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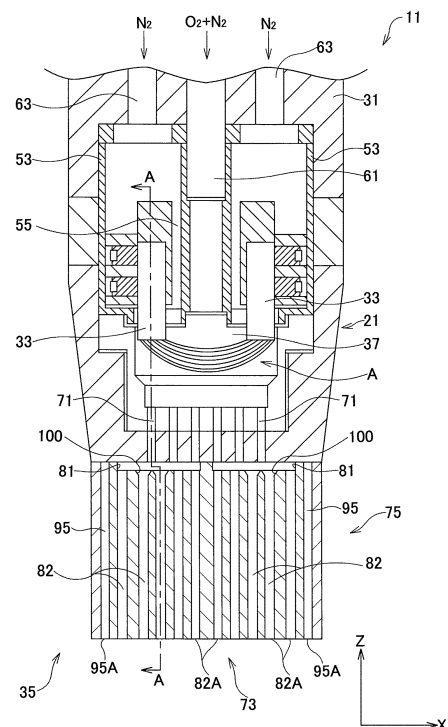
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(54) **PLASMA GENERATION DEVICE AND PLASMA PROCESSING METHOD**

(57) A plasma generation device includes a device main body in which a reaction chamber for plasmatizing a processing gas is formed, at least one discharge path connected to the reaction chamber, a diffusion chamber connected to the at least one discharge path, and multiple ejection paths that are connected to the diffusion chamber and eject a plasma gas plasmatized in the reaction chamber having a taper surface formed in an opening of at least one ejection path among the multiple ejection paths to the diffusion chamber.

[Fig. 3]



Description

Technical Field

[0001] The present disclosure relates to a plasma generation device or the like that ejects plasma gas from an ejection path.

Background Art

[0002] Examples of a plasma generation device include a structure in which a processing gas is plasmatized in a reaction chamber, and a plasma gas that is plasmatized is ejected from an ejection path formed in a nozzle. An example of such plasma generation devices is described in the following Patent Literature.

Patent Literature

[0003] Patent Literature 1: JP-A-2001-068298

Summary of the Invention

Technical Problem

[0004] An object of the present specification is to improve the usefulness of a plasma generation device having a structure in which a plasma gas is ejected from an ejection path.

Solution to Problem

[0005] In order to solve the above-mentioned problems, the present specification discloses a plasma generation device including: a device main body in which a reaction chamber for plasmatizing a processing gas is formed; at least one discharge path connected to the reaction chamber; a diffusion chamber connected to the at least one discharge path; and multiple ejection paths that are connected to the diffusion chamber and configured to eject a plasma gas plasmatized in the reaction chamber having a taper surface formed in an opening of at least one ejection path among the multiple ejection paths to the diffusion chamber.

[0006] In addition, the present specification discloses a plasma generation device including: a device main body in which a reaction chamber for plasmatizing a processing gas is formed; and a nozzle attached to the device main body and configured to eject a plasma gas plasmatized in the reaction chamber, in which the device main body includes a discharge path for discharging the plasma gas plasmatized in the reaction chamber to an outside of the device main body, and the nozzle includes a diffusion chamber formed to cover an opening of the discharge path to an outer wall surface of the device main body, and multiple ejection paths for ejecting the plasma gas through the diffusion chamber, configured to eject the plasma gas plasmatized in the reaction chamber hav-

ing a taper surface formed in an opening of at least one ejection path among the multiple ejection paths to the diffusion chamber.

[0007] In addition, the present specification discloses a plasma processing method in plasma generation device, wherein the plasma generation device includes a device main body in which a reaction chamber for plasmatizing a processing gas is formed; and a nozzle attached to the device main body and configured to eject a plasma gas plasmatized in the reaction chamber, the device main body includes a discharge path for discharging the plasma gas plasmatized in the reaction chamber to an outside of the device main body, and the nozzle includes a diffusion chamber formed to cover an opening of the discharge path to an outer wall surface of the device main body, and multiple ejection paths for ejecting the plasma gas through the diffusion chamber, configured to eject the plasma gas plasmatized in the reaction chamber having a taper surface formed in an opening of at least one ejection path among the multiple ejection paths to the diffusion chamber, and the plasma processing method includes: irradiating a treatment target object with the plasma gas ejected from the multiple ejection paths.

Advantageous Effect of the Invention

[0008] According to the present disclosure, since the taper surface is formed in the opening of the ejection path to the diffusion chamber, for example, even in a case where a foreign matter adheres to the opening, the opening is unlikely to be blocked by the foreign matter. Therefore, it is possible to secure the ejection of the plasma gas from the ejection path, and it is possible to improve the usefulness of the plasma generation device having a structure in which the plasma gas is ejected from the ejection path.

Brief Description of Drawings

[0009]

Fig. 1 is a view illustrating a plasma device.

Fig. 2 is a perspective view illustrating a plasma head.

Fig. 3 is a sectional view of the plasma head cut in an X direction and a Z direction at positions of an electrode and a body-side plasma path.

Fig. 4 is a sectional view in line AA of Fig. 3.

Fig. 5 is an enlarged sectional view of Fig. 3.

Fig. 6 is a sectional view of a plasma head to which a nozzle different from the nozzle in Fig. 3 is attached.

Description of Embodiments

[0010] Hereinafter, as exemplary embodiments of the present invention, examples of the present invention will be described in detail with reference to the drawings.

[0011] As illustrated in Fig. 1, plasma device 10 includes plasma head 11, robot 13, and control box 15. Plasma head 11 is attached to robot 13. Robot 13 is, for example, a serial link-type robot (may also be referred to as a multi-joint-type robot). Plasma head 11 is configured to be capable of irradiating plasma gas in a state where plasma head 11 is held at a tip of robot 13. Plasma head 11 is configured to be three-dimensionally movable in accordance with the driving of robot 13.

[0012] Control box 15 is configured mainly by a computer, and collectively controls plasma device 10. Control box 15 has power source section 15A for supplying electric power to plasma head 11 and gas supply section 15B for supplying gas to plasma head 11. Power source section 15A is connected to plasma head 11 via a power cable (not illustrated). Power source section 15A changes a voltage to be applied to electrode 33 (see Figs. 3 and 4) of plasma head 11 based on the control of control box 15.

[0013] Gas supply section 15B is connected to plasma head 11 via multiple (four in the present embodiment) gas tubes 19. Gas supply section 15B supplies a reaction gas, a carrier gas, and a heat gas, which will be described later, to plasma head 11 based on the control of control box 15. Control box 15 controls gas supply section 15B, and controls an amount or the like of the gas supplied from gas supply section 15B to plasma head 11. Therefore, robot 13 operates based on the control of control box 15 to irradiate treatment target object W placed on table 17 with the plasma gas from plasma head 11.

