(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 March 2002 (21.03.2002)

PCT

(10) International Publication Number
WO 02/23596 A1

(51) International Patent Classification[7]: H01L 21/00

(21) International Application Number: PCT/JP01/08068

(22) International Filing Date: 17 September 2001 (17.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2000-281371 18 September 2000 (18.09.2000) JP

(71) Applicant *(for all designated States except US)*: **TOKYO ELECTRON LIMITED** [JP/JP]; 3-6, Akasaka 5-Chome, Minato-Ku, Tokyo 107-8481 (JP).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **SHIGEOKA, Takashi** [JP/JP]; c/o TOKYO ELECTRON LIMITED, 650, Mitsuzawa, Hosaka-Cho, Nirasaki-Shi, Yamanashi 407-0192 (JP). **SAKUMA, Takeshi** [JP/JP]; c/o TOKYO ELECTRON AT LIMITED, 2-41, Machiya 1-Chome, Shiroyama-Machi, Tsukui-Gun, Kanagawa 220-0101 (JP).

(74) Agent: **ITOH, Tadahiko**; 32nd Floor, Yebisu Garden Place Tower, 20-3, Ebisu 4-chome, Shibuya-ku, Tokyo 150-6032 (JP).

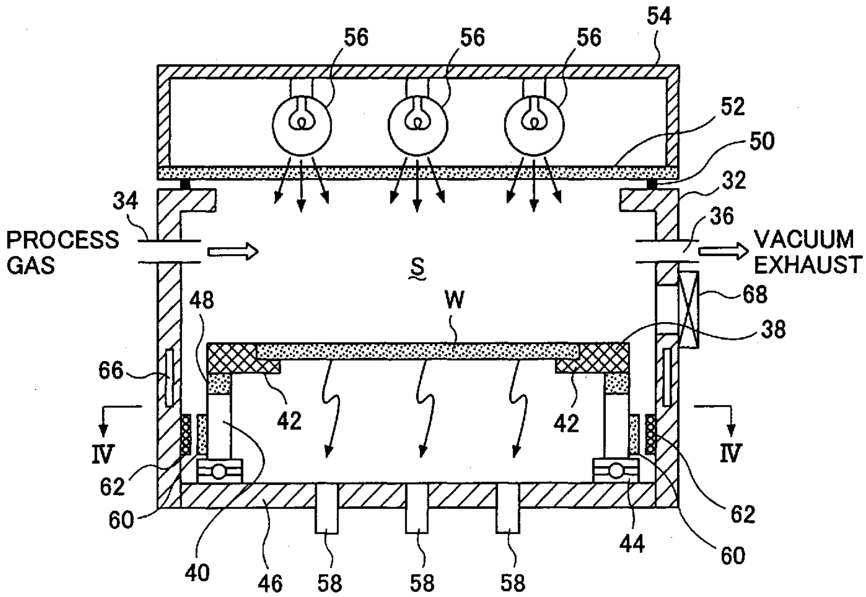
(81) Designated States *(national)*: KR, US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: HEAT TREATMENT APPARATUS



(57) Abstract: A heat treatment apparatus applies a heat treatment to an object to be processed that is placed on a placement stage (38) provided on an upper end of a cylindrical leg part (40) within a process chamber (32). The leg part is rotatably supported within the process chamber. Permanent magnets (60) for rotation and a permanent magnet (70) for floatation are provided to the leg part (40). Electromagnetic coils (62) for rotation are provided to the process chamber (32). Electromagnets (74) for floatation are provided to the process chamber (32) so as to magnetically generate a floating force in the permanent magnet (70) for floatation. Thereby, creation of particles is prevented, and the rotational speed of the object to be processed can be increased.

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DESCRIPTION

HEAT TREATMENT APPARATUS

TECHNICAL FIELD

The present invention generally relates to a heat treatment apparatuses and, more particularly, to a heat treatment apparatus having a rotatable placement stage on which an object to be processed such as a semiconductor wafer is placed.

BACKGROUND ART

Generally, a semiconductor device is manufactured by applying various heat treatment processes, such as a film deposition process, an annealing process, an oxidation process, a sputtering process, an etching process, etc., to a silicon substrate such as a semiconductor wafer for a plurality of times.

In this case, in order to maintain a good electric characteristic of integrated circuits and a high yield of products, it is required to apply the above-mentioned various heat treatment processes uniformly over an entire surface of a wafer. Therefore, since a progress of the heat treatment strongly depends on a temperature of the wafer in the heat treatment process, the in-surface uniformity of the temperature of the wafer must be maintained high during the heat treatment.

Accordingly, there are suggested various methods for maintaining high in-surface uniformity of the temperature of the wafer. For example, with respect to a single-wafer type heat treatment apparatus, which is a relatively effective means among those methods, there is a well-known method in which a placement stage, on which a semiconductor wafer is placed, is rotated so as to reduce generation of unevenness in the temperature.

A description will now be given, with reference to FIGS. 1 and 2, of an example of such a conventional heat treatment apparatus. FIG. 1 is a schematic illustration of a structure of the example of the conventional heat treatment apparatus. In FIG. 1, a process chamber 2, in which a vacuum can be formed, has a placement stage 4 having a ling-like center opening. A semiconductor wafer W is supported by the placement stage 4 by a fringe part of a backside of the semiconductor being brought into contact with an inner side of a top surface of the placement table 4. The placement table 4 is fixed on an upper end of a cylindrical leg part 6. The leg part 6 is supported on a bottom part of the process chamber 2 via a ring-like bearing 8 so that the leg part 6 is rotatable in a circumferential direction.

A rack 10 is mounted on an inner surface of the leg part along a circumferential direction. Additionally, a drive shaft 14 of a drive motor 12 is provided under the bottom part of the process chamber 2 and airtightly extends through the bottom part of the process chamber 2. A pinion fixed on an end of the drive shaft 14 is brought into engagement with the above-mentioned rack 10, thereby rotating the leg part 6 and the placement stage 4 integrated with the leg part 6. Additionally, a transmission window 18, which is made of quartz glass, is provided on a ceiling part of the process chamber 2. Further, a plurality of heating lamps 20 are provided as a heating means above the transmission window 18 so as to heat the wafer at a predetermined temperature by a heat ray emitted by lamps 20. By rotating the placement stage 4 during the heating process, the wafer W placed on the placement stage 4 is heated while being rotated, thereby enabling an improvement of the in-surface uniformity of the wafer.

FIG. 2 is a schematic illustration of a structure of another example of the conventional heat treatment apparatus. In the apparatus shown in FIG. 1, the leg part 6 is rotated by engaging the rack 10 with the pinion 16 within the process chamber 2. On the other hand, in the apparatus shown in FIG. 2, the leg part 6 is rotated by a magnetic force. That is, the apparatus shown in FIG. 2 is provided with a pair of magnets 22 for rotation on an outer surface of the leg part 6. A ling-like magnetic rotation member 24 is rotatably mounted to an outside of the bottom part of the process chamber 2 via a ling-like bearing 27. A drive magnet 26 is fixed to an inner surface of the magnetic rotation member 24 so that the drive magnet 26 faces the above-mentioned magnets 22 for rotation with a sidewall of the process chamber 2 therebetween. Thereby, the drive magnet 26 and the magnets 22 for rotation are magnetically coupled with each other. The pinion 16 rotatable by the drive motor 12 is brought into engagement with the rack 10 provided on the outer surface of the magnetic rotation member 24. Accordingly, by rotating the drive magnet 26 in a circumferential direction of the process chamber 2 by rotating the magnetic rotation member 24, the leg part6 and the wafer W are rotated according to the rotation of the drive magnet 26 since the drive magnet 26 is magnetically coupled with the magnets 22 for rotation.

In both the conventional apparatuses shown in FIG. 1 and FIG. 2, the wafer W is rotated during a heat treatment, thereby enabling an improvement in the in-surface uniformity of the temperature of the wafer.

However, in the case of the apparatus shown in FIG. 1, since the rack 10 and the pinion 16 are mechanically engages with each other within the process chamber 2, fine particles are unavoidably generated from the engaging part, which results in a cause of degradation of a yield rate.

Additionally, in the case of the apparatus shown in FIG. 2, since the rack 10 and the pinion 16 are not provided inside the process chamber 2, the problem related to the particles unlike the apparatus shown in FIG. 1. However, in order to rotate the placement stage 4, the large magnetic rotating member 24 provided around the process chamber 2 must be rotated. Thus, the rotation of the magnetic rotating member 24 may create a cause of vibration. Additionally, there is a problem in that the rotational speed of the magnetic rotation member 24 cannot be increased to a certain level although the rotational speed of the wafer is preferably increased as much as possible so as to improve the in-surface uniformity of the temperature of the wafer.

Further, since the leg part 6 is rotatably supported by the bearing 8, particles, which may cause metal pollution or degradation of an yield rate, are generated by the bearing 8 in both the above-mentioned apparatuses. Additionally, the rotational speed cannot be increased so much due to a mechanical limit of the bearing 8, and, for example, the maximum rotational speed is about 100 rpm. Also in this respect, there is a problem in that it is difficult to improve the in-surface uniformity of the temperature of the wafer.

DISCLOSURE OF INVENTION

It is a general object of the present invention to provide an improved and useful heat treatment apparatus in which the above-mentioned objects are eliminated.

A more specific object of the present invention is to provide a heat treatment apparatus which can prevent generation of particles within a process chamber.

Another object of the present invention is to provide a heat treatment apparatus having an increased rotational speed of an object to be processed while preventing generation of particles within a process chamber.

In order to achieve the above-mentioned objects, there is provided according to the present invention, there is provided according one aspect of the present invention a heat treatment apparatus for applying a predetermined heat treatment to an object to be processed that is placed on a placement stage provided on an upper end of a cylindrical leg part within a process chamber, the leg part being rotatably supported within the process chamber,

characterized in that:

at least one permanent magnet for rotation is provided to the leg part; and a plurality of electromagnetic coils for rotation are provided to the process chamber in a state in which the electromagnetic coils for rotation face the permanent magnet for rotation of the leg part so as to apply a rotating force to the permanent magnet for rotation.

