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- (72) Inventors:
• HIRATA, Hironobu
Tokyo, 1008150 (JP)
• ASHIZAWA, Noritaka
Tokyo, 1008150 (JP)
- (74) Representative: Maiwald GmbH
Engineering
Elisenhof
Elisenstrasse 3
80335 München (DE)
- (30) Priority: 07.04.2023 JP 2023062470
- (71) Applicant: Ushio Denki Kabushiki Kaisha
Tokyo 100-8150 (JP)

(54)

PLASMA GENERATION MECHANISM AND LIGHT SOURCE APPARATUS

(57) [Object] To provide a plasma generation mechanism and a light source apparatus that are capable of stably supplying a plasma raw material to an irradiation position of an energy beam.

[Solving Means] A plasma generation mechanism according to an embodiment of the present invention is a plasma generation mechanism included in a light source apparatus that transforms a liquid plasma raw material into plasma by irradiation of an energy beam to

extract radiation, including: a disturbance prevention portion. The disturbance prevention portion separates a supply liquid surface to which a new plasma raw material is supplied, of liquid surfaces of the plasma raw material, and an incident liquid surface that the energy beam enters, of the liquid surfaces of the plasma raw material, from each other and communicates the plasma raw material between a side of the supply liquid surface and a side of the incident liquid surface.

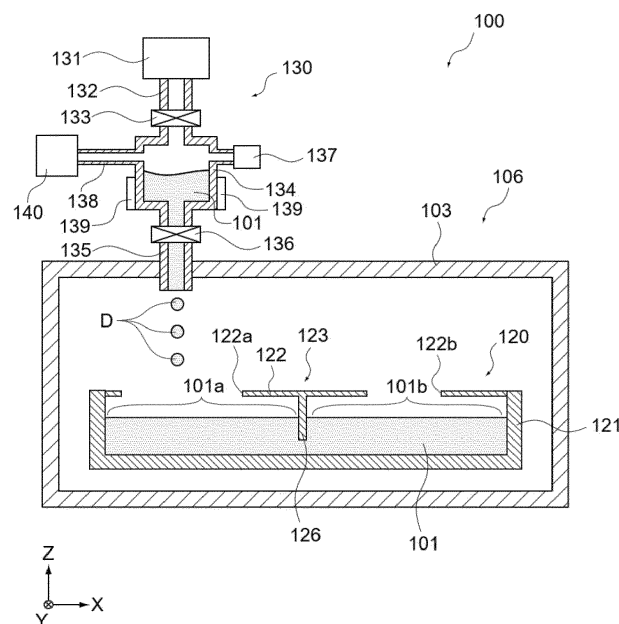


FIG.3

DescriptionTechnical Field

5 **[0001]** The present invention relates to a plasma generation mechanism and a light source apparatus that supply a plasma raw material to an incident position of an energy beam to generate plasma.

Background Art

10 **[0002]** X-rays have been conventionally used for medical, industrial and research applications. In the medical field, X-rays are used for such applications as chest radiography, dental radiography, and computed tomography (CT). In the industrial field, X-rays are used for such applications as non-destructive testing and tomographic non-destructive testing to observe the inside of materials such as structures and welds. In the research field, X-rays are used for such applications as X-ray diffraction to analyze the crystal structure of materials and X-ray spectroscopy (X-ray fluorescence analysis) to analyze the constituent composition of materials. Extreme ultraviolet light (hereinafter, referred to as "EUV light") having a wavelength of 13.5 nm, which is in the soft X-ray region having a relatively long wavelength among X-rays, has been recently used for exposure light.

15 **[0003]** Some EUV light source apparatuses that generate EUV generate high-temperature plasma by applying an energy beam to a plasma raw material such as molten tin or lithium to excite the plasma raw material and extract EUV light from the high-temperature plasma. A method of using a laser beam as an energy beam is called laser produced plasma (LPP), and a method of using discharge is called discharge produced plasma (DPP) or laser assisted discharge produced plasma (LDP).

20 **[0004]** As an EUV light source apparatus used in LPP, one that excites a raw material by collecting a laser beam on liquid droplets of a plasma raw material to generate plasma is known. Meanwhile, in recent years, a method of supplying a plasma raw material to an irradiation region of a laser beam using the centrifugal force of a rotation body has been developed (see, for example, Patent Literatures 1 and 2). Since this method does not need to supply a plasma raw material in the form of liquid droplets, it is possible to obtain high-intensity radiation with a relatively simple configuration as compared with a method of collecting a laser beam on liquid droplets.

30 Citation ListPatent Literature**[0005]**

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Patent Literature 1: Japanese Patent Application Laid-open No. 2021-1924

Patent Literature 2: Japanese Unexamined Patent Application Publication No. 2022-530497

Summary of invention

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[0006] The above Patent Literature 1 discloses that metal pellets that are sources of the plasma raw material are intermittently supplied to the rotation body while maintaining a vacuum state in a chamber using a load lock mechanism. This makes it possible to stably and regularly generate EUV light. Although this Patent Literature 1 does not disclose a raw material supply mechanism to an irradiation position of a laser beam, raw material supply is essential.

45 **[0007]** If the supply position of the plasma raw material is near the irradiation position of a laser beam, the film thickness of the plasma raw material rapidly increases and the surface of the plasma raw material, which is to be an irradiation surface of a laser beam, is disturbed. For this reason, the position where plasma is generated by laser beam irradiation fluctuates, and it is difficult to obtain a constant EUV intensity. In addition, if the supply position of the plasma raw material is far from the irradiation position of a laser beam, the supplied plasma raw material reaches the irradiation position of a laser beam at high speed by the centrifugal force due to rotation of the rotation body, which also causes the irradiation surface of a laser beam to be disturbed.