[0014] Control box 15 includes operation section 15C having a touch panel and various switches. Control box 15 displays various setting screens, operation states (for example, a gas supply state, and the like), and the like on the touch panel of operation section 15C. In addition, control box 15 receives various types of information by operation inputs to operation section 15C.

[0015] As illustrated in Fig. 2, plasma head 11 includes plasma generation section 21, heat gas supply section 23, and the like. Plasma generation section 21 plasma-tizes the processing gas supplied from gas supply section 15B (see Fig. 1) of control box 15 to generate plasma gas. Heat gas supply section 23 heats the gas supplied from gas supply section 15B to generate heat gas. Plasma head 11 of the present embodiment ejects the plasma gas generated in plasma generation section 21 to treatment target object W illustrated in Fig. 1 together with the heat gas generated by heat gas supply section 23. The processing gas is supplied to plasma head 11 from an upstream to a downstream in a direction of an arrow illustrated in Fig. 2. Plasma head 11 may have a configuration in which heat gas supply section 23 is not provided. That is, the plasma device of the present disclosure may have a configuration in which the heat gas is not used.

[0016] As illustrated in Fig. 3 and Fig. 4, plasma generation section 21 includes head main body section 31, a pair of electrodes 33, plasma irradiation section 35, and

the like. Fig. 3 is a sectional view cut along with positions of the pair of electrodes 33 and multiple body-side plasma paths 71 described later, and Fig. 4 is a sectional view in line AA of Fig. 3. Head main body section 31 is molded of ceramic having a high heat resistance, and reaction chamber 37 for generating plasma gas is formed in an inside of head main body section 31. Each of the pair of electrodes 33 has, for example, a cylindrical shape, and is fixed in a state where a tip portion thereof protrudes into reaction chamber 37. In the following description, the pair of electrodes 33 may be simply referred to as electrode 33. In addition, a direction in which the pair of electrodes 33 are arranged is referred to as an X direction, a direction in which plasma generation section 21 and heat gas supply section 23 are arranged is referred to as a Y direction, and an axial direction of cylindrical electrode 33 is referred to as a Z direction. In the present embodiment, the X direction, the Y direction, and the Z direction are directions orthogonal to each other.

[0017] Heat gas supply section 23 includes gas pipe 41, heater 43, connection section 45, and the like. Gas pipe 41 and heater 43 are attached to an outer peripheral surface of head main body section 31 and are covered with cover 47 illustrated in Fig. 4. Gas pipe 41 is connected to gas supply section 15B of control box 15 via gas tube 19 (see Fig. 1). Gas (for example, air) is supplied to gas pipe 41 from gas supply section 15B. Heater 43 is attached to an intermediate portion of gas pipe 41. Heater 43 warms the gas flowing through gas pipe 41 to generate heat gas.

[0018] As illustrated in Fig. 4, connection section 45 connects gas pipe 41 to plasma irradiation section 35. In a state where plasma irradiation section 35 is attached to head main body section 31, a first end portion of connection section 45 is connected to gas pipe 41, and a second end portion thereof is connected to heat gas flow path 51 formed in plasma irradiation section 35. Heat gas is supplied to heat gas flow path 51 via gas pipe 41.

[0019] As illustrated in Fig. 4, a part of an outer periphery portion of electrode 33 is covered with electrode cover 53 made of an insulator such as ceramic. Electrode cover 53 has a substantially hollow tubular shape, and openings are formed at both end portions in a longitudinal direction. A gap between an inner peripheral surface of electrode cover 53 and an outer peripheral surface of electrode 33 functions as gas flow path 55. An opening of electrode cover 53 on a downstream is connected to reaction chamber 37. A lower end of electrode 33 protrudes from the opening of electrode cover 53 on the downstream.

[0020] Reaction gas flow path 61 and a pair of carrier gas flow paths 63 are formed in the inside of head main body section 31. Reaction gas flow path 61 is provided substantially at a center portion of head main body section 31, is connected to gas supply section 15B via gas tube 19 (see Fig. 1), and allows the reaction gas supplied from gas supply section 15B to flow into reaction chamber 37. The pair of carrier gas flow paths 63 are disposed at

positions where reaction gas flow path 61 is interposed therebetween in the X direction. Each of the pair of carrier gas flow paths 63 is connected to gas supply section 15B via gas tube 19 (see Fig. 1), so that the carrier gas is supplied from gas supply section 15B. Carrier gas flow path 63 allows the carrier gas to flow into reaction chamber 37 via gas flow path 55.

[0021] As the reaction gas (seed gas), oxygen (O₂) can be employed. Gas supply section 15B allows, for example, a mixed gas (for example, dry air (Air)) of oxygen and nitrogen (N₂) to flow into between electrodes 33 of reaction chamber 37 via reaction gas flow path 61. Hereinafter, this mixed gas may be referred to as the reaction gas for convenience, and oxygen may be referred to as the seed gas. As the carrier gas, nitrogen can be employed. Gas supply section 15B allows the carrier gas to flow from each of gas flow paths 55 so as to surround each of the pair of electrodes 33.

[0022] An AC voltage is applied to the pair of electrodes 33 from power source section 15A of control box 15. By applying the voltage, for example, as illustrated in Fig. 4, pseudo arc A is generated between lower ends of the pair of electrodes 33 in reaction chamber 37. When the reaction gas passes through pseudo arc A, the reaction gas is plasmatized. Accordingly, the pair of electrodes 33 generate discharge of pseudo arc A, plasmatize the reaction gas, and generate the plasma gas.

[0023] In addition, multiple (six in the present embodiment) body-side plasma paths 71 arranged at intervals in the X direction and extending in the Z direction are formed in a portion of head main body section 31 toward the downstream of reaction chamber 37. An upstream end portion of each of multiple body-side plasma paths 71 is open to reaction chamber 37, and a downstream end portion of each of multiple body-side plasma paths 71 is open to a lower end surface of head main body section 31.

[0024] Plasma irradiation section 35 includes nozzle 73, nozzle cover 75, and the like. Nozzle 73 is generally T-shaped in side view from the X direction, and includes nozzle main body 77 and nozzle tip 79. Nozzle 73 is an integral object of nozzle main body 77 and nozzle tip 79, and is molded of ceramic having a high heat resistance. Nozzle main body 77 has a generally flange shape and is fixed to a lower surface of head main body section 31 by bolt 80. Accordingly, nozzle 73 is detachable from head main body section 31 so as to be changed to a nozzle of a different type. Nozzle tip 79 has a shape extending downward from a lower surface of nozzle main body 77.

[0025] A pair of grooves 81 that are open to an upper end surface of nozzle main body 77 is formed in nozzle 73. The pair of grooves 81 are formed in one row so as to extend in the X direction, and in a state where nozzle 73 is attached to head main body section 31, each of the pair of grooves 81 communicates with three body-side plasma paths 71 that are open to the lower end surface of head main body section 31. That is, the openings at

the lower ends of three body-side plasma paths 71 among six body-side plasma paths 71 communicate with one of the pair of grooves 81, and the openings at the lower ends of remaining three body-side plasma paths 71 communicate with the other of the pair of grooves 81.