According to the above-mentioned invention, a rotating magnetic field is generated by the electromagnetic coils provided to the process chamber by supplying a predetermined electric current to the electromagnetic coils according to a principle of an electric motor. Accordingly, a rotating force is applied to the permanent magnet for rotation provided to the leg part. Thus, the leg part rotates together with the placement stage, which sequentially rotates the object to be processed.

Accordingly, the in-surface uniformity of the temperature of the object to be processed can be improved due to the rotation of the object to be processed. Additionally, unlike a conventional apparatus in which a rotating magnetic field is generated by a mechanical means, the rotating speed of the rotating magnetic field generated by the electromagnetic coils for rotation can be easily increased. Thus, the rotating speed of the placement stage, that is, the rotating speed of the object to be processed can be increased correspondingly, which enables a further improvement in the in-surface uniformity of the temperature of the object to be processed.

Additionally, there is provided according to another aspect of the present invention a heat treatment apparatus for applying a predetermined heat treatment to an object to be processed that is placed on a placement stage provided on an upper end of a cylindrical leg part within a process chamber, the leg part being rotatably supported within the process chamber,

characterized in that:

at least one permanent magnet for rotation and a permanent magnet for floatation are provided to the leg part; a plurality of electromagnets for floatation are provided to the process chamber in a state in which the electromagnets for floatation face the permanent magnet for floatation so as to apply a floating force to the permanent magnet for floatation; and a plurality of electromagnetic coils for rotation are provided to the process chamber in a state in which the electromagnetic coils for rotation face the permanent magnet for rotation so as to apply a rotating force to the permanent magnet for rotation.

According to the above-mentioned invention, the entire leg part can be magnetically floated by a magnetic action between the electromagnetic coils for floatation and the permanent magnet for floatation during a heat treatment process. Thus, since the leg part rotates while magnetically floating, there is no need to provide rotational wearing parts such as a bearing, which prevents creation of particles and metal pollution. Additionally, since the leg part rotates while floating, there is no limitation in the rotational speed due to a mechanical characteristic of a bearing or the like. Thus, the rotational speed of the leg part, that is, the object to be processed can be further increased, thereby improving the in-surface uniformity of the temperature of the object to be processed.

Additionally, there is provided according to another aspect of the present invention a heat treatment apparatus for applying a predetermined heat treatment to an object to be processed that is placed on a placement stage provided on an upper end of a cylindrical leg part within a process chamber, the leg part being rotatably supported within the process chamber,

characterized in that:

at least one permanent magnet for rotation and a permanent magnet for floatation are provided to the leg part; a plurality of electromagnets for floatation are provided to the process chamber in a state in which the electromagnets for floatation face the permanent magnet for floatation so as to apply a floating force to the permanent magnet for floatation; and at least one outside magnet for rotation is provided outside the process chamber in a state in which the outside permanent magnet for rotation is magnetically coupled with the permanent magnet for rotation provided to the leg part, the outside permanent magnet for rotation being rotatable in a circumferential direction of the process chamber so as to apply a rotating force to the permanent magnet for rotation provided to the leg part.

According to the above-mentioned invention, the entire leg part can be magnetically floated by a magnetic action between the electromagnetic coils for floatation and the permanent magnet for floatation during a heat treatment process. Additionally, the leg part, i.e., the object to be processed can be rotated by the outside permanent magnet for rotation, which is magnetically coupled with the permanent magnets for rotation provided to the leg part. In this case, since the leg part rotates while magnetically floating, there is provided no rotational wearing part, which prevents creation of particles and metal pollution.

In heat treatment apparatus according to the present invention, the permanent magnet for floatation maybe provided on an inner side of the leg part; a bottom part of the process chamber may be formed so as to protrude into an interior of the leg part; and the electromagnets for floatation may be provided to the bottom part protruding into the interior of the leg part.

Additionally, a height detecting sensor may be provided in the vicinity of one of the electromagnets for floatation so as to detect a position of the leg part in a direction of height; and a height control part may be provided so as to adjust a position of the leg part in the direction of height by controlling an electric current supplied to each of the electromagnets for floatation based on an output value of the height detecting sensor.

Accordingly, the position of the floating leg part in a direction of height can always be adjusted to a proper position.

Further, the leg part may be made of a magnetic material; a plurality of horizontal force electromagnets may be provided to the process chamber so as to apply a magnetic force to the leg part in a plurality of horizontal directions; a plurality of horizontal position detection sensors may be provided in the vicinity of the respective horizontal force electromagnets so as to detect positions of the leg part in the horizontal directions; and a horizontal control part may be provided so as to adjust the position of the leg part in the horizontal directions by controlling an electric current supplied to each of the horizontal force electromagnets based on output values of the horizontal position detection sensors.

Accordingly, the position of the floating leg part in a horizontal direction can always be adjusted to a proper position.

Other objects, features and advantages of the present invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic illustration of a structure of an example of a conventional heat treatment apparatus;

FIG. 2 is a schematic illustration of a structure of another example of the conventional heat treatment apparatus;

FIG. 3 is a schematic illustration of the heat treatment apparatus according to a first embodiment of the present invention;

FIG. 4 is a cross-sectional view taken along a line IV-IV of FIG. 3;

FIG. 5 is a schematic illustration of a heat treatment apparatus according to a second embodiment of the present invention;

FIG. 6 is a partially cut-away perspective view of a placement table and a leg part shown in FIG. 5;

FIG. 7 is a cross-sectional view taken along a line VII-VII of FIG. 5;

FIG. 8 is a cross-sectional view taken along a line VIII-VIII of FIG. 5;

FIG. 9 is a block diagram of a control system of a height of the leg part;

FIG. 10 is a block diagram of a horizontal position control system of the leg part;

FIG. 11 is a graph showing a relationship between a rotational speed of a leg part (wafer) and a temperature distribution on a surface of a wafer; and

FIG. 12 is a schematic illustration of a heat treatment apparatus according to a third embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

A description will now be given of a heat treatment apparatus according to a first embodiment of the present invention.

FIG. 3 is a schematic illustration of the heat treatment apparatus according to the first embodiment of the present invention. FIG. 4 is a cross-sectional view taken along a line IV-IV of FIG. 3. As shown in the figures, the heat treatment apparatus 30 comprises a cylindrical process chamber 32 formed of stainless steel or aluminum. A process gas nozzle 34 is provided on an upper part of a sidewall of the process chamber 32 as a process gas introducing means for introducing a necessary process gas into the process chamber 32. An exhaust port 36 is provided on the sidewall of the process chamber at a position opposite to the nozzle 34. The exhaust port 36 is connected to a vacuum exhaust system with a vacuum pump so as to allow for creation of vacuum within the process chamber 32.

A guard ring 38 is provided within the process chamber 32 as a circular ring-like placement stage for supporting an object to be processed. The guard ring 38 is joined to an upper end of a leg part 40 formed in a cylindrical shape. In the guard ring 38, a wafer support part 42 is formed by removing an inner upper portion of the guard ring 38 so that the guard ring 38 has an L-shaped cross section. An outer periphery of a backside of a semiconductor wafer as an object to be processed is brought into contact with the wafer support part 42 so as to support the wafer.

An lower end of the leg part 40 is connected to a chamber bottom 46 via a large diameter bearing such as a thrust bearing 44, and, thereby, the leg part 40 is rotatable about the central axis thereof. The leg part 40 is formed of a magnetic material such as Permalloy or magnetic stainless steel. Additionally, the guard ring 38 is if formed of ceramics such as SiC that has excellent heat resistance since a temperature of the wafer is raised to 1000°C at maximum depending on the heat treatment. Further, a heat insulating material such as quartz glass is used as a connection part 48 between the guard ring 38 and the leg part 40 so as to thermally protect magnets (described later) provided in the leg part 40.

On the other hand, a ceiling part of the process chamber 32 is open, and a quartz made transmission window 52 is mounted in an airtight manner via a seal member 50 such as an O-ring. A lamp box 54 is provided outside the transmission window 52, and the lamp box 54 is provided with a plurality of heating lamps 56 (three lamps in the figure) as a heating means so as to heat the semiconductor wafer in the process chamber 32 by a heat ray emitted from the lamps 56.

A plurality of radiation thermometer 58 are provided in the bottom part 46 of the process chamber 32 so as to maintain the wafer at a predetermined temperature by feedback-controlling the temperature of the heating lamps 56 based on the wafer temperature obtained by the radiation thermometer 58.

The thus-structured heat treatment apparatus is provided with a magnetic means 60 for rotation and a coil means 62 for rotation. Specifically, as also shown in FIG. 4, the magnetic means 60 for rotation comprises permanent magnets, and in this embodiment a pair of permanent magnets are provided on an outer surface of the leg part 40 in diametrically opposite positions.

Additionally, the coil means 62 for rotation comprises a plurality of coil parts 64 arranged on an inner wall of the process chamber 32 along a circumferential direction at a predetermined interval (electrical degree). The coil parts 64 are arranged to face the magnetic means 60 in the same horizontal level with a small gap therebetween. Each coil part 64 is configured to be able to flow alternating currents having a predetermined phase difference in circumferential directions thereof, and, thereby, the coil parts 64 can generate in the bottom part of the process chamber 32 a rotating magnetic field MG of which rotating speed is adjustable. Accordingly, since the magnetic means 60, which is magnetically attracted by the rotating magnetic field MG is subjected to attraction which follows the rotation of the rotating magnetic field, the leg pat 40 is rotatable about the central axis thereof. It should be noted that the number of permanent magnets of the magnetic means 64 and the number of coil parts 64 of the coil means 62 are merely examples, and can be further increased, for example.

Returning to FIG. 3, since the coil parts 64 and the magnetic means 60 for rotation are not so excellent in heat resistance characteristic, a cooling jacket 66 is provided to the sidewall of the process chamber 32 so as to cool those parts by flowing a cooling medium.

It should be noted that, in the figure, reference numeral 68 indicates a gate valve that is open an closed when the semiconductor wafer W is carried in and out, and lifter pins (not shown in the figure), which are moved vertically when the wafer W is carried in and out, are provided in the chamber bottom 46.

