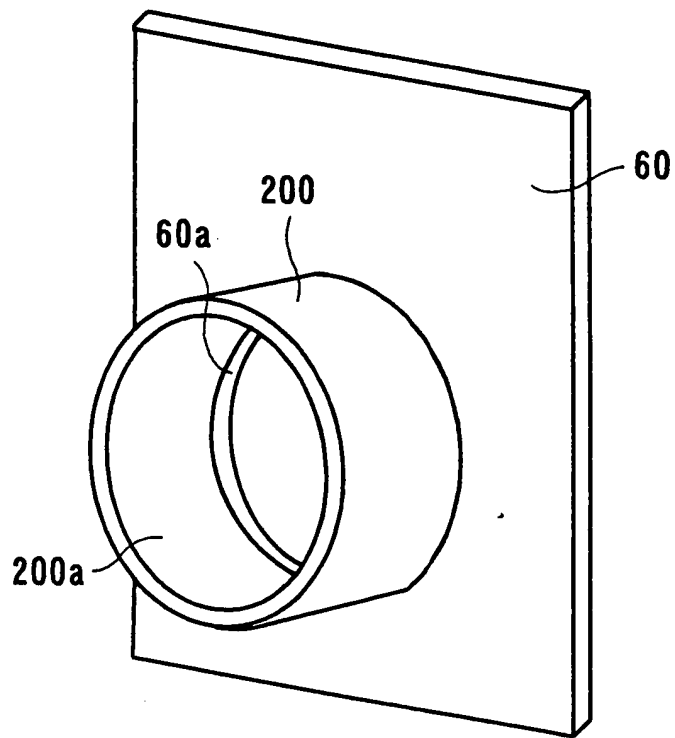


FIG. 21B

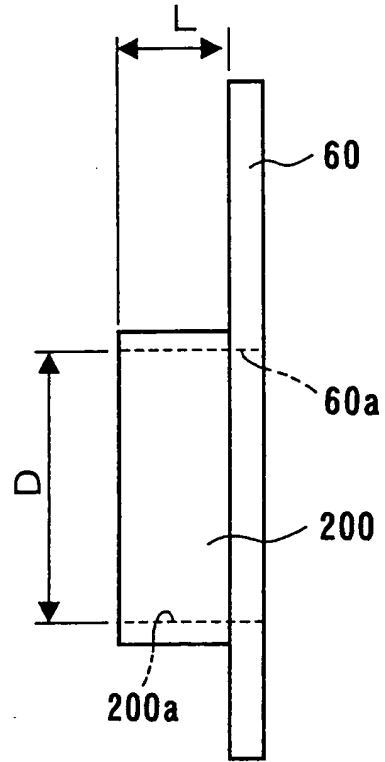


FIG. 22

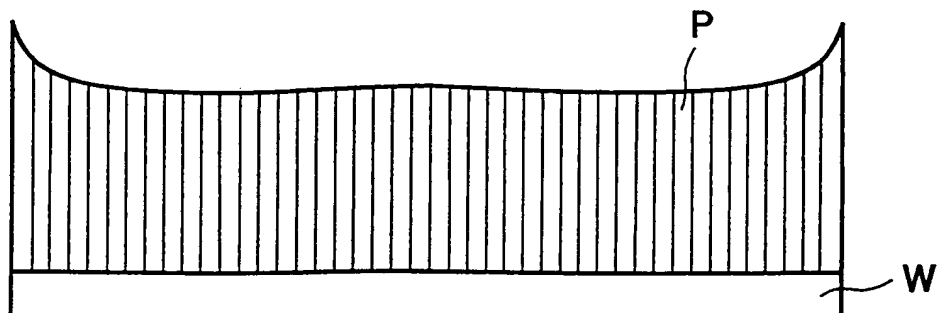


FIG. 23

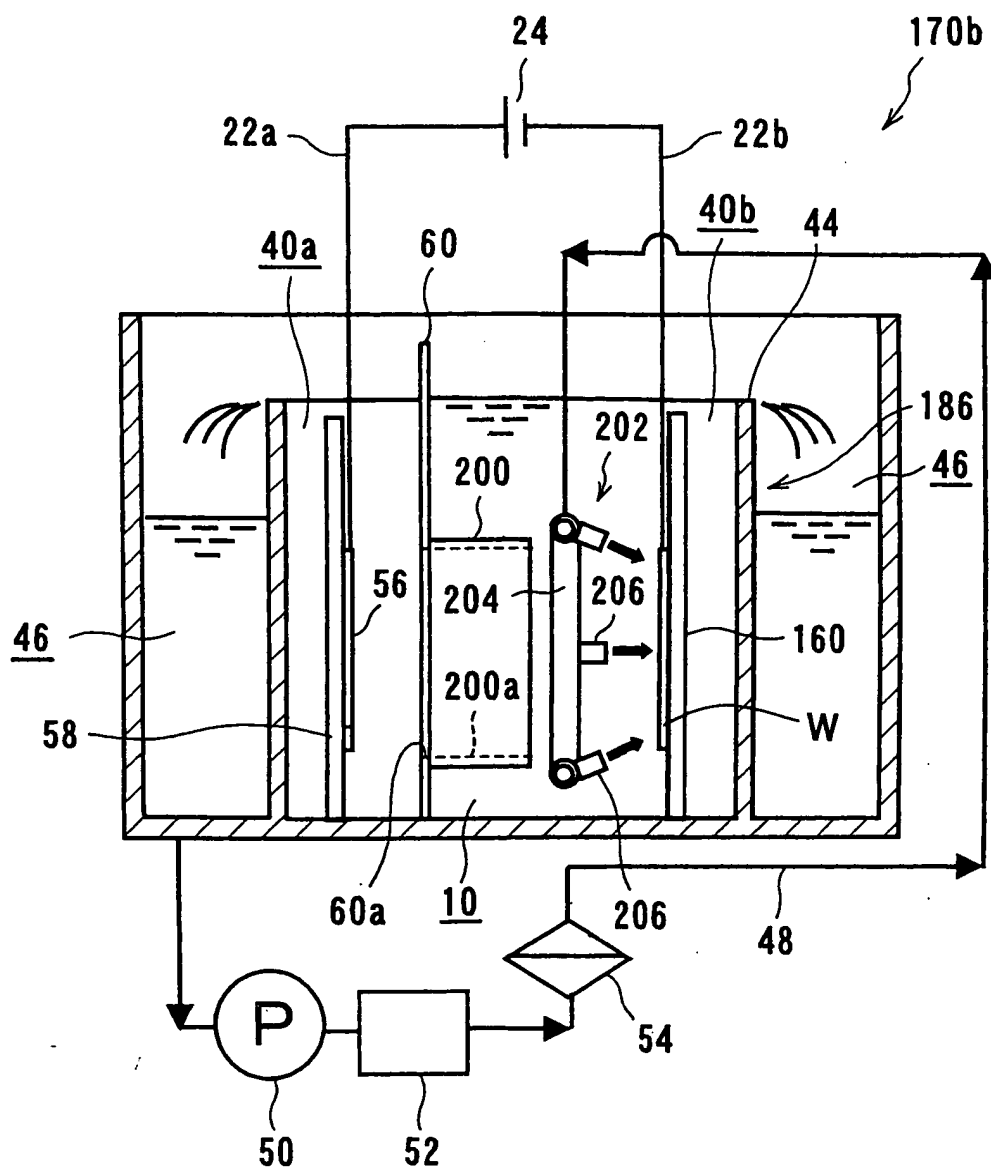


FIG. 24A

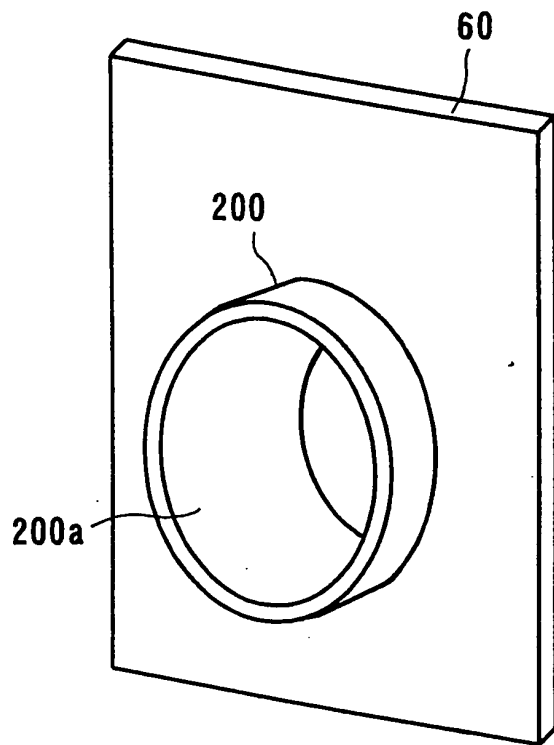


FIG. 24B

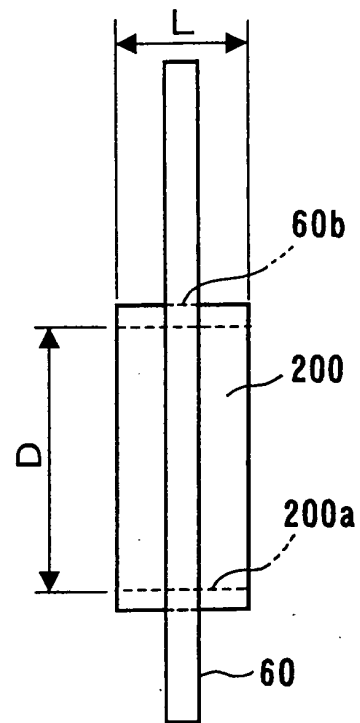


FIG. 25A