[0026] In addition, nozzle 73 is formed with multiple (ten in the present embodiment) nozzle-side plasma paths 82 that penetrate nozzle main body 77 and the nozzle tip 79 in the vertical direction, that is, the Z direction, and multiple nozzle-side plasma paths 82 are arranged at intervals in the X direction. The upper ends of five nozzle-side plasma paths 82 among ten nozzle-side plasma paths 82 are open to the bottom surface of one of the pair of grooves 81, and the upper ends of remaining five nozzle-side plasma paths 82 are open to the bottom surface of the other of the pair of grooves 81.

[0027] Nozzle cover 75 is generally T-shaped in side view from the X direction, and includes cover main body 85 and cover tip 87. Nozzle cover 75 is an integral object of cover main body 85 and cover tip 87, and is molded of a ceramic having a high heat resistance. Cover main body 85 is generally plate-shaped in plate thickness, and recess 89 having a shape open to an upper surface and recessed in the Z direction is formed in cover main body 85. Cover main body 85 is fixed to the lower surface of head main body section 31 by bolts 90 so that nozzle main body 77 of nozzle 73 is housed in recess 89. Accordingly, nozzle cover 75 is detachable from head main body section 31, and is detached from head main body section 31, for example, when nozzle 73 is exchanged. In addition, heat gas flow path 51 is formed in cover main body 85 so as to extend in the Y direction, a first end portion of heat gas flow path 51 is open to recess 89, and a second end portion of heat gas flow path 51 is open to a side surface of cover main body 85. An end portion of heat gas flow path 51 that is open to the side surface of cover main body 85 is connected to connection section 45 of heat gas supply section 23.

[0028] Cover tip 87 extends downward from a lower surface of cover main body 85. One through-hole 93 penetrating in the Z direction is formed in cover tip 87, and an upper end portion of through-hole 93 communicates with recess 89 of cover main body 85. Nozzle tip 79 of nozzle 73 is inserted into through-hole 93. Therefore, nozzle 73 is entirely covered with nozzle cover 75. The lower end of nozzle tip 79 of nozzle 73 and the lower end of cover tip 87 of nozzle cover 75 are located at the same height.

[0029] In a state where nozzle 73 is covered with nozzle cover 75, nozzle main body 77 of nozzle 73 is located in an inside of recess 89 of nozzle cover 75, and nozzle tip 79 of nozzle 73 is located in through-hole 93 of nozzle cover 75. In such a state, a gap exists between recess 89 and nozzle main body 77, and between through-hole 93 and nozzle tip 79, and the gap functions as heat gas output path 95. The heat gas is supplied to heat gas output path 95 via heat gas flow path 51.

[0030] According to such a structure, the plasma gas

generated in reaction chamber 37 is ejected to the inside of groove 81 through body-side plasma path 71 together with the carrier gas. The plasma gas diffuses in the inside of groove 81, passes through nozzle-side plasma path 82, and is ejected from opening 82A at the lower end of nozzle-side plasma path 82. The heat gas supplied from gas pipe 41 to heat gas flow path 51 flows through heat gas output path 95. The heat gas functions as a shielding gas for protecting the plasma gas. The heat gas flows through heat gas output path 95, and is ejected from opening 95A at the lower end of heat gas output path 95 along the ejection direction of the plasma gas. At this time, the heat gas is ejected so as to surround the periphery of the plasma gas ejected from opening 82A of nozzle-side plasma path 82. In this manner, by ejecting the heated heat gas to the periphery of the plasma gas, the efficiency (wettability or the like) of the plasma gas can be enhanced.

[0031] In this manner, in plasma head 11, discharge is generated in reaction chamber 37 and plasma is generated, whereby the plasma gas is ejected from the tip of nozzle 73, and a plasma process is performed on treatment target object W. However, due to the discharge in reaction chamber 37, the inner wall surface of head main body section 31 and the electrode 33 that define reaction chamber 37 are carbonized, so that foreign matter is generated. As described above, when the foreign matter is generated in reaction chamber 37, the foreign matter is discharged to groove 81 through body-side plasma path 71. At this time, the foreign matter adheres to and deposits in the opening of nozzle-side plasma path 82 that is open to groove 81 in the inside of groove 81. The foreign matter deposited in the opening of nozzle-side plasma path 82 may block the opening of nozzle-side plasma path 82, and in such a case, an internal pressure of reaction chamber 37 rises, so that an appropriate discharge cannot be secured. In order to prevent such a situation, nozzle 73 may be detached from head main body section 31 to clean the opening of nozzle-side plasma path 82 to the inside of groove 81, but it is necessary to stop the operation of plasma head 11 each time cleaning is performed, so that the productivity is deteriorated.

[0032] Accordingly, in plasma head 11, as illustrated in Fig. 5, taper surface 100 is formed in an opening of nozzle-side plasma path 82 to the inside of groove 81. That is, the opening of nozzle-side plasma path 82 to the inside of groove 81 is chamfered, so that an inner diameter of the end portion of nozzle-side plasma path 82 on the opening side to the inside of groove 81 is gradually increased. An inner diameter of a location of nozzle-side plasma path 82 where taper surface 100 is not formed is made uniform. As described above, since taper surface 100 is formed in the opening of nozzle-side plasma path 82 to groove 81, even in a case where the foreign matter adheres to the opening of nozzle-side plasma path 82 and is deposited, the opening is unlikely to be blocked. Therefore, it is possible to reduce the frequency of cleaning the opening of nozzle-side plasma path 82, so that it

is possible to suppress deterioration in productivity.

[0033] In plasma head 11, taper surface 100 is not formed in all of multiple nozzle-side plasma paths 82, and taper surface 100 is formed only in a part of nozzle-side plasma paths 82 among multiple nozzle-side plasma paths 82. Specifically, the plasma gas generated in reaction chamber 37 flows in the inside of groove 81 from body-side plasma path 71, and diffuses in the inside of groove 81. The plasma gas flows from the inside of groove 81 to multiple nozzle-side plasma paths 82. At this time, since the flows of the plasma gases are different when the plasma gas is diffused in the inside of groove 81 and when the plasma gas flows from groove 81 to each of multiple nozzle-side plasma paths 82, it is understood that the foreign matter likely stays at a location where a vortex is generated by the flow of the plasma gas.

[0034] Accordingly, at the time of manufacturing nozzle 73, the flow of the plasma gas in plasma head 11 is simulated by computer analysis based on the dimensions, the number, and the arrangement of body-side plasma path 71, groove 81, nozzle-side plasma path 82, the flow rate of the plasma gas, and the like. At this time, in the flow of the simulated plasma gas, vortices are generated in the vicinity of the second and third openings from both ends of ten nozzle-side plasma paths 82 in the X direction. Therefore, taper surfaces 100 are formed in the openings of four nozzle-side plasma paths 82 to groove 81 located at the second and third positions from the both ends of ten nozzle-side plasma paths 82 in the X direction. That is, taper surfaces 100 are formed in the openings of four nozzle-side plasma paths 82 to groove 81 located at the third and fourth positions from the center symmetrically about the center of ten nozzle-side plasma paths 82 in the arrangement direction.