50 **[0008]** The above Patent Literature 2 does not disclose a raw material supply mechanism, either, but it is essential. Regarding the configuration disclosed in Fig. 1 of Patent Literature 2, even if a liquid plasma raw material is supplied onto a disk, the liquid plasma raw material is vigorously transported to the irradiation position of a laser beam by centrifugal force of rotation of the plasma raw material. For this reason, the irradiation position of a laser beam is instantaneously overloaded with raw materials and the thickness of the plasma raw material becomes too large, making EUV light emission unstable.

55 **[0009]** Further, in the configuration shown in Fig. 6 of Patent Literature 2, the region to be irradiated with a laser beam

is referred to as an interaction zone and is surrounded by a debris shield. Although this debris shield makes it possible to prevent debris from being generated by laser beam irradiation, when supplying a plasma raw material to be consumed for each EUV light emission, it is difficult to supply a plasma raw material with the configuration shown in Fig. 6. There is a gap between the debris shield and the rotation body, but this gap is not for supplying a plasma raw material but for bringing the fixed debris shield and rotation body as close as possible and causing only the rotation body to rotate. For this reason, it is difficult to supply a plasma raw material through this gap. Therefore, it seems difficult to achieve both debris reduction and supply of a plasma raw material to the irradiation position of a laser beam.

[0010] In view of the circumstances as described above, it is an object of the present invention to provide a plasma generation mechanism and a light source apparatus that are capable of stably supplying a plasma raw material to an irradiation position of an energy beam.

[0011] In order to achieve the above-mentioned object, a plasma generation mechanism according to an embodiment of the present invention is a plasma generation mechanism included in a light source apparatus that transforms a liquid plasma raw material into plasma by irradiation of an energy beam to extract radiation, including: a disturbance prevention portion.

[0012] The disturbance prevention portion separates a supply liquid surface to which the plasma raw material is newly supplied, of liquid surfaces of the plasma raw material, and an incident liquid surface that the energy beam enters, of the liquid surfaces of the plasma raw material, from each other and communicates the plasma raw material between a side of the supply liquid surface and a side of the incident liquid surface.

[0013] The plasma generation mechanism may further include a reservoir tank that reserves the plasma raw material, the supply liquid surface being a liquid surface where the plasma raw material is added dropwise, of liquid surfaces of the plasma raw material reserved in the reservoir tank.

[0014] The plasma generation mechanism may further include a rotation body that has a drop surface where the plasma raw material is added dropwise and a holding surface that holds the plasma raw material flowed from the drop surface due to centrifugal force caused by rotation, the supply liquid surface being a liquid surface continuous to the drop surface, of liquid surface of the plasma raw material on the holding surface.

[0015] The plasma generation mechanism may further include: a reservoir tank that reserves the plasma raw material; and a rotation body that is immersed in the reservoir tank, has an adhesion surface to which the plasma raw material adheres, and includes a channel where the plasma raw material flows from the adhesion surface due to centrifugal force caused by rotation, the supply liquid surface being a liquid surface in the channel, of liquid surfaces of the plasma raw material.

[0016] The disturbance prevention portion may include a partition wall that is provided in a liquid of the plasma raw material via the liquid surfaces of the plasma raw material from above the liquid surfaces.

[0017] The partition wall may have an opening or a gap that communicates the plasma raw material between a side of the supply liquid surface and a side of the incident liquid surface of the partition wall.

[0018] The plasma generation mechanism may further include a lid portion that faces the liquid surfaces of the plasma raw material above the liquid surfaces, the disturbance prevention portion including a partition wall that is provided in a liquid of the plasma raw material via the liquid surfaces from the lid portion.

[0019] The disturbance prevention portion may further include a protruding portion that protrudes from a bottom portion opposed to the liquid surfaces of the plasma raw material toward the liquid surface below the liquid surfaces.

[0020] The disturbance prevention portion may include a plurality of partition walls that is provided in a liquid of the plasma raw material via the liquid surfaces from the lid portion, and the protruding portion may be provided between the plurality of partition walls.

[0021] The plasma generation mechanism may further include a shield portion that covers the incident liquid surface, the disturbance prevention portion including a partition wall that is provided in a liquid of the plasma raw material via the liquid surfaces from the shield portion.

[0022] The holding surface may have a first region that is located at a first distance from a rotation axis of the rotation body and a second region that is located at a second distance from the rotation axis of the rotation body, the second distance being smaller than the first distance, and the supply liquid surface may be located on the first region and the incident liquid surface may be located on the second region.

[0023] The disturbance prevention portion may include a protruding portion that protrudes from the holding surface toward the liquid surfaces.

[0024] The supply liquid surface may be a liquid surface that is parallel to the rotation axis of the rotation body, the incident liquid surface may be a liquid surface that is perpendicular to the rotation axis of the rotation body, and the disturbance prevention portion may be a partition wall that is located between the supply liquid surface and the incident liquid surface and forms the channel between the partition wall and an opposing member.

[0025] The disturbance prevention portion may form the channel that passes through a position spaced apart from the rotation axis of the rotation body than the incident liquid surface.

[0026] The supply liquid surface may be spaced apart from the adhesion surface in a direction parallel to the rotation

axis.