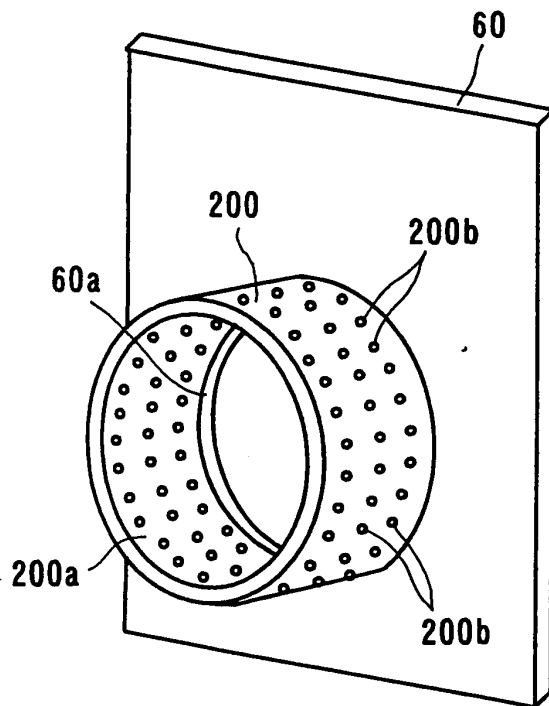


FIG. 25B

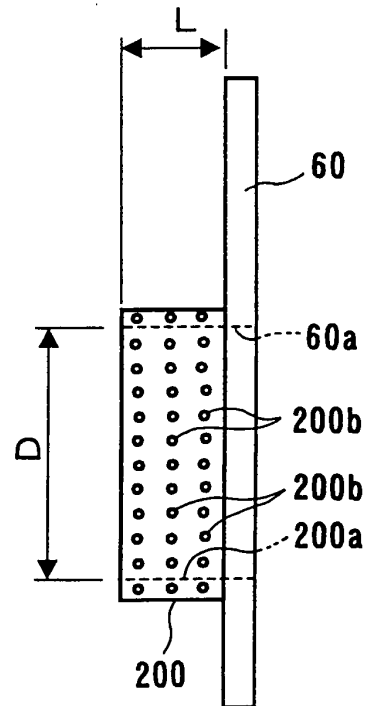


FIG. 26A

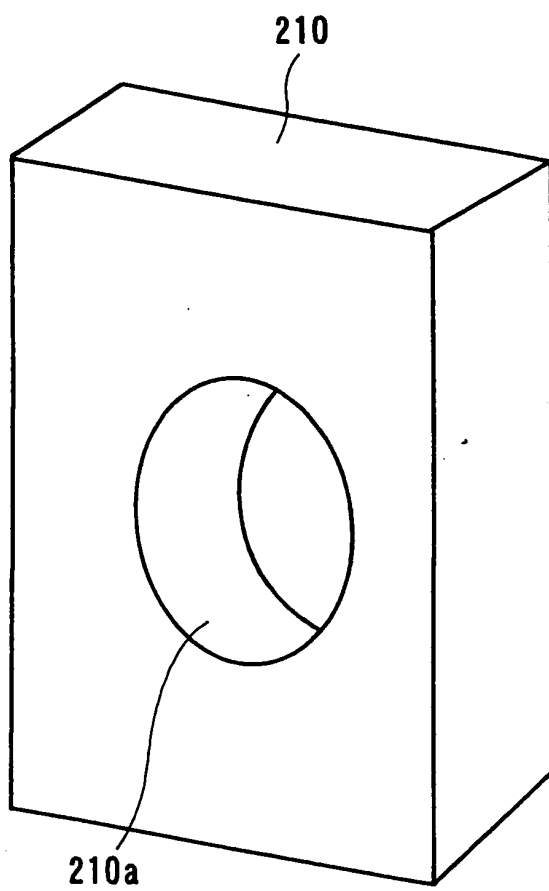


FIG. 26B

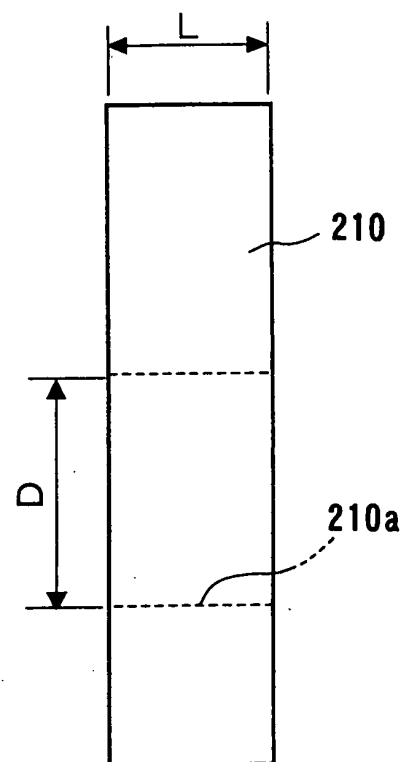


FIG. 27A

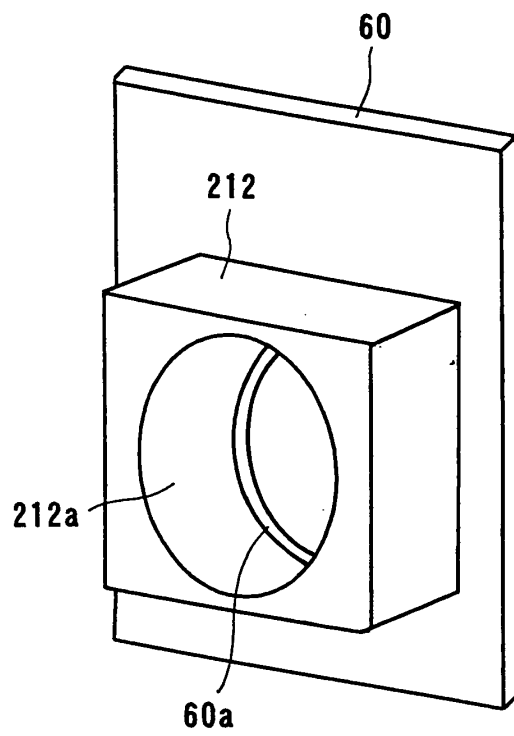


FIG. 27B

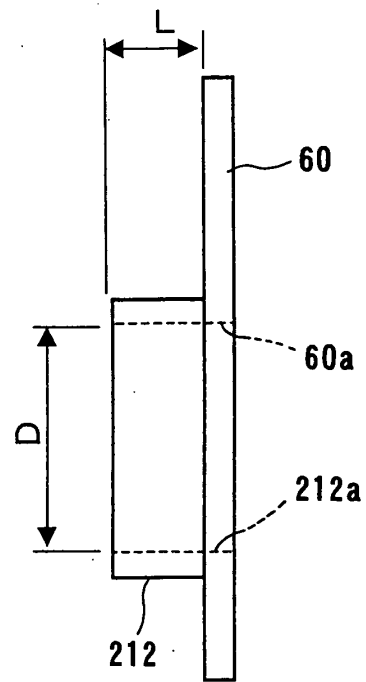


FIG. 28