[0035] As described above, by forming taper surface 100 in the opening of a part of nozzle-side plasma path 82 among multiple nozzle-side plasma paths 82, the opening of nozzle-side plasma path 82 where the foreign matter is likely to deposit is increased. Therefore, even in a case where the foreign matter is deposited in the opening to groove 81 of nozzle-side plasma path 82 over time, a difference in the flow rate of the plasma gas between nozzle-side plasma path 82 having the opening where the foreign matter is likely to deposit and nozzle-side plasma path 82 having the opening where the foreign matter is unlikely to deposit is reduced, so that it is possible to secure an appropriate plasma process.

[0036] In plasma head 11, as described above, nozzle 73 can be exchanged, and for example, nozzle 110 illustrated in Fig. 6 can be attached to head main body section 31 instead of nozzle 73. A pair of grooves 112 and six nozzle-side plasma paths 114 are formed in nozzle 110. Three nozzle-side plasma paths 114 of six nozzle-side plasma paths 114 are open to one of the pair of grooves 112, and remaining three nozzle-side plasma paths 114 are open to the other of the pair of grooves 112.

[0037] In addition, even at the time of manufacturing nozzle 110, the flow of the plasma gas in plasma head

11 is simulated by computer analysis based on the dimensions, the number, and the arrangement of body-side plasma path 71, groove 112, nozzle-side plasma path 114, the flow rate of the plasma gas, and the like. At this time, in the flow of the simulated plasma gas, vortices are generated in the vicinity of the second openings from both ends of six nozzle-side plasma paths 114 in the X direction. Therefore, taper surfaces 120 are formed in the openings of two nozzle-side plasma paths 114 to groove 112 located at the second positions from the both ends of six nozzle-side plasma paths 114 in the X direction. That is, taper surfaces 120 are formed in the openings of two nozzle-side plasma paths 114 to groove 112 located at the second positions from the center symmetrically about the center of six nozzle-side plasma paths 114 in the arrangement direction.

[0038] As described above, taper surfaces 100 and 120 are formed in the openings of a part of nozzle-side plasma paths 82 and 114 among multiple nozzle-side plasma paths 82 and 114 for each type of nozzles 73 and 110. Therefore, each of multiple types of nozzles 73 and 110 is configured to prevent deterioration in productivity due to deposition of the foreign matter, secure an appropriate plasma process, and the like.

[0039] Plasma device 10 is an example of a plasma generation device. Head main body section 31 is an example of a device main body. Reaction chamber 37 is an example of a reaction chamber. Nozzle 73 is an example of a nozzle. Body-side plasma path 71 is an example of a discharge path. Groove 81 is an example of a diffusion chamber. Nozzle-side plasma path 82 is an example of an ejection path. Taper surface 100 is an example of a taper surface. Nozzle 110 is an example of a nozzle. Groove 112 is an example of a diffusion chamber. Nozzle-side plasma path 114 is an example of an ejection path. Taper surface 120 is an example of a taper surface.

[0040] The present embodiment, which has been described heretofore, provides the following effects.

[0041] In plasma head 11, taper surfaces 100 and 120 are formed in the openings of one or more of nozzle-side plasma paths 82 and 114 among multiple nozzle-side plasma paths 82 and 114. Therefore, it is possible to reduce the frequency of cleaning the opening of nozzle-side plasma path 82, so that it is possible to suppress deterioration in productivity.

[0042] In addition, in plasma head 11, taper surfaces 100 and 120 are not formed in all of multiple nozzle-side plasma paths 82 and 114, and taper surfaces 100 and 120 are formed only in a part of nozzle-side plasma paths 82 and 114 among multiple nozzle-side plasma paths 82 and 114. Therefore, it is possible to reduce the difference in the flow rate of the plasma gas between nozzle-side plasma paths 82 and 114 having the openings where the foreign matter is likely to deposit and nozzle-side plasma paths 82 and 114 having the openings where the foreign matter is unlikely to deposit, so that it is possible to secure an appropriate plasma process.

[0043] In addition, in plasma head 11, taper surfaces 100 and 120 are formed so as to be located symmetrically about the center of multiple nozzle-side plasma paths 82 and 114 in the arrangement direction. Therefore, it is possible to appropriately suppress nozzle blocking in all of multiple nozzle-side plasma paths 82 and 114.

[0044] In addition, in plasma head 11, nozzles 73 and 110 are attached to head main body section 31 so as to be immovable relative to each other. Therefore, the plasma gas can be stably ejected to treatment target object W. More specifically, in plasma head 11, as described above, the heat gas is ejected so as to surround the periphery of the ejected plasma gas. Therefore, nozzles 73 and 110 are attached to head main body section 31 so as to be immovable relative to each other, so that the plasma gas can be ejected in a state of being appropriately covered with the heat gas.

[0045] The present disclosure is not limited to the above embodiments, and can be practiced in various forms where various changes and improvements are made based on the knowledge of those skilled in the art. Specifically, for example, in plasma head 11, taper surfaces 100 and 120 are formed only in a part of multiple nozzle-side plasma paths 82 and 114, but taper surfaces 100 and 120 may be formed in all of multiple nozzle-side plasma paths 82 and 114.

[0046] In the above embodiments, groove 81 is employed as the diffusion chamber, but as long as it communicates with body-side plasma path 71, various things such as a recess, a path, and a defined space can be employed as the diffusion chamber.

[0047] In the above embodiments, body-side plasma path 71 is formed in head main body section 31, groove 81 and nozzle-side plasma path 82 are formed in nozzle 73, but body-side plasma path 71 and groove 81 may be formed in head main body section 31, and nozzle-side plasma path 82 may be formed in nozzle 73.

[0048] In the above embodiments, head main body section 31 and nozzle 73 are detachable from each other, but head main body section 31 and nozzle 73 may be integrally formed. That is, reaction chamber 37, body-side plasma path 71, groove 81, and nozzle-side plasma path 82 may be formed in an inside of an integral device main body.

[0049] In plasma head 11, the flow of the plasma gas is simulated, and the nozzle-side plasma path in which the taper surface is formed is determined based on the simulated flow of the plasma gas, but the nozzle-side plasma path in which the taper surface is formed may be determined based on another method. For example, based on empirical rules, the nozzle-side plasma path at a position where the foreign matter is likely to deposit may be determined as the nozzle-side plasma path where the taper surface is formed.