[0027] The disturbance prevention portion may include a flow velocity suppression portion that is provided in a liquid of the plasma raw material and suppresses flow velocity of the plasma raw material passing through the disturbance prevention portion.

[0028] The flow velocity suppression portion may include a protruding portion that protrudes from a portion opposed to the liquid surfaces of the plasma raw material toward the liquid surfaces below the liquid surfaces.

[0029] The flow velocity suppression portion may be a porous structure provided in a liquid of the plasma raw material.

[0030] The energy beam may be a laser beam.

[0031] The radiation may be extreme ultraviolet light or X-rays.

[0032] The plasma raw material may be tin, lithium, gadolinium, terbium, gallium, bismuth, or an alloy including at least one of these materials.

[0033] In order to achieve the above-mentioned object, a light source apparatus according to an embodiment of the present invention is a light source apparatus that transforms a liquid plasma raw material into plasma by irradiation of an energy beam to extract radiation, including: a plasma generation mechanism; and a beam source.

[0034] The plasma generation mechanism includes a disturbance prevention portion that separates a supply liquid surface to which a new plasma raw material is supplied, of liquid surfaces of the plasma raw material, and an incident liquid surface that the energy beam enters, of the liquid surfaces of the plasma raw material, from each other and communicates the plasma raw material between a side of the supply liquid surface and a side of the incident liquid surface.

[0035] The beam source causes the energy beam to enter the incident liquid surface.

Advantageous Effects of Invention

[0036] According to the present invention, it is possible to provide a plasma generation mechanism and light source apparatus that are capable of stably supplying a plasma raw material to an irradiation position of an energy beam.

Brief Description of Drawings

[0037]

[Fig. 1] Fig. 1 is a schematic diagram of a light source apparatus according to a first embodiment of the present invention.

[Fig. 2] Fig. 2 is an enlarged view of a partial configuration of the above light source apparatus.

[Fig. 3] Fig. 3 is a schematic diagram of a plasma generation mechanism and a raw material supply device included in the above light source apparatus.

[Fig. 4] Fig. 4 is a cross-sectional view of a raw material container included in the above plasma generation mechanism.

[Fig. 5] Fig. 5 is a plan view of the above raw material container.

[Fig. 6] Fig. 6 is a schematic diagram showing supply of a plasma raw material and application of an energy beam to the above raw material container.

[Fig. 7] Fig. 7 is a schematic diagram showing another configuration of the above raw material container.

[Fig. 8] Fig. 8 is a schematic diagram showing another configuration of the above raw material container.

[Fig. 9] Fig. 9 is a schematic diagram showing another configuration of the above raw material container.

[Fig. 10] Fig. 10 is a schematic diagram of a light source apparatus according to a second embodiment of the present invention.

[Fig. 11] Fig. 11 is an enlarged view of a partial configuration of the above light source apparatus.

[Fig. 12] Fig. 12 is a schematic diagram of a plasma generation mechanism and a raw material supply device included in the above light source apparatus.

[Fig. 13] Fig. 13 is a cross-sectional view of a rotation body included in the above plasma generation mechanism.

[Fig. 14] Fig. 14 is an enlarged view of the above rotation body.

[Fig. 15] Fig. 15 is a plan view of the above rotation body.

[Fig. 16] Fig. 16 is a schematic diagram of the above rotation body and plasma raw material.

[Fig. 17] Fig. 17 is a schematic diagram showing supply of a plasma raw material and application of an energy beam to the above rotation body.

[Fig. 18] Fig. 18 is a schematic diagram showing another configuration of the above rotation body.

[Fig. 19] Fig. 19 is a schematic diagram showing another configuration of the above rotation body.

[Fig. 20] Fig. 20 is a schematic diagram showing another configuration of the above rotation body.

[Fig. 21] Fig. 21 is a schematic diagram of a light source apparatus according to a third embodiment of the present invention.

[Fig. 22] Fig. 22 is an enlarged view of a partial configuration of the above light source apparatus.

[Fig. 23] Fig. 23 is a schematic diagram of a plasma generation mechanism and a raw material supply device included in the above light source apparatus.

[Fig. 24] Fig. 24 is a cross-sectional view of a rotation body included in the above plasma generation mechanism.

[Fig. 25] Fig. 25 is an enlarged view of the above rotation body.

[Fig. 26] Fig. 26 is a plan view of the above rotation body.

[Fig. 27] Fig. 27 is a schematic diagram of the above rotation body and plasma raw material.

[Fig. 28] Fig. 28 is a schematic diagram showing supply of a plasma raw material and application of an energy beam to the above rotation body.

[Fig. 29] Fig. 29 is a schematic diagram showing another configuration of the above rotation body.

[Fig. 30] Fig. 30 is a schematic diagram showing another configuration of the above rotation body.

[Fig. 31] Fig. 31 is a schematic diagram of the above rotation body and plasma raw material.

Description of Embodiments

[0038] Embodiments of the present invention will be described below with reference to the drawings.

<First embodiment>

[Basic configuration of light source apparatus]

[0039] Fig. 1 is a schematic diagram showing a configuration example of a light source apparatus 100 according to a first embodiment of the present invention, and Fig. 2 is a schematic enlarged view showing part of the light source apparatus 100. The light source apparatus 100 is a laser produced plasma (LPP)-based light source apparatus. That is, as shown in Fig. 2, the light source apparatus 100 is an apparatus that excites a plasma raw material 101 by applying an energy beam EB to the plasma raw material 101 to generate plasma P, extracts radiation R emitted from the plasma P, and uses the extracted radiation R as a light source. The radiation R is extreme ultraviolet (EUV), X-rays, or other electromagnetic waves.