A description will now be given of an operation of the thus-structured heat treatment apparatus according to the present invention.

First, the semiconductor wafer W is carried in the process chamber 32, which is maintained at a vacuum stated beforehand, from a load lock chamber (not shown in the figure) via the opened gate valve 68. The wafer W is placed on and supported by the wafer support part 42 of the guard ring 38 by driving the lifter pins (not shown in the figure).

Then, when the carry-in of the wafer W is completed, the gate valve 68 is closed to hermetically seal the process chamber 32. A predetermined process gas for a process to be performed is introduced into the process chamber 32 through the process gas nozzle 34 while creating a vacuum in the process chamber 32 so as to maintain a predetermined process pressure. If, for example, a film deposition process is performed as a heat treatment, a film deposition gas is introduced into a process space S in the process chamber 32 together with a carrier gas such as N_2.

At this time, the heating lamps 56 provided in the ceiling part of the chamber are driven, and, thereby, a heat ray emitted by the heating lamps 56 enters the process space S via the transmission window 52 provided in the ceiling part, and sequentially irradiated on the surface of the semiconductor wafer W so as to heat and maintain the wafer W at a predetermined temperature. At the same time, the rotating magnetic field MG (refer to FIG. 4) of a predetermined rotational speed is generated by sequentially supplying alternating currents having a predetermined phase difference to each coil part 64 of the coil means 62 for rotation arranged in a lower part of the inner wall of the process chamber 32. Thereby, the magnetic means 60 for rotation provided in the leg part 40 moves together with the rotating magnetic field MG, which rotates the leg part 40 and the guard ring 38. Accordingly, the semiconductor wafer W supported on the guard ring 38 rotates during the heat treatment, which improves the in-surface uniformity of the wafer temperature.

In this case, unlike the conventional apparatus in which a rotating magnetic field is generated by a mechanical means, the rotational speed of the rotating magnetic field MG generated by the coil means for rotation can be easily increased. For example, although the rotational speed of the conventional apparatus is about 100 rpm at maximum when processing a wafer having a diameter of 300 mm, the rotational speed of the apparatus according to the present invention can be increased to about 250 rpm at maximum. Accordingly, the in-surface uniformity of the temperature of the wafer can be improved.

A description will now be given, with reference to FIGS. 5 to 10, of a second embodiment of the present invention. FIG. 5 is a schematic illustration of a heat treatment apparatus according to the second embodiment of the present invention. FIG. 6 is a partially cut-away perspective view of a placement table and a leg part shown in FIG. 5. FIG. 7 is a cross-sectional view taken along a line VII-VII of FIG. 5. FIG. 8 is a cross-sectional view taken along a line VIII-VIII of FIG. 5. FIG. 9 is a block diagram of a control system of a height of the leg part. FIG. 10 is a block diagram of a horizontal position control system of the leg part. In these figures, parts that are the same as the parts shown in FIGS. 3 and 4 are given the same reference numerals, and descriptions thereof will be omitted.

The second embodiment differs from the above-mentioned first embodiment in that the lower end of the leg part 40 is rotatably supported on the chamber bottom 46 via the bearing 44 (refer to FIG. 3) in the first embodiment whereas the leg part does not contact any parts and is magnetically floated so as to be rotatable in the second embodiment. Additionally, the chamber bottom 46 is formed so as to protrude into the interior of the cylindrical leg part 40 and has a cylindrical shape having a flat ceiling part in an upper part thereof.

The second embodiment is the same as the first embodiment in that the magnetic means 60 is provided to the lower part of the outer surface of the leg part 40 and the coil means 62 comprising a plurality of coil parts 64 is provided on an inner wall of the process chamber at positions facing the magnetic means 60 with a small gap therebetween so as to apply a rotational force to the leg part 40 by a magnetic interaction of these parts.

Alternatively, the magnetic means 60 may be provided to the lower part of the inner surface of the leg part 40 and the coil means 62 comprising the coil parts 64 may be provided on an outer surface of the chamber bottom 46 at positions facing the magnetic means 60 with a small gap therebetween so as to apply a rotational force to the leg part 40 by a magnetic interaction of these parts. It should be noted that the structure in which the magnetic means 60 is provided to the outer surface of the leg part 40 is shown in the right-hand part of FIG. 5, and the structure in which the magnetic means 60 is provided to the inner surface of the leg part 40 is shown in the left-hand part of FIG. 5.

The permanent magnets forming the magnetic means 60 contain iron, chrome, neodymium, strontium, samarium and other rare earth elements. If the heat radiated by the lamps 56 directly reach the magnetic means 60 and the coil means, particles may be generated or meal pollution occurs due to a high-temperature, or a magnetic force of the permanent magnets may be reduced due to a high-temperature. Accordingly, the structure in which the magnetic means 60 and the coil means 62 are provided inside the leg part 40 has advantages in that: 1) generation of particles and metal pollution during a heat treatment can be prevented since the magnetic means 60 and the coil means 62 are not directly exposed to a heat ray; and 2) the permanent magnets forming the magnetic means 60 are prevented from being reduced in their magnetic force due to a high temperature since the radiation heat of the lamps 56 cannot directly reach the permanent magnets.

The lower end of the cylindrical leg part 40 of the second embodiment is not joined to an upwardly protruding flange part 46A of the chamber bottom 46 but separated to float above the flange part 46A. Specifically, as also shown in FIG. 6, a magnetic means 70 for floatation is mounted on the middle stage of the cylindrical leg part 40, on which the guard ring 38, is mounted along an inner surface thereof in a collar-like shape. The magnetic means 70 for floatation comprises a circular ring-like thin plate permanent magnet, which extends inwardly in horizontal directions.

It is now assumed that the upper surface of the magnetic means 70 for floatation is an N pole, and the lower surface is an S pole. The sidewall of the process chamber 32 has a slightly thicker wall than the above-mentioned first embodiment. Additionally, the protruding chamber bottom 46 has a slightly thicker sidewall. Then, a magnet accommodating part 72 is provided on the outer surface of the sidewall of the chamber bottom 46. The magnet accommodating part 72 has a concave cross section in a horizontal direction so as to accommodate the collar-like magnetic means 70 in a loose fitting state.

The magnet accommodating part 72 is formed in a ring-like shape along the circumference of the cylindrical chamber bottom 46. Then, a plurality of electromagnetic means 74 are provided in predetermined positions of the magnet accommodating part 72 so as to apply a magnetic floating force to the magnetic means 70 for floatation.

In the second embodiment, as also shown in FIG. 7, three electromagnetic means 74 are provided at an equal interval along the circumferential direction of the chamber bottom 46. The electromagnetic means 74 comprises upper coil parts 76A, 76B, 76C and lower coil parts 78A, 78B, 78C so as to sandwich the magnetic means 70 for floatation (refer to FIG. 9). The generated electromagnetic force, for example, a repulsive force can be adjusted by separately control the electric current supplied to each of the coil parts 76A-76C and 78A-78C. In this case, as also shown in FIG. 9, in order to cause a floatation of the leg part 40, i.e., the magnetic means 70 for floatation, an electric current is supplied to each of the coil parts 76A-76C and 78A-78C so as to generate an electromagnetic repulsive force against the magnetic means 70 for floatation.

In the case shown in FIG. 9, an N pole appears on a lower surface of each coil parts 76A-76C, and an S pole appears on an upper surface of each coil parts 78A-78C so that a repulsive force is generated against the magnetic means 70 for floatation and the magnetic means 70 floats. It should be noted that a larger current is supplied to the lower coil parts 78A-78C than the upper coil parts 76A-76C so as to generate an electromagnetic force sufficient for cause a floatation of a heavy weight material such as the lag part 40, the guard ring 38 and the wafer W.

Then, height position detection parts 80A, 80B, 80C are provided in the vicinity of the corresponding lower coil parts 78A-78C. Each of the height position detection parts 80A-80C comprises a capacitive distance meter, which obtain a distance based on a change in a capacitance between the magnetic means 70 for floatation, or a laser distance meter, which has a transmitter and receiver of a laser light. The height position detection parts 80A-80C obtain distances 82A, 82B, 82C in the direction of height between the magnetic means 70 for floatation at the respective positions (refer to FIG. 9). The output values of the height position detection parts 80A-80C are supplied to a height control part 84. The height control part 84 sends a control signal to a power source 86 so that the distances 82A, 82B, 82C in the direction of height are maintained at a predetermined value, and, thereby, the power source 80 adjusts the current supplied to each of the coil parts 76A-76C and 78A-78C so as to control a height level.

On the other hand, the lower part of the inner wall of the process chamber 32 is provided with a plurality of, for example, three horizontal force electromagnetic means 90A, 90B, 90C in the figure, along the circumferential direction thereof at a equal interval as shown in FIG. 8. The number of horizontal force electromagnetic means is not limited to three, and can be any number equal to or greater than three so as to stabilize the position. Then, the electromagnetic force, i.e., the attraction force can be adjusted for each horizontal force electromagnetic means 90A-90C by individually controlling the current to the horizontal force electromagnetic means 90A-90C (refer to FIG. 10). Then, horizontal position detection sensor parts 92A, 92B, 92C are provided in the vicinity of the corresponding horizontal force electromagnetic means 90A-90C. Similar to the above-mentioned height position detection sensor parts 80A-80C, a capacitive distance meter or a laser distance meter can be used for the horizontal position detection sensor parts 92A, 92B, 92C so that the horizontal position detection sensor parts 92A, 92B, 92C obtain horizontal distances between the leg part 40 at respective positions (refer to FIG. 10). The output values of the horizontal position detection sensor parts 92A-92C are supplied to a horizontal control part 96. The horizontal control part 96 sends a control signal to a power source 98 so that the horizontal distances 94A, 94B, 94C are maintained at a predetermined value. As a result, the power source 98 adjusts the current supplied to each of the horizontal force electromagnetic means 90A-90C so as to perform the position adjustment of the leg part in horizontal directions.

Similar to the coil means 62, the horizontal force electromagnetic means 90A, 90B and 90C and the horizontal position detection sensor parts 92A, 92B and 92C may be provided to the outer surface of the chamber bottom 46 as shown in the left-hand part of FIG. 5 for the same reason as the coil means being provided to the outer surface of the chamber bottom 46.