Reference Signs List

[0050] 10: plasma device (plasma generation device),

31: head main body section (device main body), 37: reaction chamber, 71: body-side plasma path (discharge path), 73: nozzle, 81: groove (diffusion chamber), 82: nozzle-side plasma path (ejection path), 100: taper surface, 110: nozzle, 112: groove (diffusion chamber), 114: nozzle-side plasma path (ejection path), 120: taper surface

Claims

1. A plasma generation device comprising:

a device main body in which a reaction chamber for plasmatizing a processing gas is formed;
at least one discharge path connected to the reaction chamber;
a diffusion chamber connected to the at least one discharge path; and
multiple ejection paths that are connected to the diffusion chamber and configured to eject a plasma gas plasmatized in the reaction chamber having a taper surface formed in an opening of at least one ejection path among the multiple ejection paths to the diffusion chamber.

2. A plasma generation device comprising:

a device main body in which a reaction chamber for plasmatizing a processing gas is formed;
and
a nozzle attached to the device main body and configured to eject a plasma gas plasmatized in the reaction chamber,
wherein the device main body includes a discharge path for discharging the plasma gas plasmatized in the reaction chamber to an outside of the device main body, and
the nozzle includes
a diffusion chamber formed to cover an opening of the discharge path to an outer wall surface of the device main body, and
multiple ejection paths for ejecting the plasma gas through the diffusion chamber, configured to eject the plasma gas plasmatized in the reaction chamber having a taper surface formed in an opening of at least one ejection path among the multiple ejection paths to the diffusion chamber.

3. The plasma generation device according to claim 2, wherein the taper surface is not formed in the openings of all of the ejection paths of the multiple ejection paths to the diffusion chamber but the taper surface is formed in the opening of a part of the ejection paths among the multiple ejection paths to the diffusion chamber.

4. The plasma generation device according to claim 3,

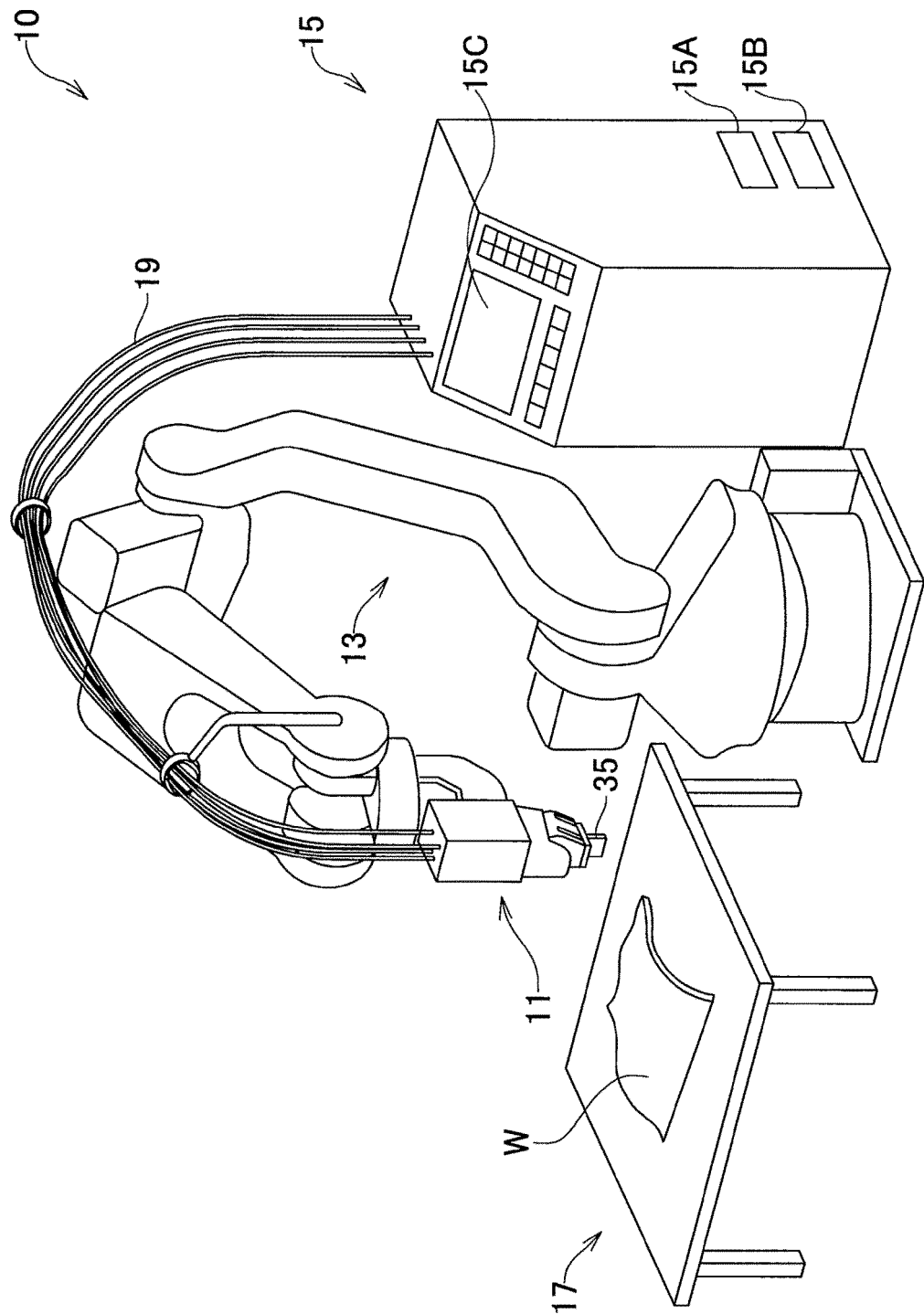
wherein the multiple ejection paths are formed in the nozzle in one row, and
the taper surface is formed symmetrically about a center of the one row of the multiple ejection paths in an arrangement direction.

5. The plasma generation device according to any one of claims 2 to 4, wherein the nozzle is attached to be immovable relative to the device main body.