[0040] The plasma raw material 101 is tin (Sn), lithium (Li), gadolinium (Gd), terbium (Tb), gallium (Ga), bismuth (Bi),

or an alloy including at least one of these materials and is liquid. In the case where EUV light is emitted as the radiation R, molten Sn or Li is used as the plasma raw material 101. In the case where X-rays are emitted as the radiation R, molten Ga, Ga alloy, Sn compound, or the like is used as the plasma raw material 101.

[0041] Fig. 1 illustrates a schematic cross section of the light source apparatus 100 when the light source apparatus 100 is cut along the horizontal direction at a predetermined height from its installation surface and viewed from vertically above.

[0042] In Fig. 1, the illustration of the cross section is omitted for portions for which the configuration of the cross section does not need to be explained, in order to facilitate the understanding of the configuration and operation of the light source apparatus 100. Hereinafter, the X direction is denoted as the left-right direction in the horizontal direction (the positive side of the X axis is the right side and the negative side is the left side), the Y direction is denoted as the front-rear direction in the horizontal direction (the positive side of the Y axis is the front side and the negative side is the rear side), and the Z direction is denoted as the vertical direction (the positive side of the Z axis is the upper side and the negative side is the lower side). Obviously, regarding the application of the present technology, the orientation in which the light source apparatus 100 is used, and the like are not limited.

[0043] As shown in Fig. 1, the light source apparatus 100 includes an enclosure 102, a vacuum chamber 103, an energy beam incident chamber 104, a radiation emission chamber 105, a plasma generation mechanism 106, a controller 107, and a raw material supply device 130. Note that although the raw material supply device 130 is schematically illustrated in Fig. 1, the detailed configuration will be described below.

[0044] In the example shown in Fig. 1, the enclosure 102 is configured such that its external shape is approximately a cube. Note that the shape of the enclosure 102 is not limited to a cube and may be an arbitrary three-dimensional shape. The enclosure 102 includes an emission hole 102a formed in the front face of the enclosure 102, an incident hole 102b formed in the right side face thereof, and a through-hole 102c formed in the left side face thereof. The material of the enclosure 102 is not limited, and a metal is used, for example.

[0045] In the present embodiment, the radiation R is set to allow an emission axis EA to pass through the emission hole 102a in the front face and extend in the Y direction (front-rear direction). The radiation R is extracted along the emission axis EA and emitted through the emission hole 102a toward the front side. Further, in the present embodiment, the energy beam EB is set to allow an incident axis IA to extend from the incident hole 102b in the right side face toward the rear side at an oblique angle to the left.

[0046] As shown in Fig. 1, a beam source 108 that emits the energy beam EB is disposed outside the enclosure 102. The beam source 108 is disposed to allow the energy beam EB to enter the inside of the enclosure 102 along the incident axis IA. Examples of the energy beam EB include an electron beam and a laser beam. The beam source 108 may employ any configurations capable of emitting these energy beams EB.

[0047] The light source apparatus 100 is provided with a chamber section C that includes a plurality of chambers. Specifically, the chamber section C includes the vacuum chamber 103, the energy beam incident chamber (hereinafter, referred to simply as the "incident chamber") 104, and the radiation emission chamber (hereinafter, referred to simply as the "emission chamber") 105. The vacuum chamber 103 and the incident chamber 104 are connected to each other, and the vacuum chamber 103 and the emission chamber 105 are connected to each other.

[0048] The incident chamber 104 is formed to be located on the incident axis IA of the energy beam EB, and the emission chamber 105 is formed to be located on the emission axis EA of the radiation R. Further, the vacuum chamber 103 is provided with the plasma generation mechanism 106 that generates the plasma P.

[0049] In the present embodiment, the chamber section C (the vacuum chamber 103, the incident chamber 104, and the emission chamber 105) includes a chamber body 109, an outer protrusion 109a protruding from the front face of the chamber body 109 toward the front side, and two inner protrusions 109b and 109c protruding inward from the inner circumferential face of the chamber body 109. As the material of the chamber body 109, a metal material is used.

[0050] The chamber body 109 is configured such that its external shape is approximately a rectangular parallelepiped shape, and has its front, rear, left, and right faces that are arranged to face the front, rear, left, and right faces of the enclosure 102, respectively. The chamber body 109 has a right-front corner that is disposed to be on the incident axis IA of the energy beam EB, the right-front corner being located between the front face and the right side face.

[0051] As shown in Fig. 1, an emission hole 109d is formed in the front face of the chamber body 109. The emission hole 109d is formed along the emission axis EA of the radiation R, and in line with the emission hole 102a in the front face of the enclosure 102. The outer protrusion 109a is formed to protrude from the circumferential edge portion of the emission hole 109d in the chamber body 109 toward the front side. The outer protrusion 109a is configured to protrude more forward than the emission hole 102a of the enclosure 102 with being inscribed in the emission hole 102a of the enclosure 102.

[0052] An inner protrusion 109b is formed to protrude inward from the circumferential edge portion of the emission hole 109d inside the chamber body 109. The space surrounded by the outer protrusion 109a and the inner protrusion 109b serves as the emission chamber 105. The outer protrusion 109a and the inner protrusion 109b themselves, which are the components constituting the emission chamber 105, can also be referred to as the emission chamber. The outer

protrusion 109a and the inner protrusion 109b may be formed integrally with the chamber body 109, or they may be formed separately and then connected to the chamber body 109.