A description will now be given of an operation of the thus-structured heat treatment apparatus according to the second embodiment.

In the second embodiment, it is the same as the first embodiment to generate a rotational force by a magnetic interaction between the magnetic means 60 for rotation provided to the leg part 40 and the coil parts 64 of the coil means 62 for rotation arranged so as to face the magnetic means 60. The second embodiment features the leg portion 40 being magnetically floated. That is, a repulsive force is generated between the magnetic means 70 for floatation positioned between the upper coil parts 76A-76C and the lower coil parts 78A-78C by supplying currents to the three upper coil parts 76A-76C upper coil parts and the three lower coil parts 78A-78C of the electromagnetic means 74 provided in the magnet accommodating part 72 of the chamber bottom 46 so as to float the magnetic means 70 for floatation and the leg part 40 integrally mounted to the magnetic means 70 by the generated repulsive force. Accordingly, the leg part 40 is rotated while being magnetically floated.

In this case, in order to prevent the leg part 40 and the magnetic means 70 for floatation from contacting or colliding with the inner surface of the process chamber 32, the position in the direction of height and the horizontal position of the magnetic means 70 for floatation must be adjusted.

With regard to the adjustment in the direction of height, the height position detection parts 80A-80C measure the distances 82A-82C in the direction of height between the magnetic means 70 for floatation at respective positions, and the measurements are supplied to the height control part 84. Then, the height control part 84 individually controls, via the power source 86, the currents supplied to the coil parts 76A-76C and 78A-78 so as to maintain the distances 82A-82C in the direction in height at a constant value. Thus, the leg part 40 is stably controlled so that the position in the direction of height is always constant while the leg part 40 is rotated.

Moreover, with regard to the position adjustment in the horizontal direction, the horizontal position detection sensor parts 92A-92C measures the horizontal distances 94A-94C in the direction between the leg part 40 at the respective positions, and the measurements are supplied to the horizontal control part 96. Then, the horizontal control part 96 equalizes the attraction force of each horizontal force electromagnetic means 90A-90C by individually controlling, via the power source 98, the currents supplied to the horizontal force electromagnetic means 90A-90C so as to equalize the horizontal distances 94A-94C. Thus, the position adjustment of the leg part 40 in horizontal directions can be performed with high accuracy while the leg part 40 is rotated.

As mentioned above, since the leg part 40 is stably rotated in a magnetically floating state, the leg part 40 is supported in a non-contact manner without using a bearing or the like. Thus, a problem relates to generation of particles or metal pollution can be solved.

Additionally, since the leg part 40 can be rotated in a non-contact manner, the rotational speed can be greatly increased to, for example, about 250 rpm. Thus, the in-surface uniformity of the wafer temperature can be greatly improved.

Further, since a bearing is not used for rotatably supporting the leg part 40, a vibration due to rotation of the leg part 40 can be prevented.

A description will now be given of a result of evaluation for a simulation of a relationship between the rotational speed of the leg part 40 (wafer) and the in-surface uniformity of the wafer temperature. FIG. 11 is a graph showing a relationship between the rotational speed of the leg part 40 (wafer) and the in-surface uniformity of the wafer temperature. The wafer temperature is set at 1100°C.

According to the graph, the temperature distribution gradually decreases as the rotational speed of the wafer increases. Especially, when the rotational speed exceeds 120 rpm, the temperature distribution is below 0.95. Thus, it is verified that the apparatus according to the present invention, which can rotate a wafer at a high speed, is capable of further improving the in-surface uniformity of the wafer temperature.

Moreover, in this case, since the chamber bottom 46 is formed in a concave shape, a distance between the wafer W and the radiation thermometer 58 provided in the ceiling part of the bottom chamber 46 becomes very small. Thus, the controllability of the wafer temperature can be improved.

It should be noted that, although the height position detection part 80A-80C are provided in the vicinity of the lower coil parts 78A-78C as shown in FIG. 9 in the above-mentioned embodiment, the height position detection part 80A-80C may be provided upper coil parts 76A-76C.

A description will now be given, with reference to FIG. 12, of a third embodiment of the present invention. FIG. 12 is a schematic illustration of a heat treatment apparatus according to the third embodiment of the present invention. In FIG. 12, parts that are the same as the parts previously explained are given the same reference numerals, and descriptions thereof will be omitted. The third embodiment is the same as the previously explained second embodiment with respect to the leg part 40 being magnetically floated. The third embodiment greatly differs from the second embodiment in that the third embodiment uses the mechanism explained and shown in FIG. 2 so as to generate rotational force to rotate the leg part 40. Accordingly, in the third embodiment, although the magnetic means 70 for floatation and the electromagnetic means 74 for floatation as shown in FIG. 5 are provided, the coil means 62 (refer to FIG. 5) is not provided. Instead, an outside magnetic means 98 for rotation is provided outside the process chamber 32. Specifically, the outside magnetic means 98 has a magnet rotation member 24 having an L-shaped cross section outside the lower part of the process chamber 32 so as to cover the corner of the process chamber 32 with a small distance therebetween. The lower inner end of the magnetic rotation member 24 is mounted to the peripheral part of the bottom surface of the chamber bottom 46 via a bearing such as a thrust bearing 36 so that the magnetic rotation member 24 is rotatable about the central axis thereof. Drive magnets 26 comprising permanent magnets are provided on an upper inner surface of the magnet rotation member 24 along a circumferential direction with a preferred interval. Additionally, the magnetic means 60 for rotation, which has opposite magnetic poles with the drive magnets 26, is provided on the outer surface of the leg part 40 opposite to the drive magnets 26. The drive magnets 26 are magnetically coupled with the magnetic means 60 for rotation. It should be noted that electromagnets may be used as the drive magnets 26.

Accordingly, the drive magnets 26 and the magnetic means 60 for rotation are magnetically coupled with each other so as to form a magnetic coupling. Thus, the leg part 40 magnetically coupled with the magnet rotation member 24 can be sequentially rotated by rotating the magnet rotation member 24 in a circumferential direction of the process chamber 32. In this case, the rack 10 is formed on a lower side surface of the magnet rotation member 24 along a circumferential direction, and the rack 10 is engaged with the pinion 16 which is rotated by the drive motor 12 so as to rotate the magnet rotation member 24.

According to the third embodiment, since the leg part 40 is stably rotated in a magnetically floating stated similar to the case of the second embodiment, the leg part 40 is supported in a non-contact manner without using a bearing or the like. Thus, a problem relates to generation of particles or metal pollution can be solved.

Additionally, since the leg part 40 can be rotated in a non-contact manner, the rotational speed can be greatly increased to, for example, about 250 rpm. Thus, the in-surface uniformity of the wafer temperature can be greatly improved.

Further, since a bearing is not used for rotatably supporting the leg part 40, a vibration due to rotation of the leg part 40 can be prevented.

It should be noted that although the above-mentioned embodiments are explained with the heat treatment apparatuses using heating lamps as a heating means, the present invention is not limited to such a structure and is applicable to an apparatus using a resistance heating heater. Additionally, the present invention is not limited to the apparatus having a structure in which the heating means is provided in the ceiling part, and is applicable to a heat treatment apparatus having a structure in which the heating means is provided inside the placement stage or under the placement stage.

Additionally, the present invention is applicable to not only the case in which the placement stage is formed as a ring-like guard ring but also a case in which the placement stage is formed as a thin circular plate or a cylindrical member made of aluminum.

Further, the method for supplying a process gas is not limited to a so-called side flow supply method which introduces a process gas from a sidewall of a process chamber as in the present embodiments, and a so-called shower head supply method may be used, which supplies a process gas though a showerhead provided in a ceiling part.

Additionally, a film deposition process is described as an example of a heat treatment in the present specification, the present invention is not limited to this and is applicable to an apparatus, which performs other heat treatments such as an annealing process, a sputtering process, or an etching process.

Further, the object to be processed is not limited to the semiconductor wafer, and the present invention is applicable to a case in which an LCD substrate, a glass substrate or the like is processed.

The present invention is not limited to the specifically disclosed embodiments, and variations and modifications may be made without departing from the scope of the present invention.

CLAIMS

1. A heat treatment apparatus for applying a predetermined heat treatment to an object to be processed that is placed on a placement stage (42) provided on an upper end of a cylindrical leg part (40) within a process chamber (32), said leg part (40) being rotatably supported within said process chamber,

characterized in that:

at least one permanent magnet (60) for rotation is provided to said leg part (40); and

a plurality of electromagnetic coils (62) for rotation are provided to said process chamber (32) in a state in which the electromagnetic coils (62) for rotation face the permanent magnet (60) for rotation of said leg part so as to apply a rotating force to said permanent magnet (60) for rotation.

2. A heat treatment apparatus for applying a predetermined heat treatment to an object to be processed that is placed on a placement stage (42) provided on an upper end of a cylindrical leg part (40) within a process chamber (32), said leg part (40) being rotatably supported within said process chamber,

characterized in that:

at least one permanent magnet (60) for rotation and a permanent magnet (70) for floatation are provided to said leg part (40);

a plurality of electromagnets (76A-76C, 78A-78C) for floatation are provided to said process chamber (32) in a state in which the electromagnets (76A-76C, 78A-78C) for floatation face the permanent magnet (70) for floatation so as to apply a floating force to the permanent magnet (70) for floatation; and

a plurality of electromagnetic coils (62) for rotation are provided to said process chamber in a state in which the electromagnetic coils (62) for rotation face the permanent magnet (60) for rotation so as to apply a rotating force to the permanent magnet (60) for rotation.