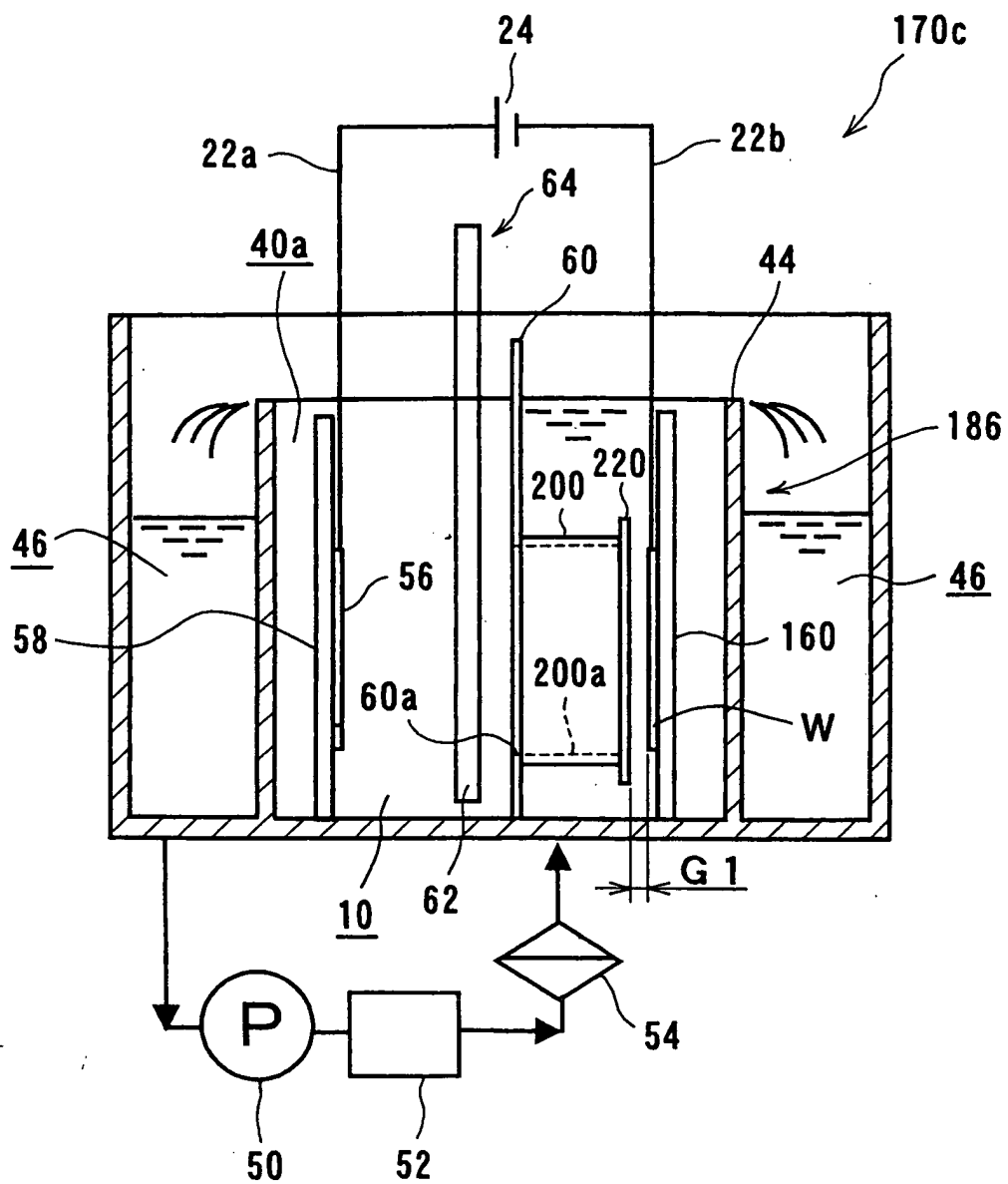


FIG. 29A

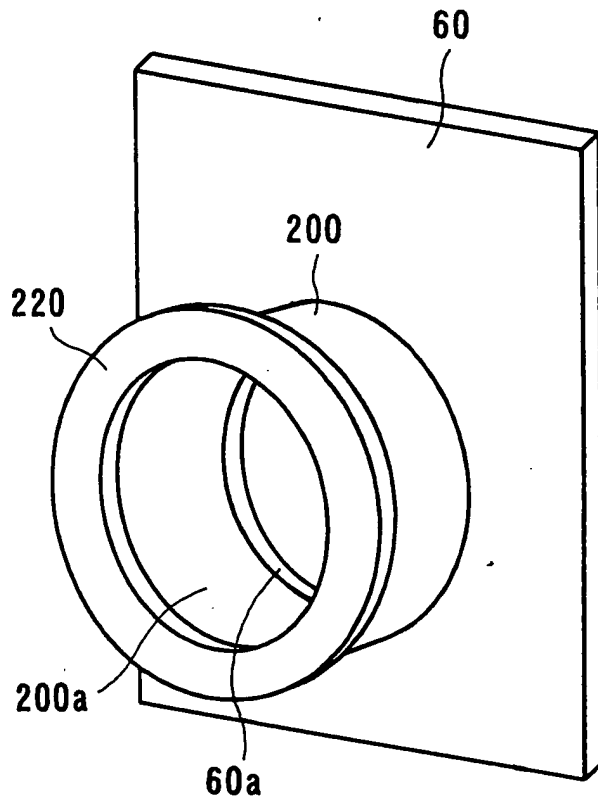


FIG. 29B

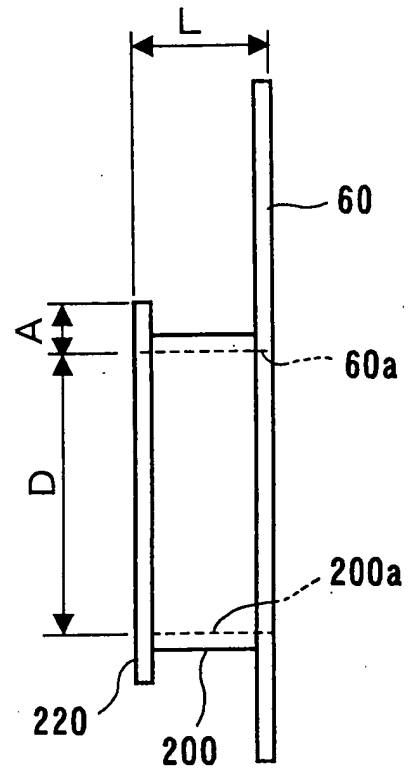


FIG. 30

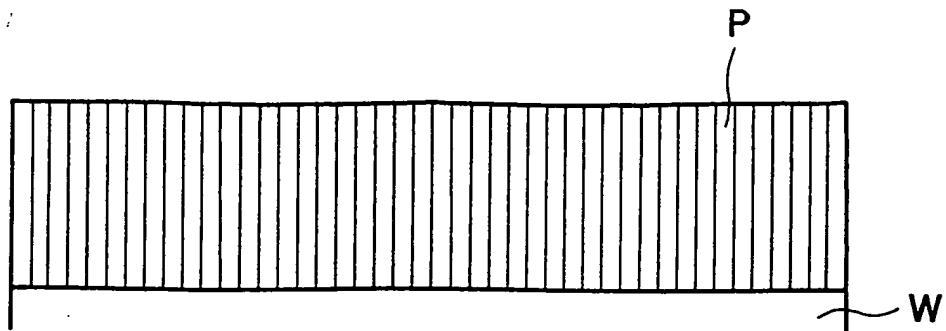


FIG. 31

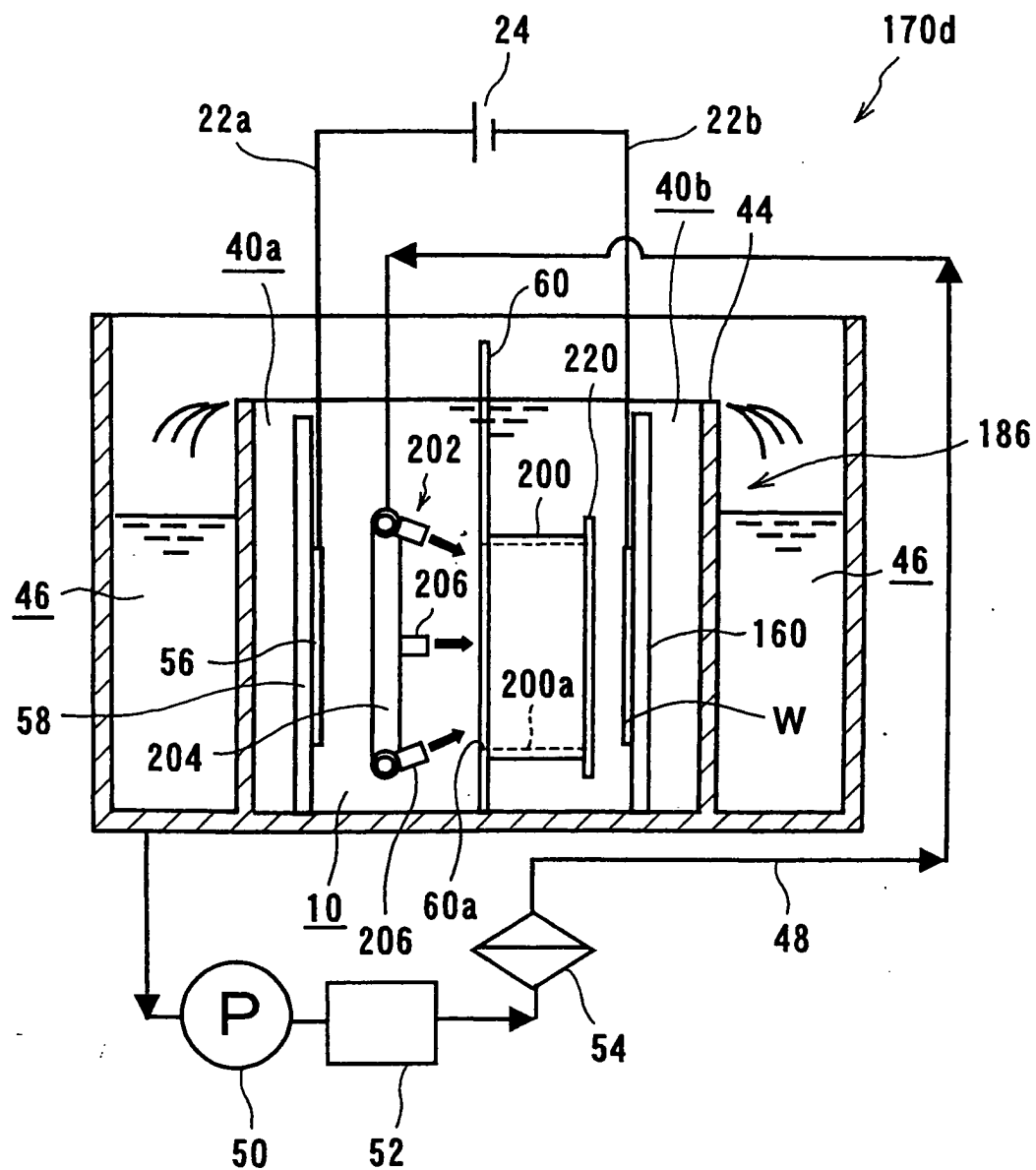


FIG. 32A

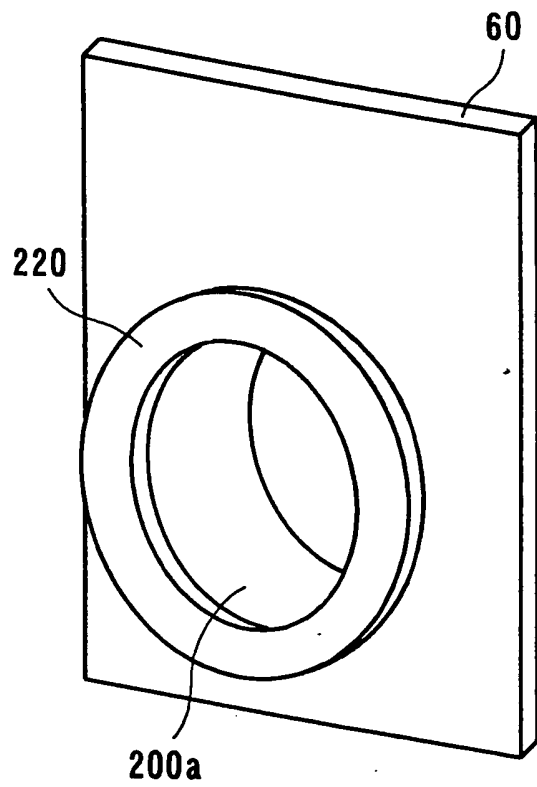


FIG. 32B