[0053] The emission chamber 105 is configured to have a cone shape with its central axis being aligned with the emission axis EA of the radiation R. The emission chamber 105 is configured to have a large cross-sectional area at its center portion in the direction of the emission axis EA of the radiation R, and have the cross-sectional area being decreased toward the front and rear ends. In other words, the emission chamber 105 is shaped to taper toward the front and rear ends. The emission chamber 105 is provided with an opening (aperture) through which the radiation R passes at the front and rear ends.

[0054] A utilization device such as a mask inspection device is connected to the end portion of the emission chamber 105 on the front side (end portion of the outer protrusion 109a on the front side). In the example shown in Fig. 1, an application chamber 110 is connected as a chamber constituting part of the utilization device. The pressure inside the application chamber 110 may be an atmospheric pressure. The inside of the application chamber 110 may be purged with gas (e.g., inert gas) from a gas injection channel as necessary. The gas inside the application chamber 110 may be exhausted by an exhaust means, which is not shown in the figure.

[0055] A filter film 111 for physically separating a region where the plasma P is generated and the application chamber 110 from each other is provided between the emission chamber 105 and the application chamber 110. The filter film 111 is made of a material that is transmissive to the radiation R, and prevents the plasma raw material 101 and debris scattered due to generation of the plasma P from entering the application chamber 110.

[0056] A collector (focusing mirror) 112 for guiding and focusing the radiation R that has entered the emission chamber 105 into the utilization device (inside the application chamber 110) is disposed inside the emission chamber 105. In Fig. 1, the components of the radiation R that enter the emission chamber 105 and are focused are illustrated in hatching.

[0057] A shielding member (central occultation) 113 is disposed inside the emission chamber 105. The shielding member 113 is located in line with the emission hole 109d of the chamber body 109, the emission hole 102a of the enclosure 102, and the filter film 111 along with the emission axis EA of the radiation R. In the present embodiment, the shielding member 113 can block the radiation components that are not focused by the collector 112.

[0058] An incident window 114 is provided in the right-front corner of the chamber body 109. The incident window 114 is disposed along the incident axis IA of the energy beam EB, and in line with the incident hole 102b in the right side face of the enclosure 102. An inner protrusion 109c is formed to protrude inside the right-front corner of the chamber body 109 along the incident axis IA of the energy beam EB from a position surrounding the incident window 114.

[0059] In the internal space of the chamber body 109, the space surrounded by the inner protrusion 109c serves as the incident chamber 104. The inner protrusion 109c and the right-front corner of the chamber body 109 themselves, which are the components constituting the incident chamber 104, can also be referred to as the incident chamber. The inner protrusion 109c may be formed integrally with the chamber body 109, or it may be formed separately and then connected to the chamber body 109.

[0060] The incident chamber 104 is configured to have a cone shape with its central axis being aligned with the incident axis IA of the energy beam EB. The incident chamber 104 is configured to have a cross-sectional area being decreased toward its end inside the chamber body 109 in the direction of the incident axis IA of the energy beam EB. In other words, the incident chamber 104 has a tapered shape toward the end thereinside. The incident chamber 104 is provided with an opening (aperture) through which the energy beam EB passes at the end thereinside.

[0061] A capturing mechanism is disposed to capture the scattered plasma raw material 101 and debris inside the incident chamber 104. In the example shown in Fig. 1, a rotary window 115 that is a plate-shaped rotation member for causing the energy beam EB to be transmitted therethrough and capturing the plasma raw material 101 and debris is disposed as the capturing mechanism. Rotating the rotary window 115 makes it possible to increase the substantial area of the beam transmission region of the rotary window 115 and reduce the frequency of replacement of the rotary window 115.

[0062] As shown in Fig. 1, gas injection channels 116a and 116b are respectively provided in the emission chamber 105 and the incident chamber 104, and gas is supplied to the emission chamber 105 and the incident chamber 104 from a gas supply device, which is omitted in the figure. A gas that has high transmittance to the radiation R is supplied to the emission chamber 105. A gas that has high transmittance to the energy beam EB is supplied to the incident chamber 104.

[0063] The gases to be supplied to the emission chamber 105 and the incident chamber 104 may be the same type of gas or different types of gases. For example, argon or helium can be used as a gas that has high transmittance to both the energy beam EB and the radiation R. In addition, the type of gas to be supplied to the emission chamber 105 and the incident chamber 104 is not limited. By supplying gas, it is possible to set the pressure inside the emission chamber 105 and the incident chamber 104 to a pressure higher than the pressure inside the vacuum chamber 103, and prevent debris and the like from entering.

[0064] In the internal space of the chamber body 109, the space excluding the internal space of the inner protrusion 109b, which serves as the emission chamber 105, and the internal space of the inner protrusion 109c, which serves as

the incident chamber 104, serves as the vacuum chamber 103. The components themselves constituting the vacuum chamber 103 can also be referred to as the vacuum chamber.