3. A heat treatment apparatus for applying a predetermined heat treatment to an object to be processed that is placed on a placement stage (42) provided on an upper end of a cylindrical leg part (40) within a process chamber (32), said leg part (40) being rotatably supported within said process chamber,

characterized in that:

at least one permanent magnet (60) for rotation and a permanent magnet (70) for floatation are provided to said leg part (40);

a plurality of electromagnets (76A-76C, 78A-78C) for floatation are provided to said process chamber (32) in a state in which the electromagnets (76A-76C, 78A-78C) for floatation face the permanent magnet (70) for floatation so as to apply a floating force to the permanent magnet (70) for floatation; and

at least one outside magnet (26) for rotation is provided outside said process chamber (32) in a state in which the outside permanent magnet (26) for rotation is magnetically coupled with the permanent magnet (60) for rotation provided to said leg part (40), the outside permanent magnet (26) for rotation being rotatable in a circumferential direction of said process chamber (32) so as to apply a rotating force to the permanent magnet (60) for rotation provided to said leg part (40).

4. The heat treatment apparatus as claimed in claim 2 or 3, characterized in that:

said permanent magnet (70) for floatation is provided on an inner side of said leg part (40);

a bottom part (46) of said process chamber (32) is formed so as to protrude into an interior of said leg part (40); and

said electromagnets (76A-76C, 78A-78C) for floatation are provided to the bottom part (46) protruding into the interior of said leg part (40).

5. The heat treatment apparatus as claimed in one of claims 2 to 4, characterized in that:

a height detecting sensor (80A-80C) is provided in the vicinity of one of said electromagnets (76A-76C, 78A-78C) for floatation so as to detect a position of said leg part (40) in a direction of height; and

a height control part (84) is provided so as to adjust a position of said leg part (49) in the direction of height by controlling an electric current supplied to each of said electromagnets (76A-76C, 78A-78C) for floatation based on an output value of said height detecting sensor (80A-80C).

6. The heat treatment apparatus as claimed in one of claims 2 to 5, characterized in that:

said leg part (40) is made of a magnetic material;

a plurality of horizontal force electromagnets (90A-90C) are provided to said process chamber (32) so as to apply a magnetic force to said leg part (40) in a plurality of horizontal directions;

a plurality of horizontal position detection sensors (92A-92C) are provided in the vicinity of the respective horizontal force electromagnets (90A-90C) so as to detect positions of said leg part (40) in the horizontal directions; and

a horizontal control part (96) is provided so as to adjust the position of said leg part (40) in the horizontal directions by controlling an electric current supplied to each of said horizontal force electromagnets (90A-90C) based on output values of said horizontal position detection sensors (92A-92C).

FIG.1

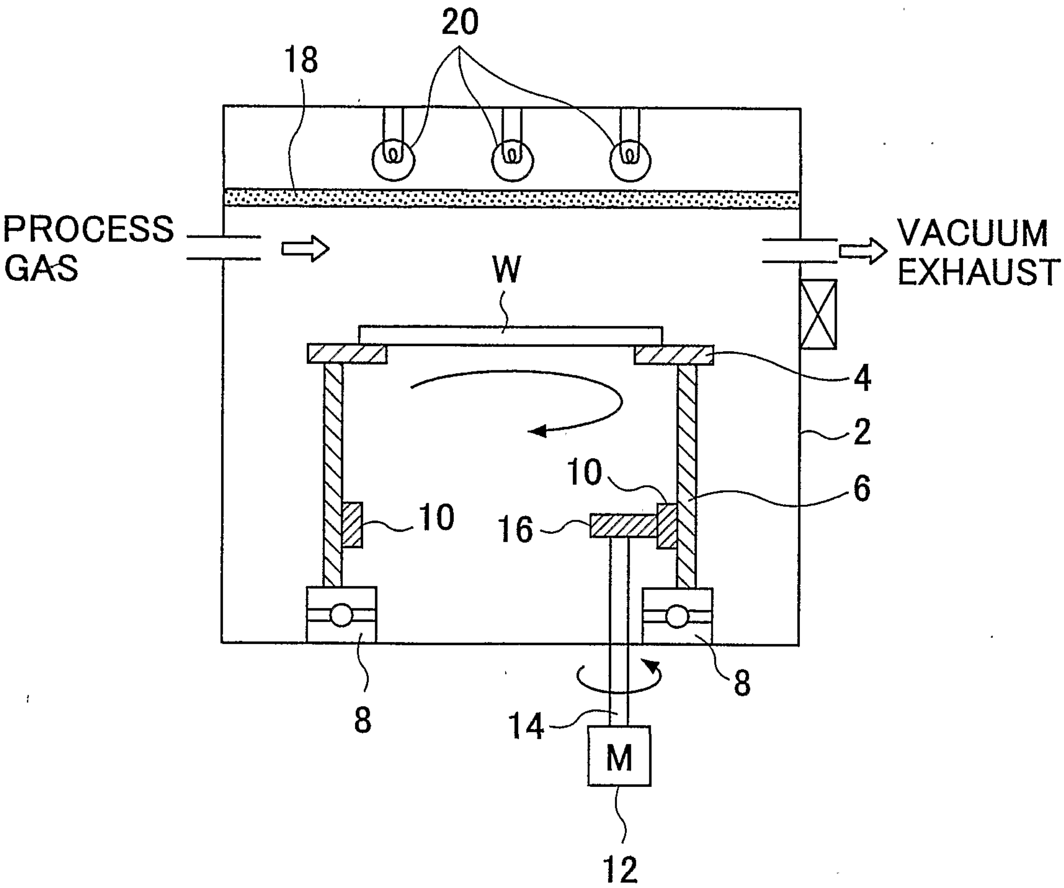
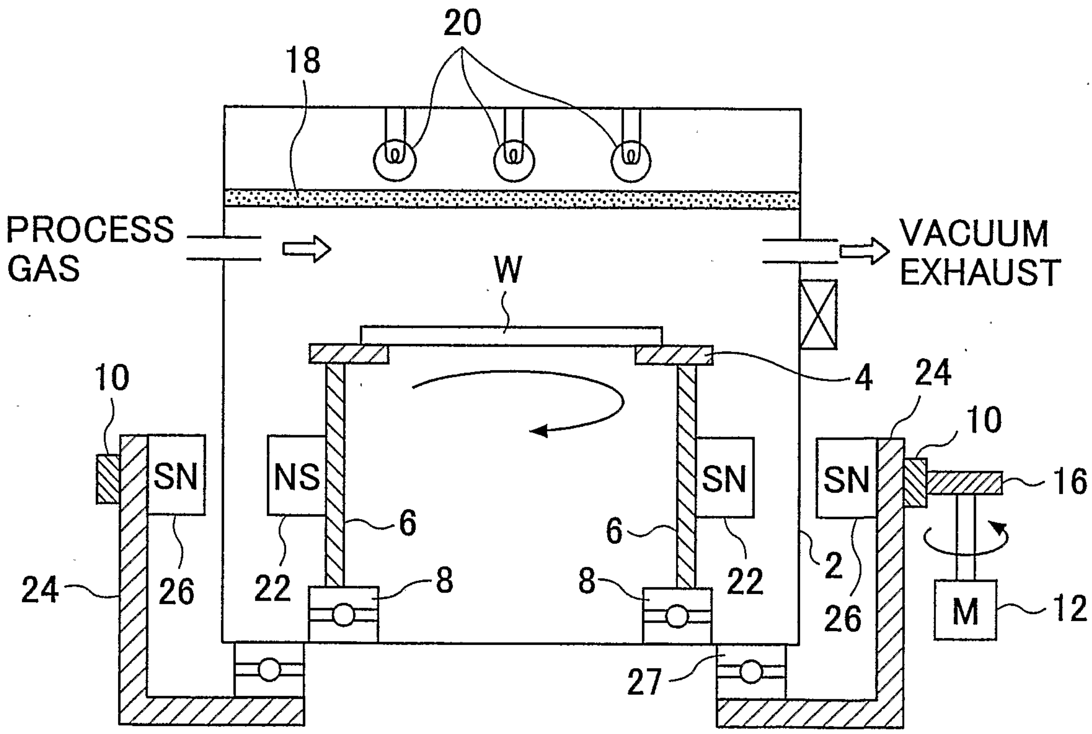


FIG.2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12
27

FIG.3

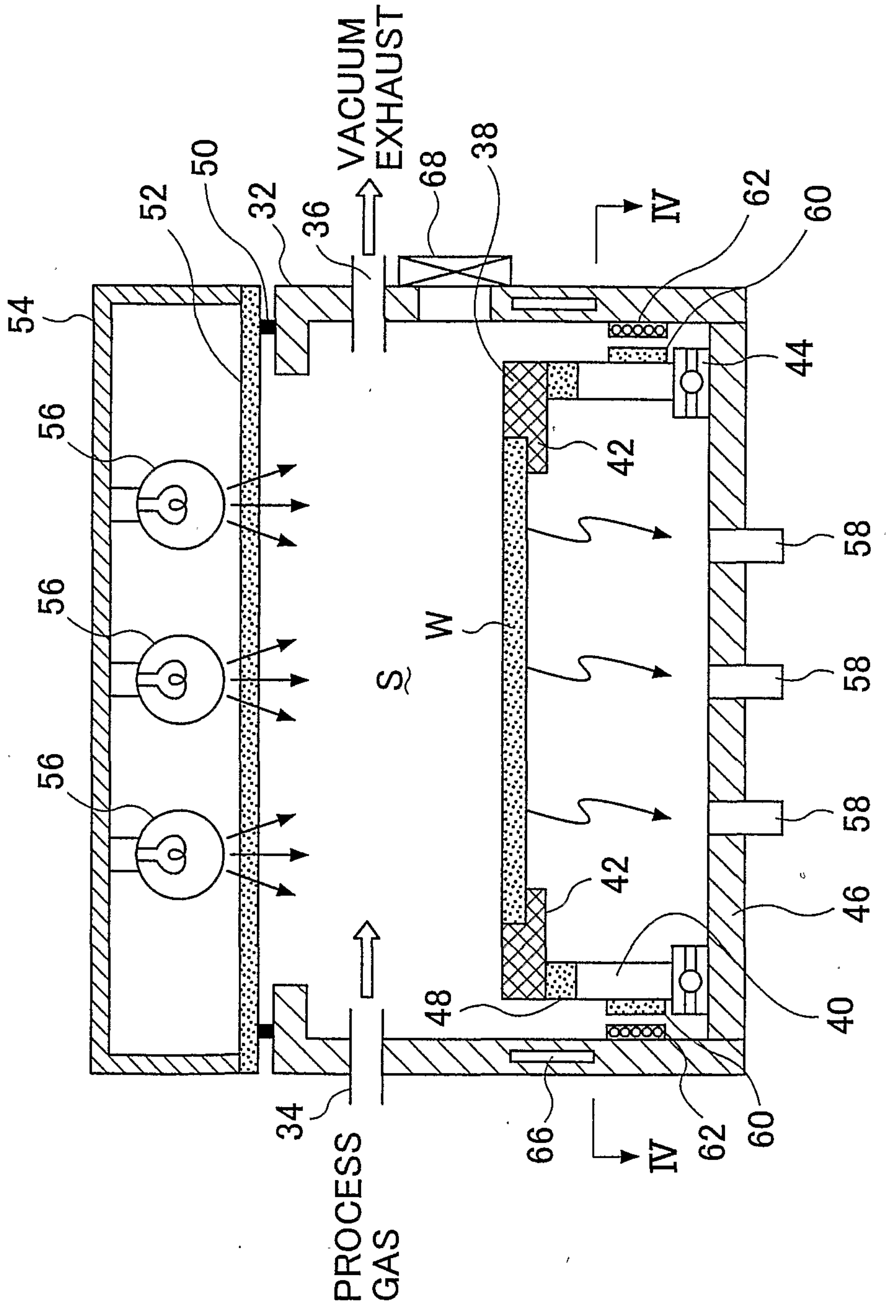
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FIG.4