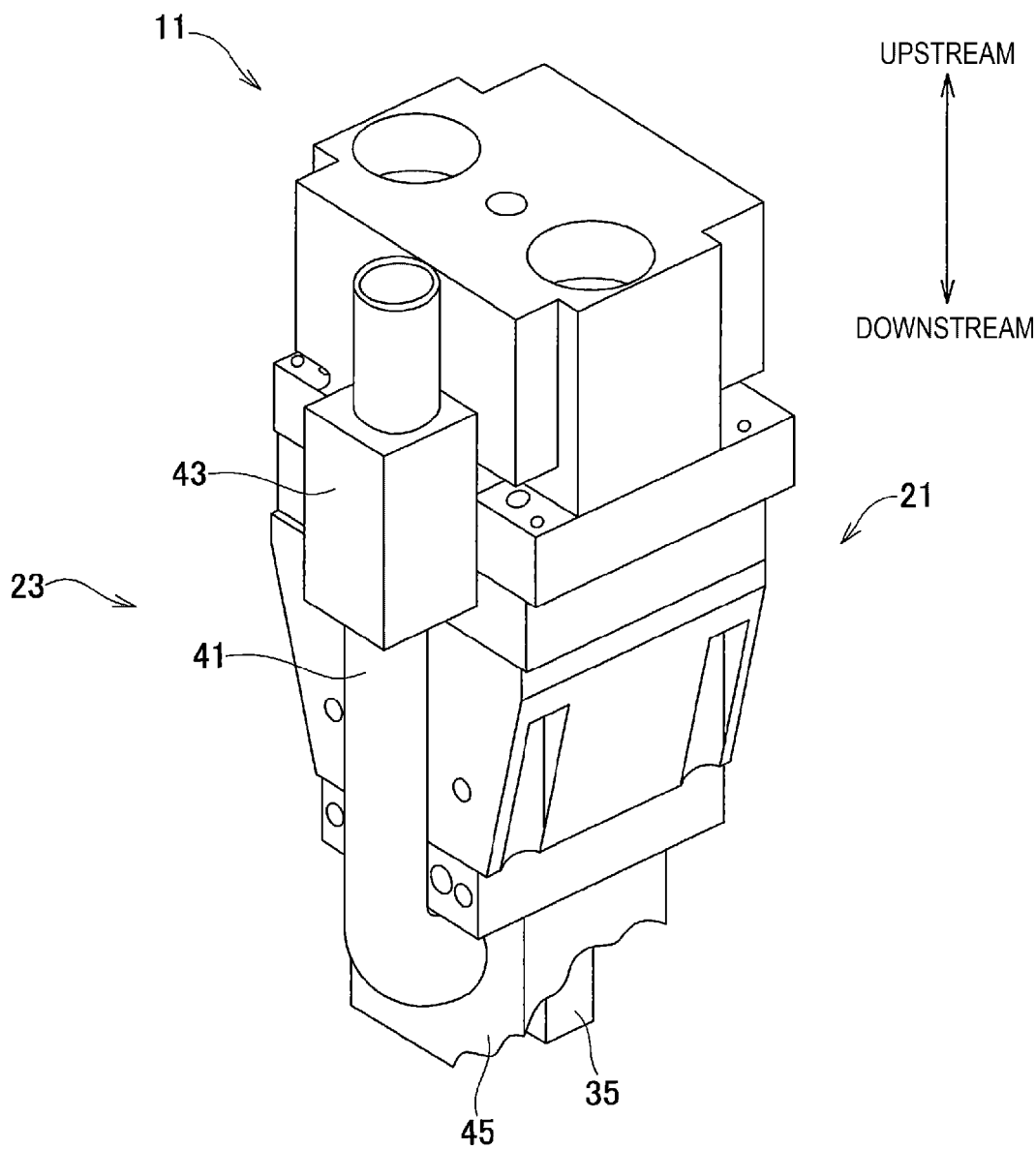
6. A plasma processing method in plasma generation device, wherein the plasma generation device includes

a device main body in which a reaction chamber for plasmatizing a processing gas is formed,
and
a nozzle attached to the device main body and configured to eject a plasma gas plasmatized in the reaction chamber,
the device main body includes a discharge path for discharging the plasma gas plasmatized in the reaction chamber to an outside of the device main body, and
the nozzle includes
a diffusion chamber formed to cover an opening of the discharge path to an outer wall surface of the device main body, and
multiple ejection paths for ejecting the plasma gas through the diffusion chamber, configured to eject the plasma gas plasmatized in the reaction chamber having a taper surface formed in an opening of at least one ejection path among the multiple ejection paths to the diffusion chamber, and
the plasma processing method comprises:
irradiating a treatment target object with the plasma gas ejected from the multiple ejection paths.

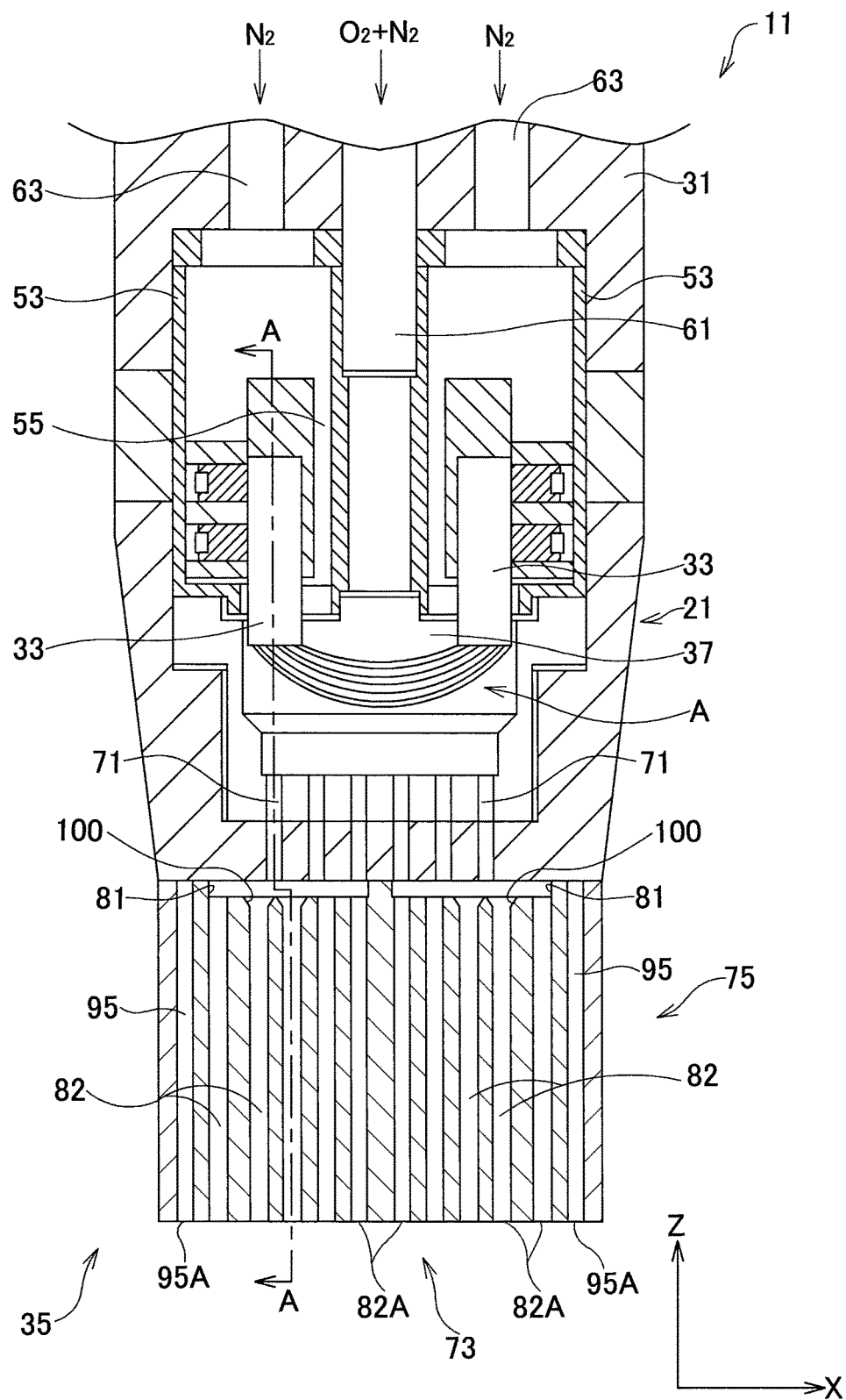
[Fig. 1]