[0065] As shown in Fig. 1, the chamber body 109 has a portion that protrudes through the through-hole 102c in the left side face of the enclosure 102 to the outside of the enclosure 102, and the portion has an end connected to an exhaust pump 117. The specific configuration of the exhaust pump 117 is not limited, and an arbitrary pump such as a vacuum pump may be used. The exhaust pump 117 exhausts the inside the vacuum chamber 103 and depressurizes the vacuum chamber 103. This suppresses the attenuation of the radiation R generated in the vacuum chamber 103. The inside of the vacuum chamber 103 is not necessarily a vacuum atmosphere, provided that it is a reduced-pressure atmosphere with respect to the incident chamber 104 and the emission chamber 105. The inside of the vacuum chamber 103 may be supplied with an inert gas.

[0066] In the present embodiment, a gas nozzle 118 is disposed to extend in the left-right direction toward the region between the incident axis IA and the emission axis EA. The gas nozzle 118 is disposed on the right side face of the chamber body 109 via a seal member or the like. The gas nozzle 118 is connected to a gas supply device, which is omitted in the figure, and supplies gas to the inside of the chamber body 109. In the example shown in Fig. 1, the gas nozzle 118 ejects gas from the right side of the region between the incident axis IA and the emission axis EA toward the left side thereof in the left-right direction. This allows the debris that has been released from the plasma P to move in a direction away from the incident axis IA and the emission axis EA.

[0067] The plasma generation mechanism 106 is a mechanism for generating the plasma P inside the vacuum chamber 103 and emitting the radiation R (X-rays, EUV light). As shown in Fig. 2, the plasma generation mechanism 106 includes a raw material container 120, and the energy beam EB enters the raw material container 120. The raw material container 120 is disposed inside the vacuum chamber 103 such that an irradiation position I of the energy beam EB is placed at the intersection between the incident axis IA and the emission axis EA.

[0068] A liquid plasma raw material 101 is supplied to the raw material container 120 from the raw material supply device 130. The plasma raw material 101 is reserved in the raw material container 120 and supplied to the irradiation position I, and the plasma P is generated when the energy beam EB enters the irradiation position I. Details of the plasma generation mechanism 106 and the raw material supply device 130 will be described below.

[0069] The controller 107 controls the operation of each component provided in the light source apparatus 100. For example, the controller 107 controls the operation of the beam source 108 and the exhaust pump 117. In addition, the controller 107 controls the operation of the raw material supply device 130, which will be described below. The controller 107 includes hardware circuits necessary for computers, such as CPUs and memories (RAM, ROM). A CPU loads a control program stored in a memory into a RAM and executes it to perform various processes. As the controller 107, a programmable logic device (PLD) such as field programmable gate array (FPGA), and other devices such as application specific integrated circuit (ASIC) may be used. In Fig. 1, the controller 107 is schematically illustrated as a function block. However, the controller 107 may be designed in any desired manner including the position at which the controller 107 is configured.

[0070] As shown in Fig. 1, in the present embodiment, a radiation diagnosis section 119 is provided on the front side of the chamber body 109, in the region spatially connected to the vacuum chamber 103. The radiation diagnosis section 119 is disposed at a position at which the radiation R radiated in a direction different from the emission axis EA of the radiation R enters. The radiation diagnosis section 119 measures the state of the radiation R emitted from the plasma P. Here, the state of the radiation R means the physical state of the radiation R, such as intensity, wavelength, and spectrum of the radiation R. The radiation diagnosis section 119 includes a detector that detects the presence or absence of the radiation R and a measurement device that measures the output of the radiation, for example. The measurement results with the radiation diagnosis section 119 are used to diagnose the radiation R or to control the operation of the raw material supply device 130 described below.

[Configuration of raw material supply device]

[0071] Fig. 3 is a schematic diagram showing a configuration of the plasma generation mechanism 106 and the raw material supply device 130. Note that in Fig. 3, the enclosure 102, the energy beam incident chamber 104, and the radiation emission chamber 105 are omitted. As shown in Fig. 3, the raw material supply device 130 is connected to the vacuum chamber 103 of the light source apparatus 100. The raw material supply device 130 is a device that supplies the plasma raw material 101 to the vacuum chamber 103.

[0072] The raw material supply device 130 includes a raw material supply section 131, a raw material replenishment pipe 132, a replenishment valve 133, a raw material tank 134, a raw material supply pipe 135, a supply valve 136, a pressure gauge 137, an exhaust pipe 138, a heating mechanism 139, and a vacuum exhaust device 140.

[0073] The raw material supply section 131 supplies the plasma raw material 101 for replenishing the raw material tank 134. The raw material supply section 131 is a mechanism for accommodating the plasma raw material 101 and supplying the necessary amount of the plasma raw material 101. The raw material replenishment pipe 132 connects

the raw material supply section 131 and the raw material tank 134 and causes the plasma raw material 101 supplied from the raw material supply section 131 to pass therethrough. The replenishment valve 133 is provided to the raw material replenishment pipe 132 and maintains the reduced-pressure atmosphere of the raw material tank 134. As the replenishment valve 133, for example, a mechanical valve that opens and closes the raw material replenishment pipe 132 such that the plasma raw material 101 can pass therethrough is used.

[0074] The raw material tank 134 is provided outside the vacuum chamber 103 and reserves the plasma raw material 101 in the liquid state. The raw material replenishment pipe 132 and the raw material supply pipe 135 are connected to the raw material tank 134 so as to be communicated with the inside of the raw material tank 134. The raw material tank 134 includes the heating mechanism 139. The heating mechanism 139 is a mechanism for heating the plasma raw material 101 in the raw material tank 134. As the heating mechanism 139, for example, a heater using a heating wire or the like is used.