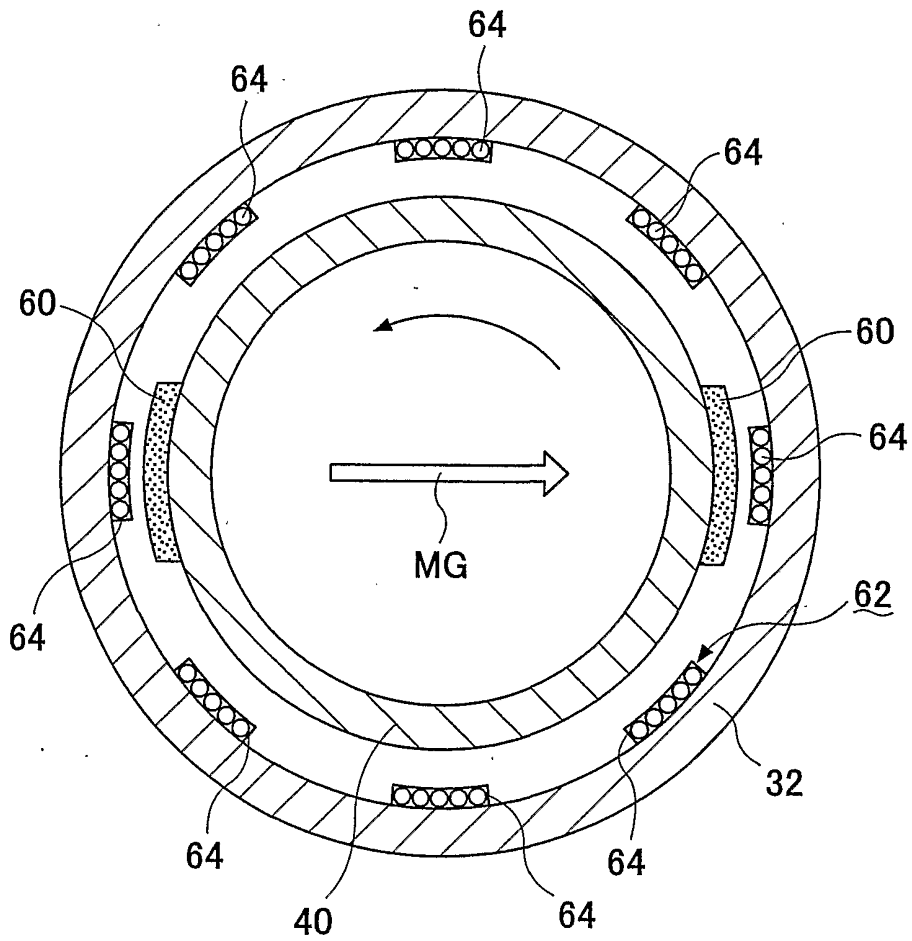
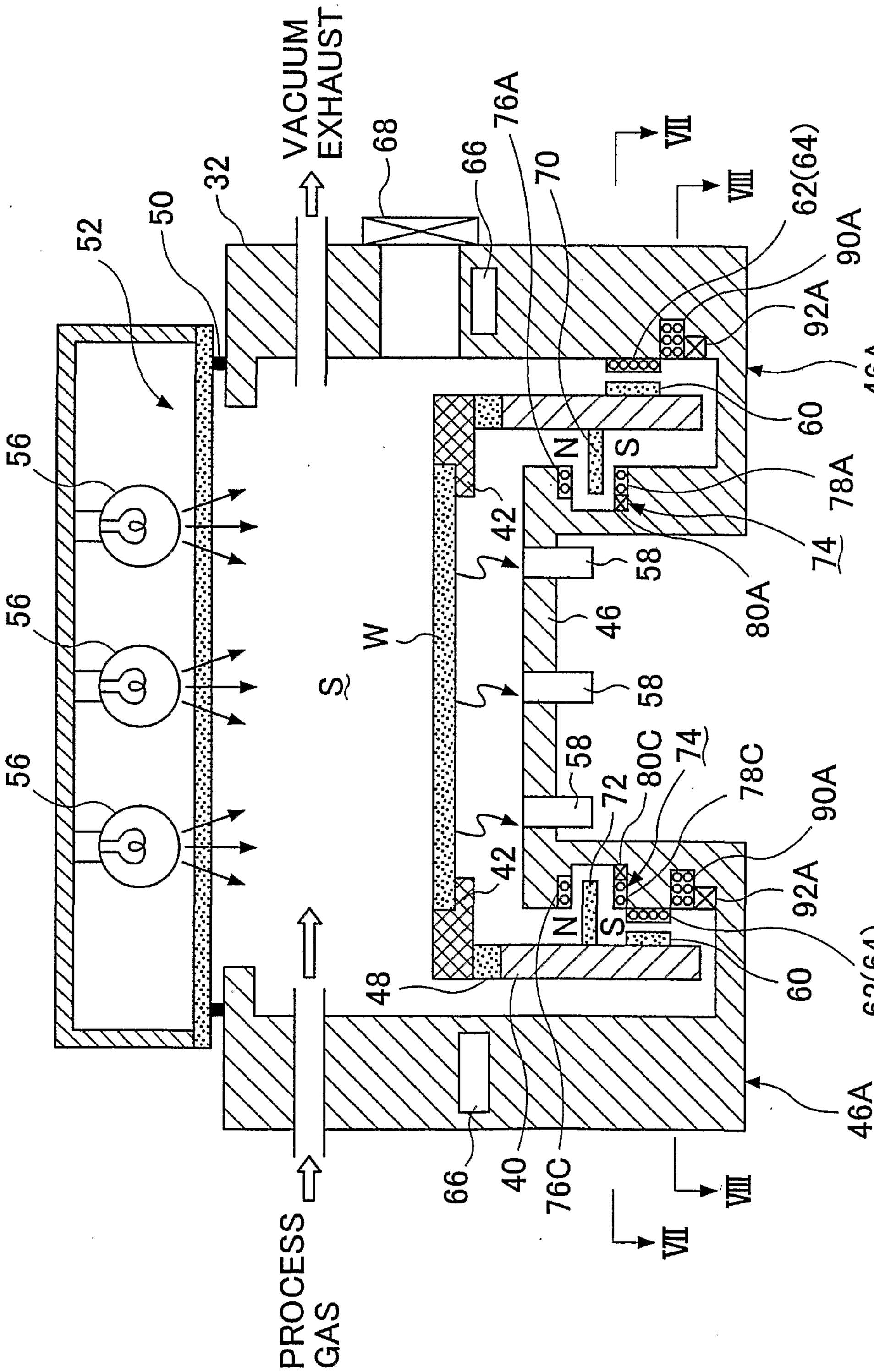


FIG.5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EXHAUST
PROCESS
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92A
46A
60
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76C
N
S