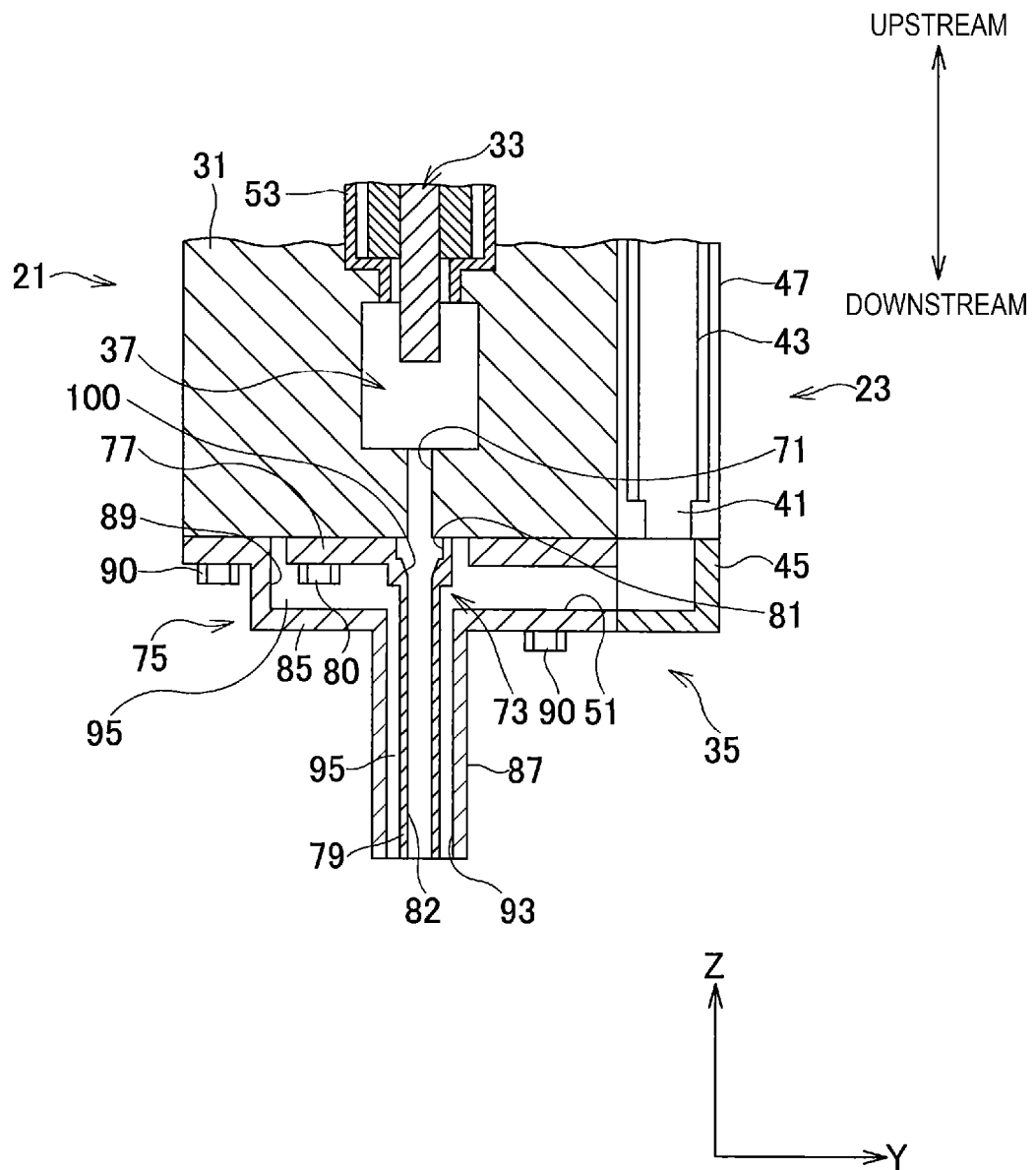
[Fig. 2]



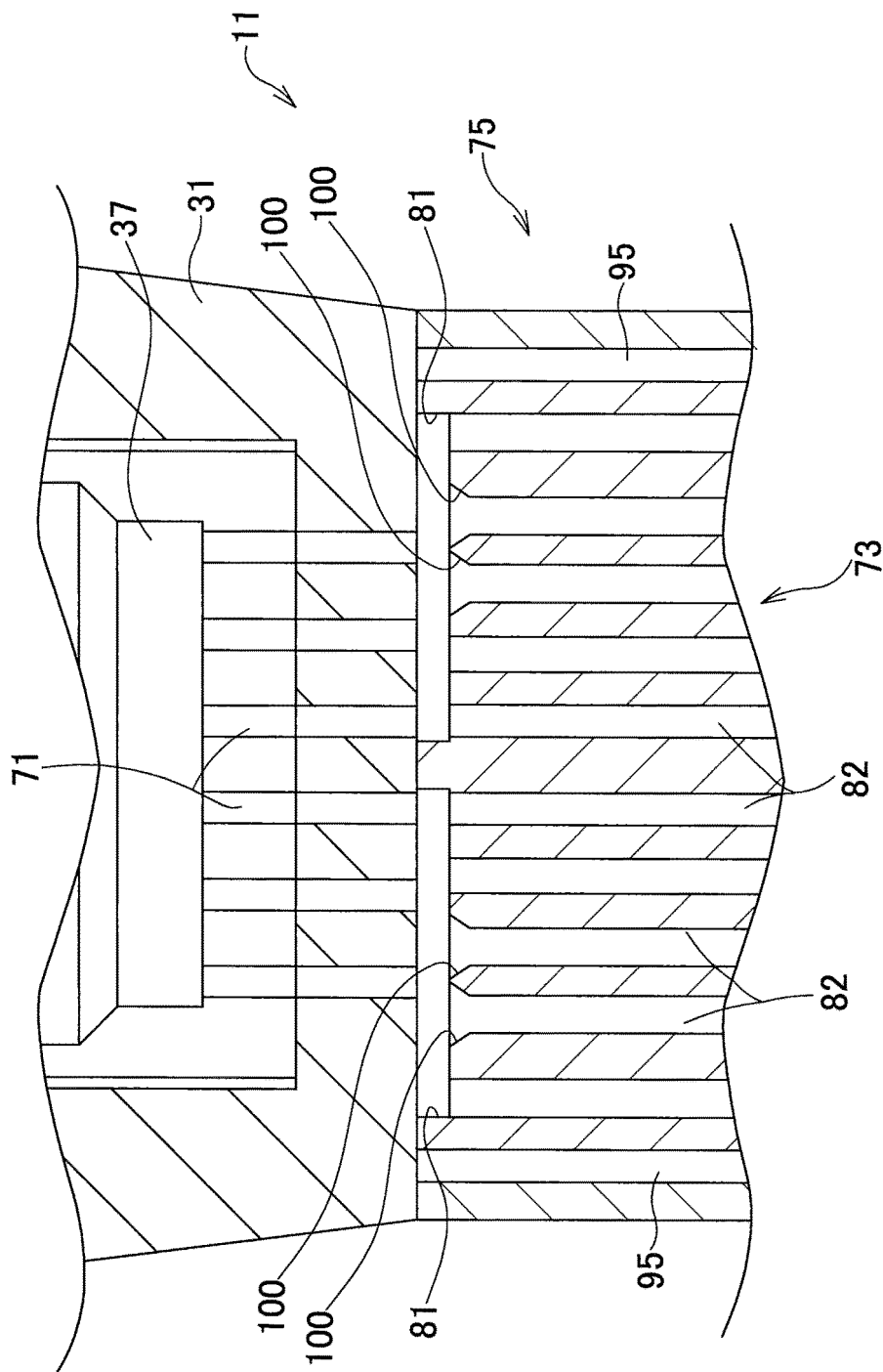
[Fig. 3]