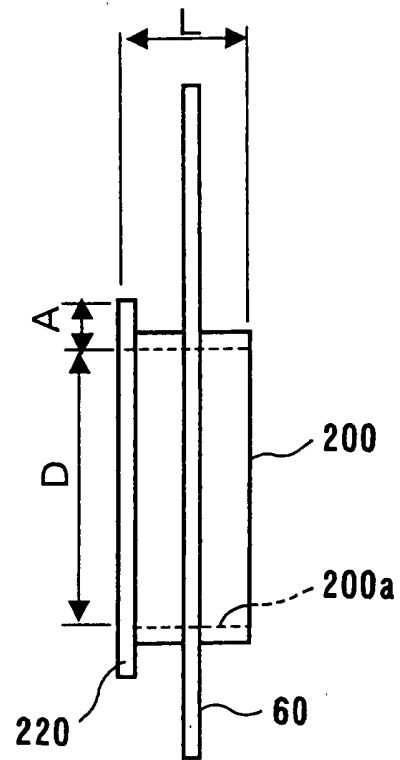


FIG. 33A

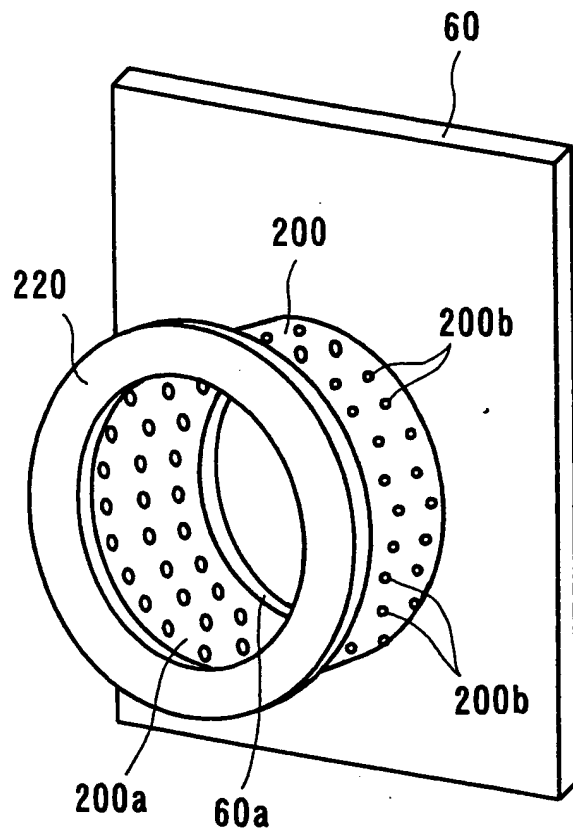


FIG. 33B

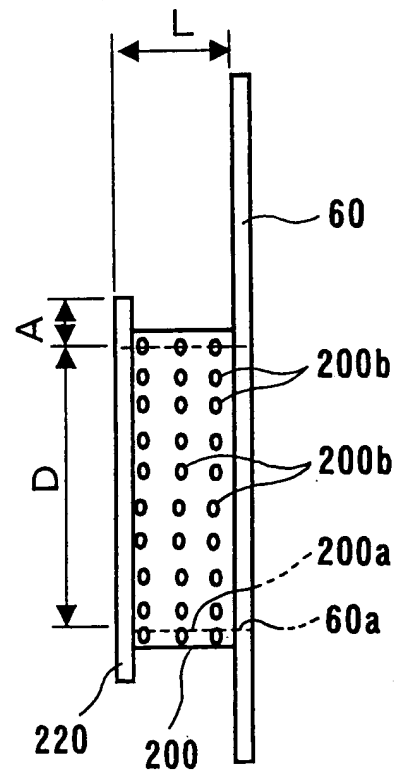


FIG. 34A

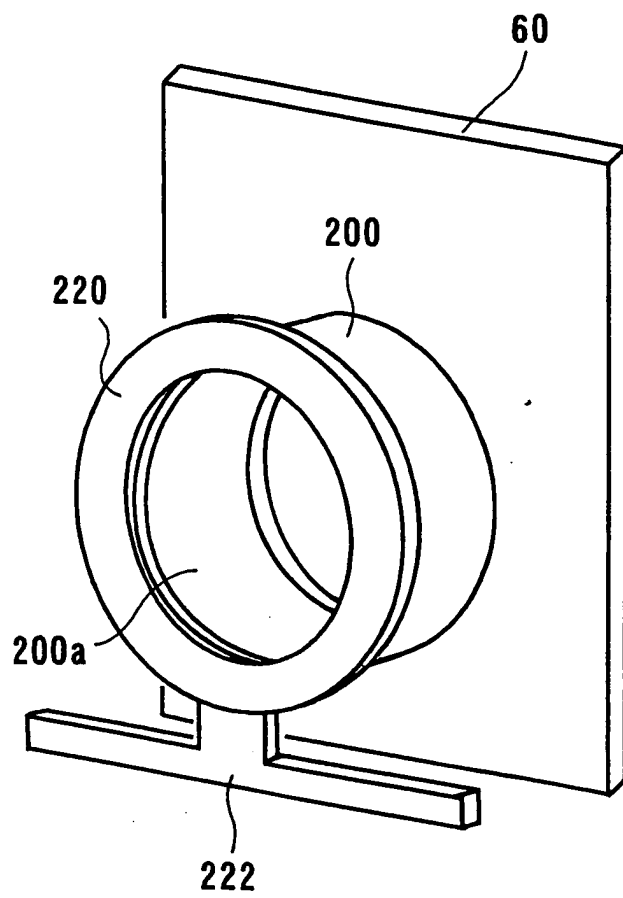


FIG. 34B

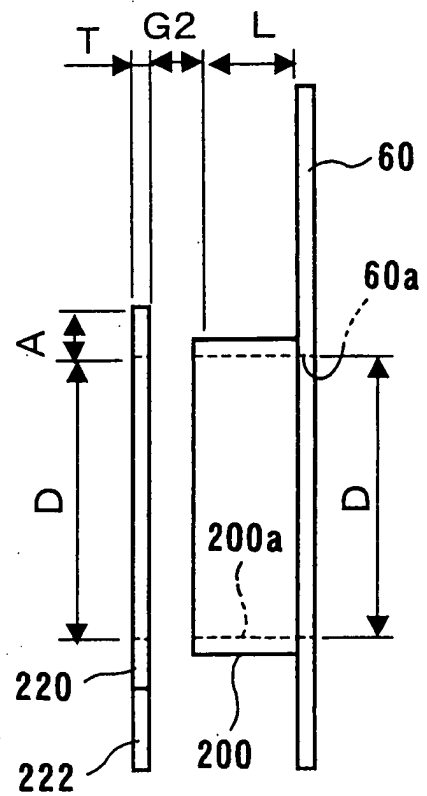


FIG. 35A

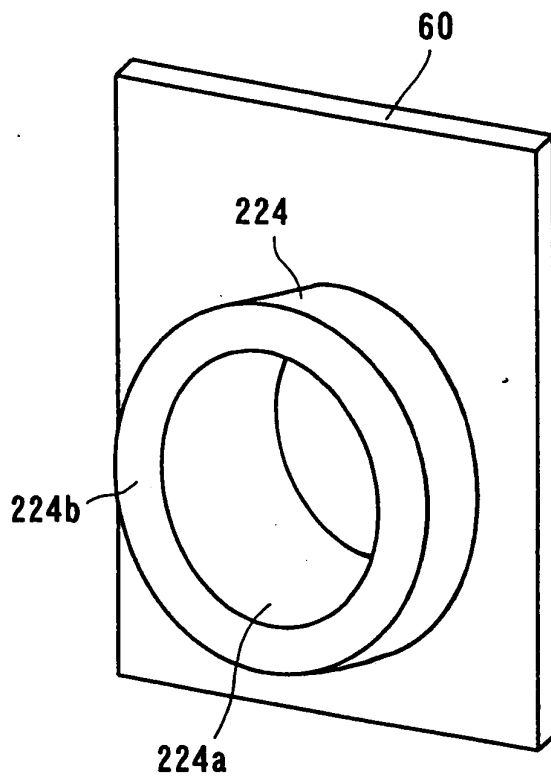


FIG. 35B