FIG.6

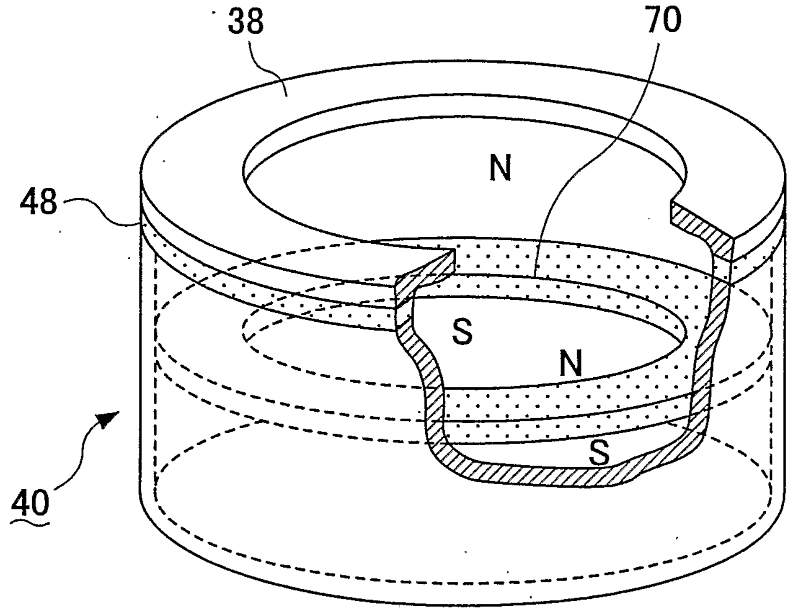


FIG.7

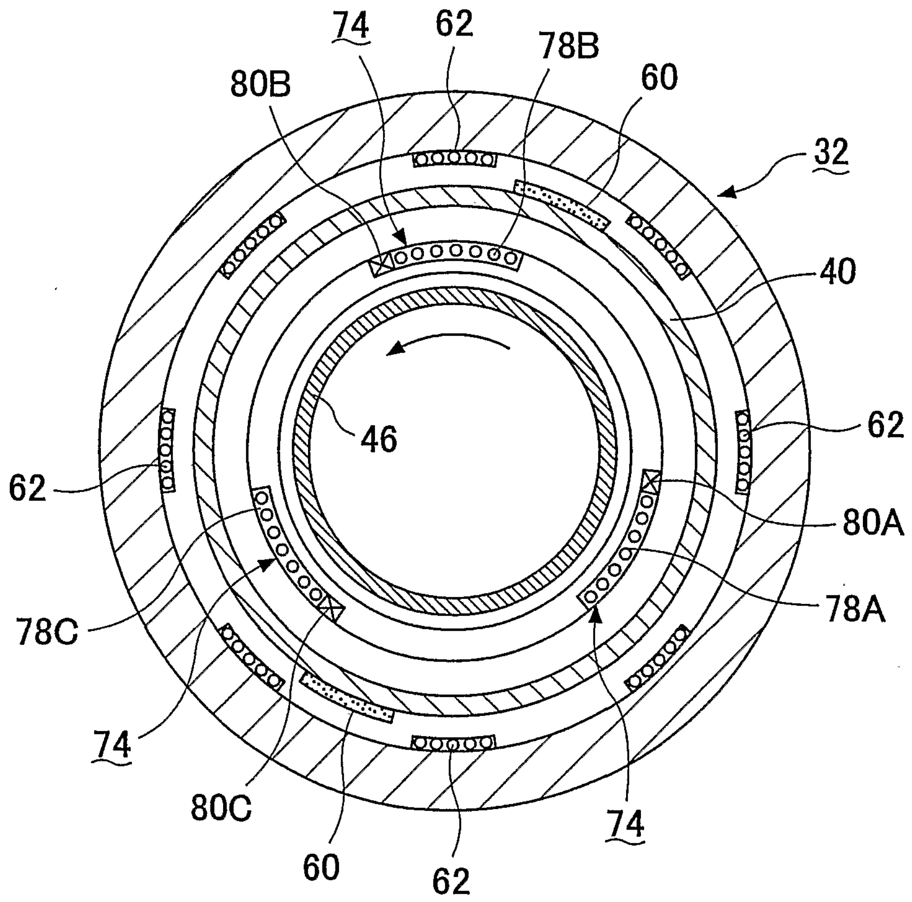


FIG.8

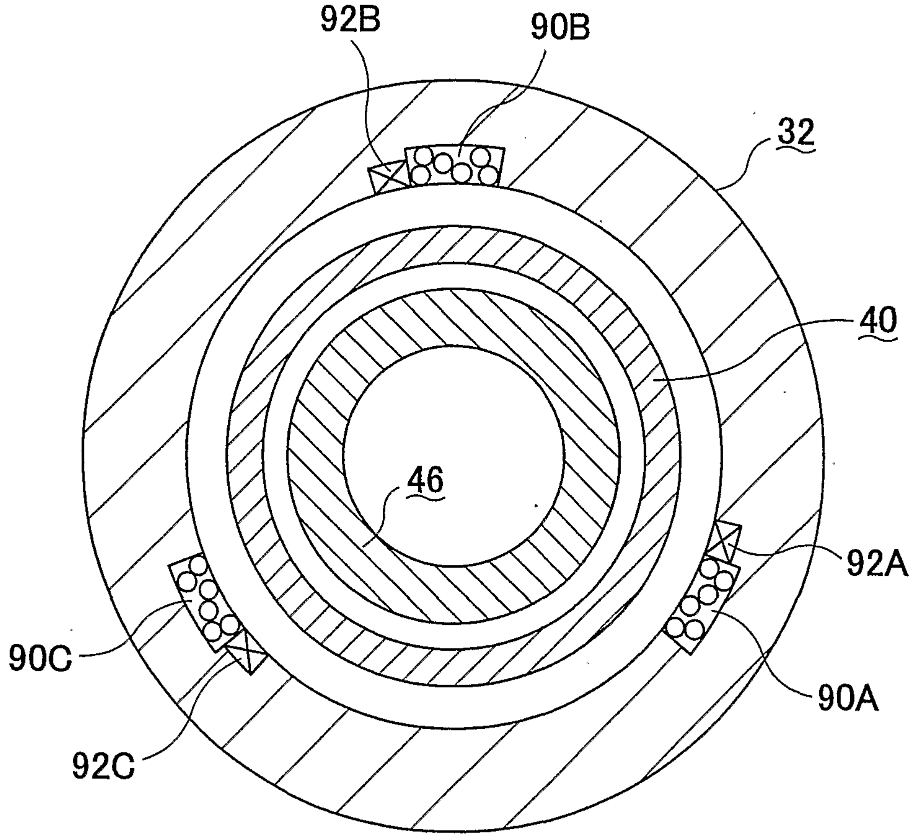
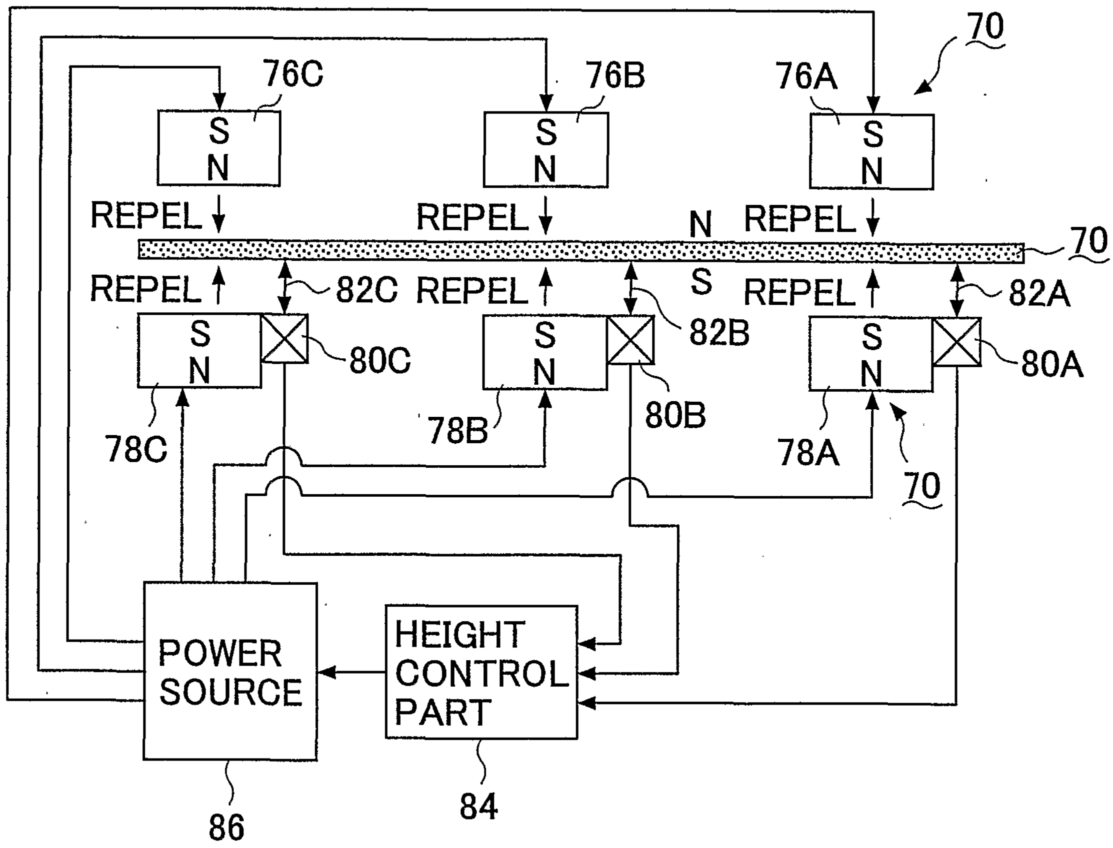


FIG.9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76B
76A
S
N
REPEL
N
S
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82C
82B
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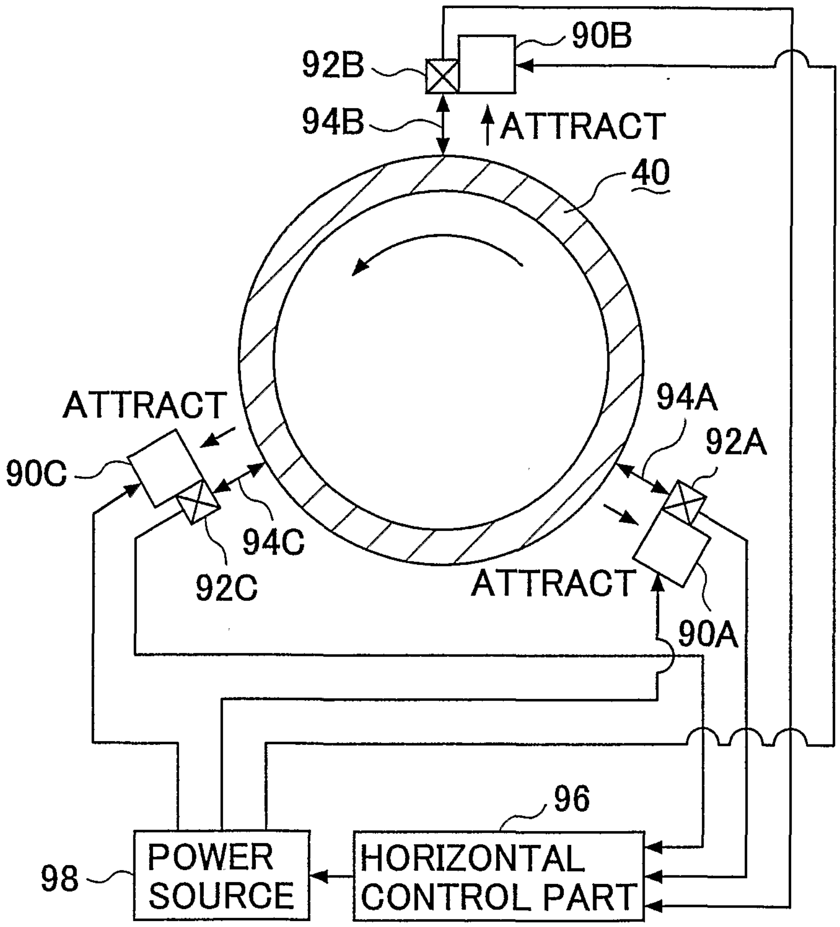
78C
78B
78A
70
POWER SOURCE
HEIGHT CONTROL PART
86
84