[0075] The heating by the heating mechanism 139 maintains the plasma raw material 101 to be supplied from the raw material replenishment pipe 132 to the raw material tank 134 at a predetermined temperature such that the plasma raw material 101 is in the liquid state, regardless of the state at the time of replenishment (a solid state or a liquid state).

[0076] The raw material supply pipe 135 connects the raw material tank 134 and the vacuum chamber 103, and supplies liquid droplets D of the liquid plasma raw material 101 reserved in the raw material tank 134 to the raw material container 120. The raw material supply pipe 135 penetrates the wall surface of the vacuum chamber 103 to connect the raw material tank 134 and the vacuum chamber 103. The supply valve 136 is provided to the raw material supply pipe 135 and opens and closes the flow of the plasma raw material 101. The pressure gauge 137 is connected to the raw material tank 134 and measures the pressure in the raw material tank 134. The exhaust pipe 138 connects the vacuum exhaust device 140 and the raw material tank 134.

[0077] As shown in Fig. 3, the raw material supply device 130 is disposed vertically above the vacuum chamber 103. This makes it possible to introduce the liquid droplets D into the vacuum chamber 103 by its own weight and make the device configuration simple. In addition, by using the raw material supply device 130, it is possible to supply the liquid plasma raw material 101 to the raw material container 120 as necessary. Therefore, it is possible to reduce the reserve amount of the plasma raw material 101, reduce energy consumption, and stably supply the plasma raw material.

[Configuration of plasma generation mechanism]

[0078] As shown in Fig. 3, the plasma generation mechanism 106 includes the raw material container 120. The raw material container 120 is disposed inside the vacuum chamber 103. The material of the raw material container 120 is not particularly limited as long as the molten plasma raw material 101 can be accommodated.

[0079] Fig. 4 is a cross-sectional view of the raw material container 120, and Fig. 5 is a plan view of the raw material container 120. Fig. 4 shows the cross section of the raw material container 120 taken along the line A-A in Fig. 5. As shown in Fig. 4 and Fig. 5, the raw material container 120 includes a reservoir tank 121, a lid portion 122, and a disturbance prevention portion 123.

[0080] The reservoir tank 121 includes a bottom portion 124 and a side wall portion 125, and reserves the plasma raw material 101 as shown in Fig. 3. The bottom portion 124 is a plate-shaped portion and may have a disc shape. The bottom portion 124 includes a bottom 124a. The bottom 124a is a surface of the bottom portion 124 on the upper side and is, for example, a horizontal surface.

[0081] The side wall portion 125 is a cylindrical wall portion continuous to the peripheral edge of the bottom portion 124 and has, for example, a cylindrical shape. The side wall portion 125 has a side surface 125a. The side surface 125a is a surface of the side wall portion 125 on the inner side, is continuous to the peripheral edge of the bottom 124a, and is, for example, a surface perpendicular to the bottom 124a. The side surface 125a may be a surface that is inclined inward or outward from the surface perpendicular to the bottom 124a.

[0082] The lid portion 122 is attached to the end of the side wall portion 125 opposite to the bottom portion 124 and faces liquid surfaces of the plasma raw material 101 above the liquid surfaces. A raw material supply port 122a and a beam incident port 122b are provided to the lid portion 122. As shown in Fig. 3, the raw material supply port 122a is an opening through which the plasma raw material 101 supplied from the raw material supply device 130 passes. As shown in Fig. 2, the beam incident port 122b is an opening where the energy beam EB enters and the radiation R is emitted.

[0083] As shown in Fig. 3, the disturbance prevention portion 123 separates a supply liquid surface 101a and an incident liquid surface 101b, which are liquid surfaces of the plasma raw material 101, from each other. The supply liquid surface 101a is a liquid surface to which the plasma raw material 101 is newly supplied, of the liquid surfaces of the plasma raw material 101, and is a liquid surface where the liquid droplets D of the plasma raw material 101 are added dropwise from the raw material supply device 130 as shown in Fig. 3. The incident liquid surface 101b is a liquid surface that the energy beam EB enters, of the liquid surfaces of the plasma raw material 101. The disturbance prevention portion 123 communicates the plasma raw material 101 between the side of the supply liquid surface 101a and the side of the incident liquid surface 101b.

[0084] Specifically, the disturbance prevention portion 123 includes a partition wall 126. The partition wall 126 is provided in a liquid of the plasma raw material 101 via the liquid surfaces of the plasma raw material 101 from the lid portion 122. The partition wall 126 is spaced apart from the bottom 124a and has a gap 126a between the partition wall 126 and the bottom 124a. As shown in Fig. 5, the partition wall 126 is provided between the raw material supply port 122a and the beam incident port 122b and separates the supply liquid surface 101a and the incident liquid surface 101b from each other.

[0085] Fig. 6 is a schematic diagram showing supply of the plasma raw material 101 and application of the energy beam EB to the raw material container 120 from the raw material supply device 130. As shown in the figure, when the liquid droplets D of the plasma raw material 101 are added dropwise from the raw material supply device 130, the liquid droplets D reach the incident liquid surface 101b via the raw material supply port 122a. As shown by an arrow in Fig. 6, the plasma raw material 101 flows from the side of the supply liquid surface 101a to the side of the incident liquid surface 101b via the gap 126a.