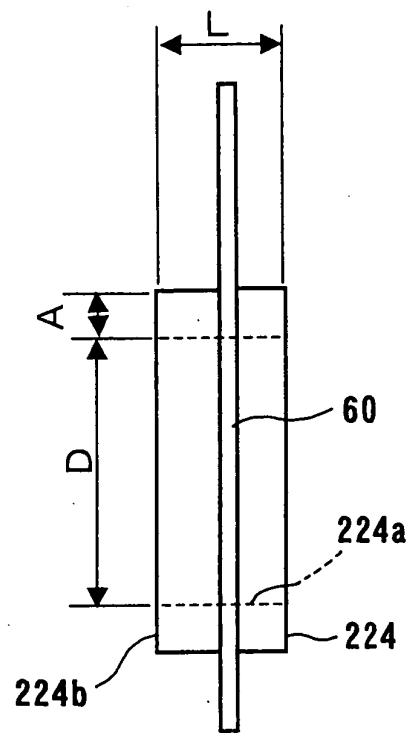


FIG. 36

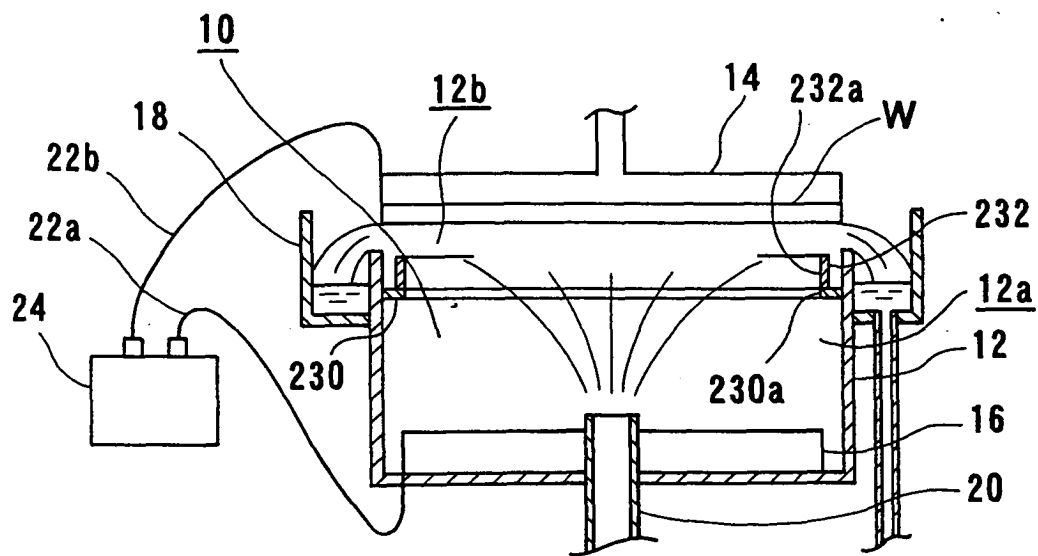


FIG. 37

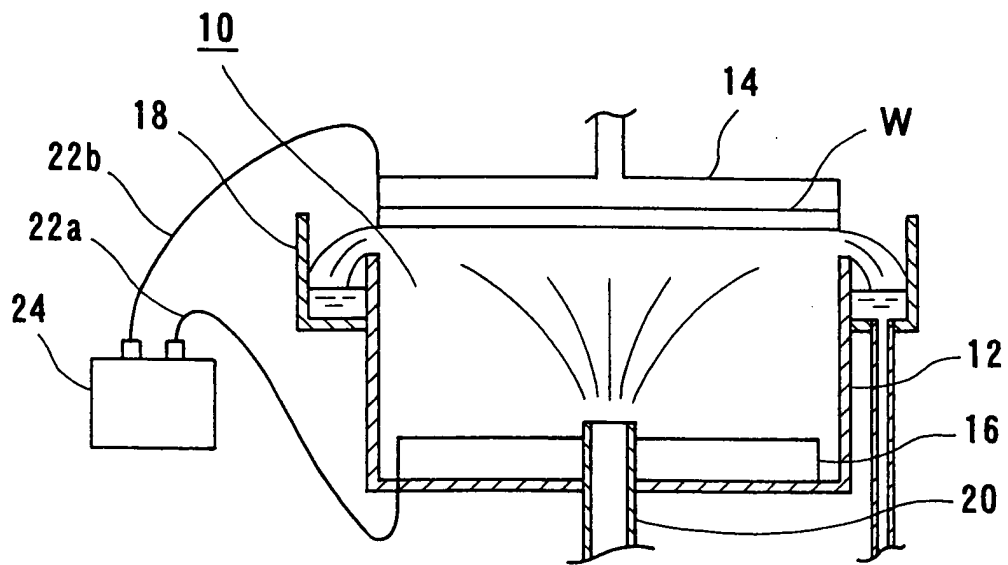


FIG. 38

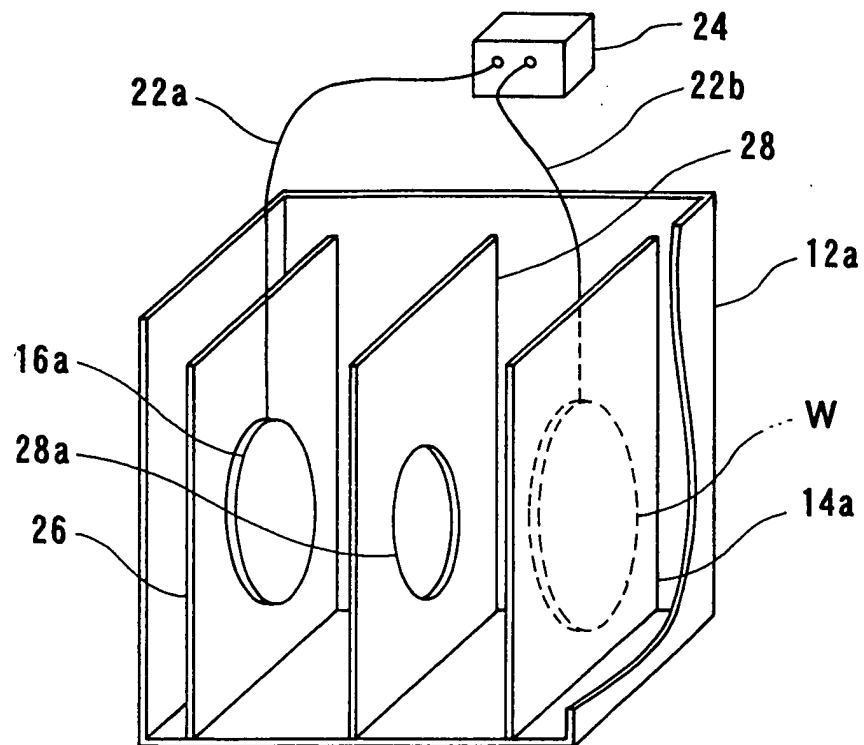


FIG. 39

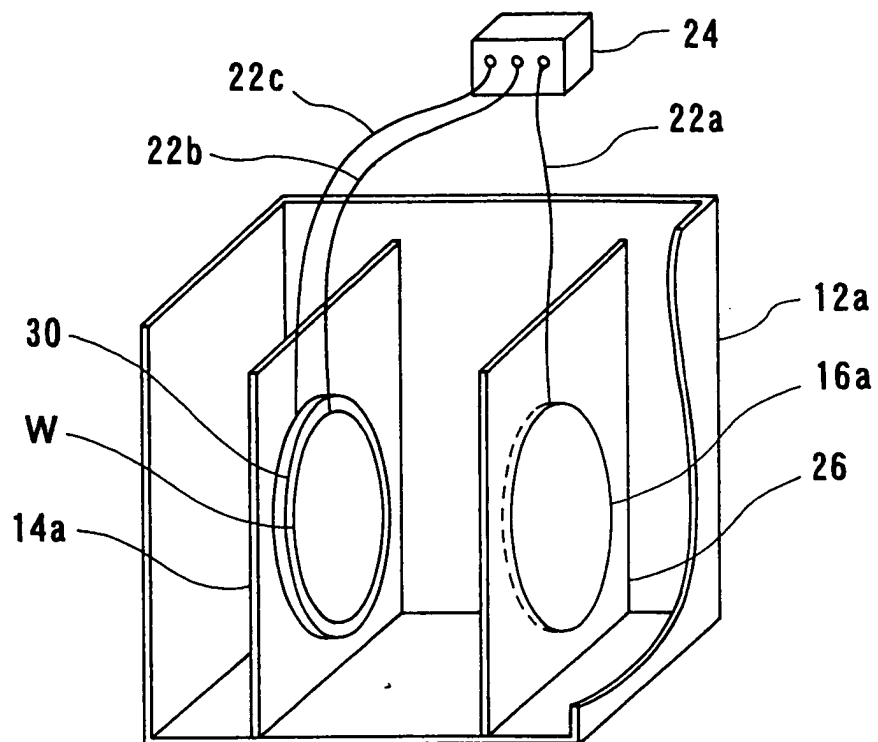


FIG. 40A

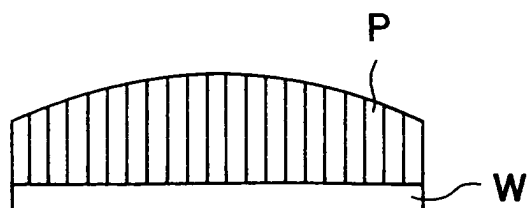


FIG. 40B

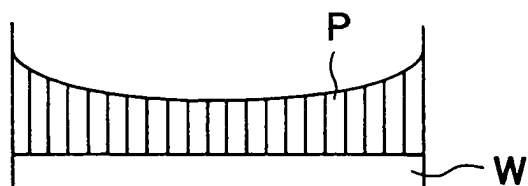
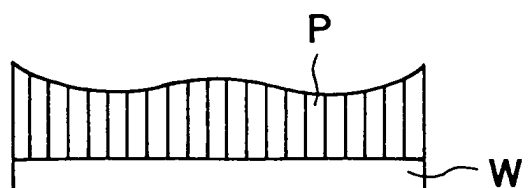


FIG. 40C



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP03/09144

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. ⁷ C25D21/12		
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) Int.Cl. ⁷ C25D21/12		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2003 Kokai Jitsuyo Shinan Koho 1971-2003 Jitsuyo Shinan Toroku Koho 1996-2003		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2000-313990 A (Dainippon Screen Mfg. Co., Ltd.), 14 November, 2000 (14.11.00), (Family: none)	1-26
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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 "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "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 21 October, 2003 (21.10.03)		Date of mailing of the international search report 04 November, 2003 (04.11.03)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)