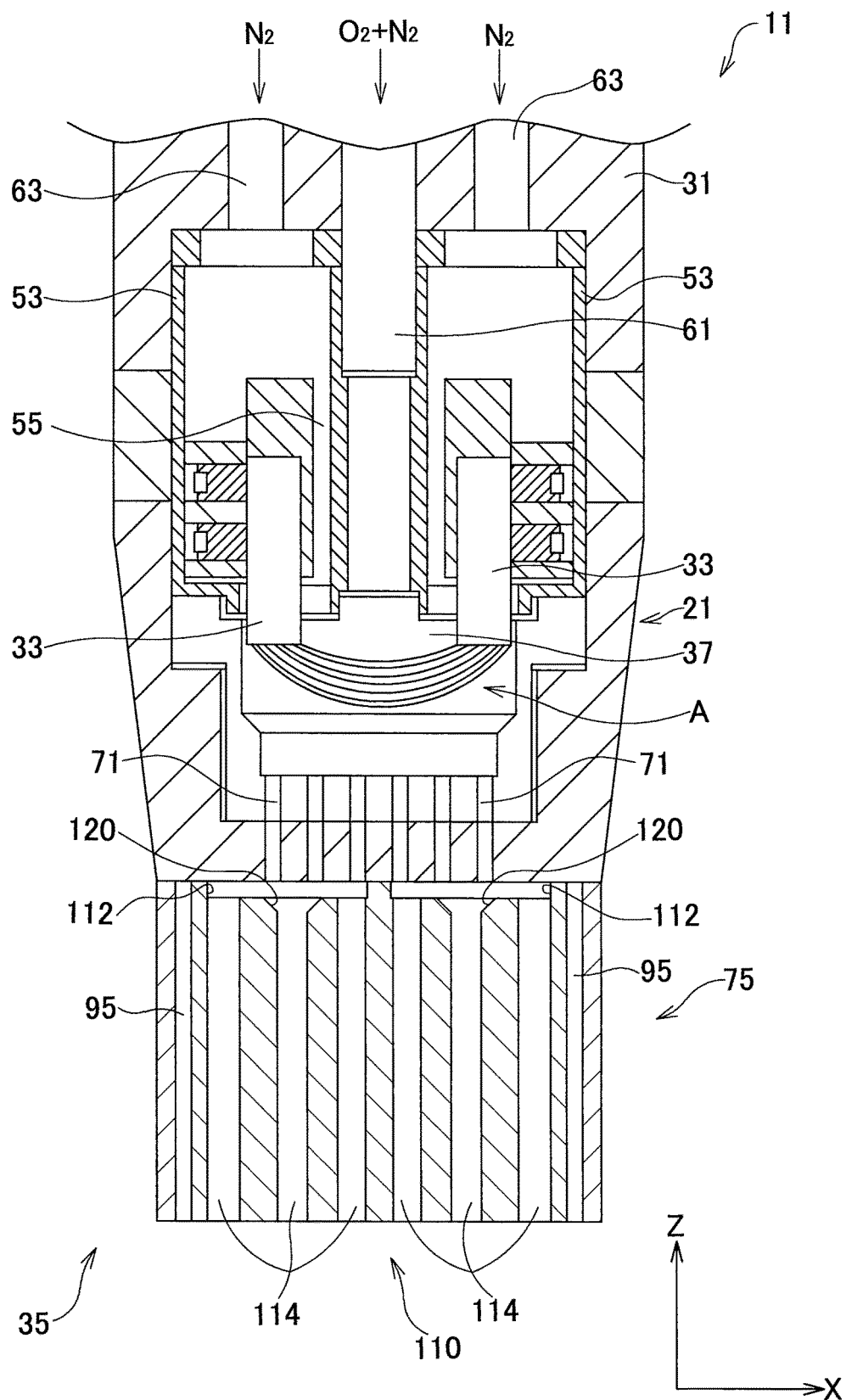
[Fig. 4]



[Fig. 5]



[Fig. 6]



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/041419

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A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H05H1/24 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. H05H1/24, H01J37/32

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

20

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2016/194138 A1 (FUJI MACHINE MFG. CO., LTD.) 08	1-2, 5-6
A	December 2016, fig. 3, 4; paragraphs [0011]-[0016] & US 2018/0146537 A1, fig. 3, 4; paragraphs [0021]-[0026]	3-4

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

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Date of the actual completion of the international search
18 December 2019 (18.12.2019)Date of mailing of the international search report
07 January 2020 (07.01.2020)

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Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/041419

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 36-21622 Y1 (OSAKA DENKI CO., LTD.) 21 August 1961, fig. 2; page 1, right column, lines 4-11 (Family: none)	1-2, 5-6
Y	JP 2005-302681 A (SEKISUI CHEMICAL CO., LTD.) 27 October 2005, fig. 11; paragraphs [0056]-[0057] & US 2007/0002515 A1, fig. 18; paragraphs [0159]-[0160] & TW 200428469 A & KR 10-2006-0010798 A & CN 101296549 A	1-2, 5-6
Y	JP 2015-144078 A (FUJI MACHINE MFG. CO., LTD.) 06 August 2015, fig. 1 (Family: none)	1-2, 5-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2001068298 A [0003]