FIG.10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90A
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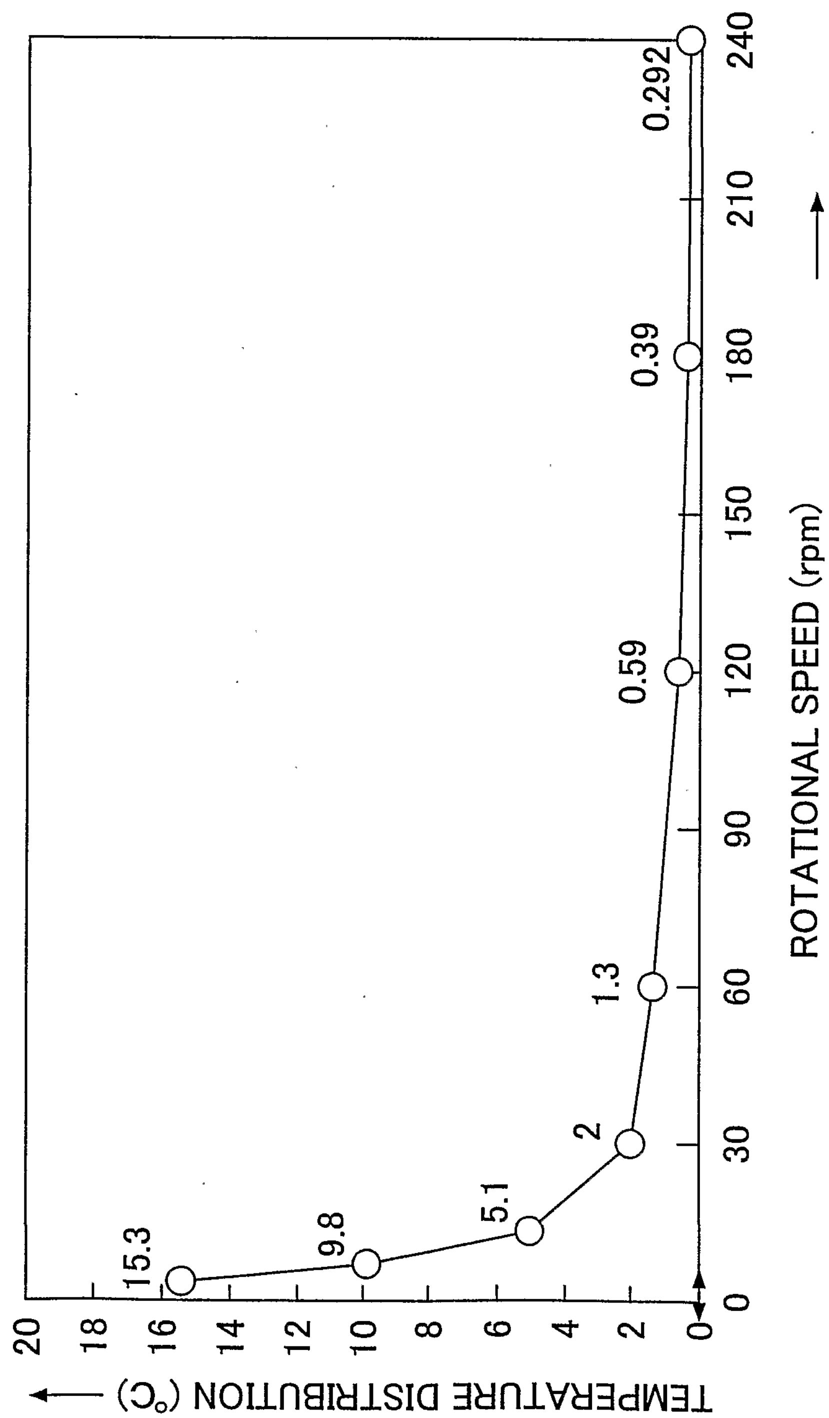
POWER SOURCE
HORIZONTAL CONTROL PART

FIG.11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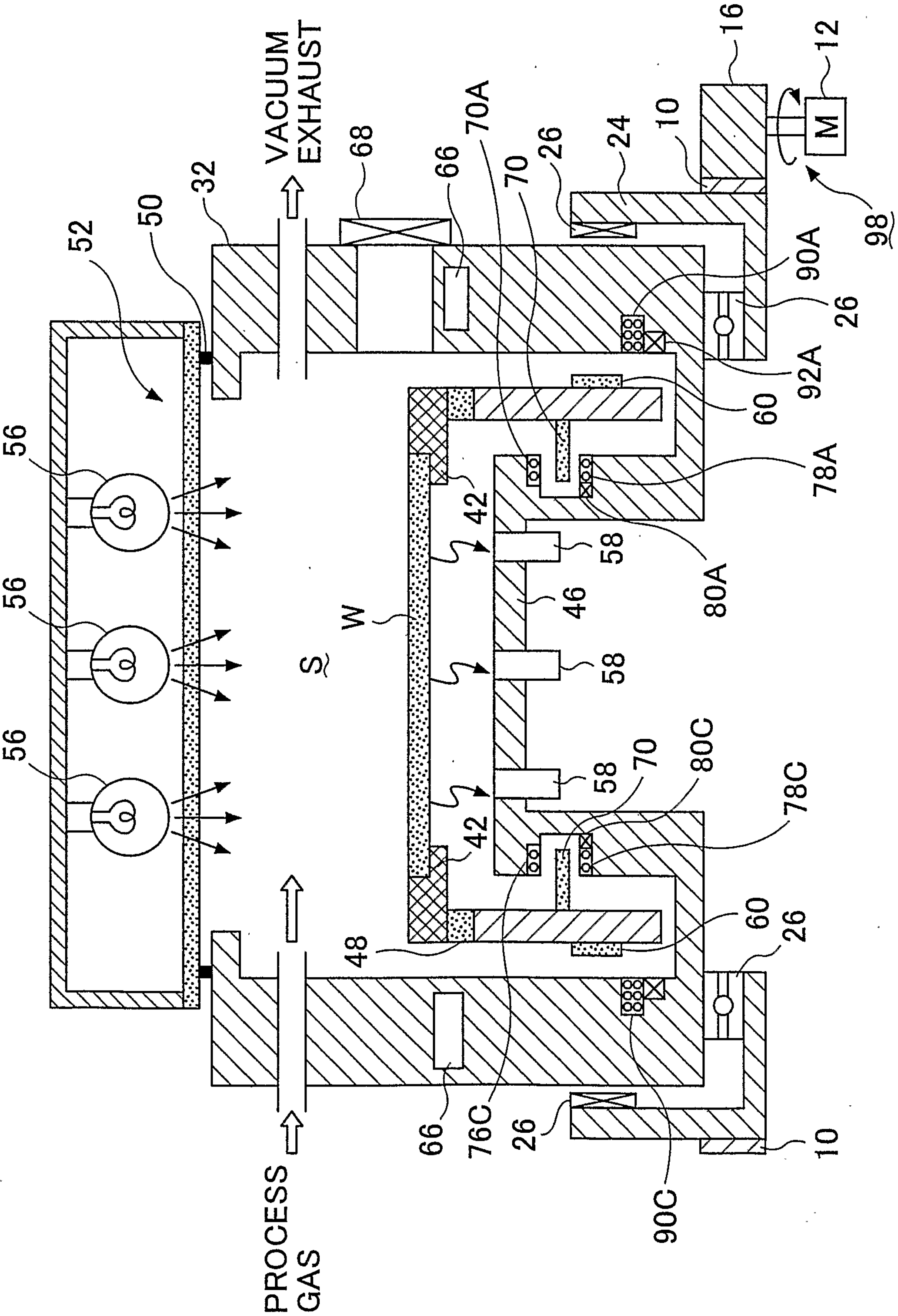
5.1
2
1.3
0.59
0.39
0.292

FIG.12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76C
78A
78C
80A
80C
90A
90C
92A
98

INTERNATIONAL SEARCH REPORT

In[illegible]onal Application No
PCT/JP 01/08068

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L21/00

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)
IPC 7 H01L

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

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

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 871 588 A (MOSLEHI ET AL.) 16 February 1999 (1999-02-16) the whole document	1
Y		2

X	US 5 916 366 A (UEYAMA ET AL.) 29 June 1999 (1999-06-29) column 7, line 40-60	1
A		2,3

Y	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 05, 30 May 1997 (1997-05-30) -& JP 09 017846 A (NIKON CORP), 17 January 1997 (1997-01-17) abstract	2,3
A		1

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 February 2002	27/02/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Oberle, T

Form PCT/ISA/210 (second sheet) (July 1992)

In ›nal Application No
PCT/JP 01/08068

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 821 404 A (APPLIED MATERIALS) 28 January 1998 (1998-01-28) column 3, line 31-42	3
A		1,2
A	US 5 818 137 A (NICHOLS ET AL.) 6 October 1998 (1998-10-06) abstract column 7, line 33-55	1-3,5,6
P,X	EP 1 071 118 A (EBARA CORPORATION) 24 January 2001 (2001-01-24) the whole document	1,2

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte nal Application No
PCT/JP 01/08068

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US 5916366	A	29-06-1999	JP	10112453	A	28-04-1998
			JP	10223735	A	21-08-1998
			JP	10223591	A	21-08-1998
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			EP	0821404	A2	28-01-1998
			JP	10092916	A	10-04-1998
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			JP	11513880	T	24-11-1999
			WO	9715978	A1	01-05-1997
			US	6049148	A	11-04-2000
EP 1071118	A	24-01-2001	JP	2001093967	A	06-04-2001
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