[0086] As shown in Fig. 6, the energy beam EB enters the incident liquid surface 101b via the beam incident port 122b to generate the plasma P. Since the plasma raw material 101 is consumed due to transformation into plasma by application of the energy beam EB, the liquid droplets D are continuously added dropwise into the supply liquid surface 101a also during the application of the energy beam EB.

[Effects of disturbance prevention portion]

[0087] As shown in Fig. 6, when the liquid droplets D of the plasma raw material 101 are added dropwise into the supply liquid surface 101a, the impact causes wavefront fluctuations on the supply liquid surface 101a. The disturbance prevention portion 123 includes the partition wall 126 that separates the supply liquid surface 101a and the incident liquid surface 101b from each other, and the partition wall 126 prevents the wavefront fluctuations from being transmitted to the incident liquid surface 101b. As a result, the incident liquid surface 101b becomes stable, the irradiation position I does not fluctuate, and the intensity of the radiation R is also stable.

[Other configurations of raw material container]

[0088] Fig. 7 to Fig. 9 are each a schematic diagram showing another configuration of the raw material container 120. As shown in Fig. 7, the disturbance prevention portion 123 may further include a flow velocity suppression portion 127. The flow velocity suppression portion 127 is provided in a liquid of the plasma raw material 101 and suppresses flow velocity of the plasma raw material 101 passing through the disturbance prevention portion 123.

[0089] Specifically, as shown in Fig. 7, the flow velocity suppression portion 127 may be a protruding portion that protrudes from the bottom portion 124 toward the liquid surfaces of the plasma raw material 101. This protruding portion blocks the flow of the plasma raw material 101 that has passed through the gap 126a and changes the flow direction to suppress the flow velocity of the plasma raw material 101. As a result, the disturbance prevention portion 123 is capable of further suppressing the fluctuations of the incident liquid surface 101b. In addition, the flow velocity suppression portion 127 may be a hilly structure provided on the bottom 124a or a porous structure provided on the bottom 124a. The flow velocity suppression portion 127 may be provided on the side of the supply liquid surface 101a than the gap 126a.

[0090] As shown in Fig. 8, the disturbance prevention portion 123 may include a plurality of partition walls 126. In this case, the flow velocity suppression portion 127 can be provided between the plurality of partition walls 126. As a result, the disturbance prevention portion 123 is capable of further suppressing the fluctuations of the incident liquid surface 101b. The disturbance prevention portion 123 does not necessarily need to include the flow velocity suppression portion 127 and may include only the plurality of partition walls 126. Further, the disturbance prevention portion 123 may include one or more partition walls 126 and one or more flow velocity suppression portions 127.

[0091] Further, as shown in Fig. 9, the raw material container 120 does not necessarily need to include the lid portion 122, and the disturbance prevention portion 123 may include a partition wall 128 that protrudes above the liquid surfaces of the plasma raw material 101 from the bottom 124a. The partition wall 128 includes an opening 128a located in the liquid of the plasma raw material 101, and the plasma raw material 101 is movable from the side of the supply liquid surface 101a to the side of the incident liquid surface 101b via the opening 128a. The number and shape of openings 128a are not particularly limited. Also in this configuration, the disturbance prevention portion 123 may include one or more partition walls 128 and one or more flow velocity suppression portions 127.

<Second embodiment>

[Basic configuration of light source apparatus]

[0092] A light source apparatus according to a second embodiment of the present invention will be described. In the

following description, description of configurations and effects similar to those in the light source apparatus 100 described in the above embodiment will be omitted or simplified.

[Configuration of plasma generation mechanism]

[0093] Fig. 10 is a schematic diagram showing a configuration example of a light source apparatus 200 according to the second embodiment of the present invention, and Fig. 11 is a schematic enlarged view of part of the light source apparatus 100. Fig. 12 is a schematic diagram of a plasma generation mechanism 206 included in the light source apparatus 200. Of the configurations of the light source apparatus 200, configurations other than the plasma generation mechanism 206 are similar to those in the first embodiment. As shown in Fig. 12, the plasma generation mechanism 206 includes a rotation body 220, a rotational drive source 231, a shaft 232, and a bearing 233.

[0094] The rotational drive source 231 is disposed outside the vacuum chamber 103 and generates rotational power of the rotation body 220. The rotational drive source 231 is, for example, a motor. The shaft 232 connects the rotational drive source 231 and the rotation body 220 and transmits the rotational power generated by the rotational drive source 231 to the rotation body 220. The bearing 233 is disposed between the shaft 232 and the vacuum chamber 103 and allows the shaft 232 to rotate relative to the vacuum chamber 103.

[0095] The rotation body 220 is disposed inside the vacuum chamber 103 and is connected to the shaft 232. As shown by an arrow S in Fig. 12, the rotation body 220 rotates by the rotation of the shaft 232. Hereinafter, the rotation axis of the rotation body 220 and the shaft 232 will be referred to as a rotation axis M. The rotation axis M is disposed along the vertical direction (Z direction) such that the rotation surface is in the horizontal direction.

[0096] Fig. 13 is a cross-sectional view of the rotation body 220, Fig. 14 is an enlarged view of Fig. 13, and Fig. 15 is a plan view of the rotation body 220. Fig. 13 shows the cross section of the rotation body 220 taken along the line B-B in Fig. 15. Fig. 16 is a schematic diagram showing the rotation body 220 and the plasma raw material 101. As shown in these figures, the rotation body 220 includes a body portion 221, a shield portion 222, and a disturbance prevention portion 223.

[0097] As shown in Fig. 13, the body portion 221 includes a bottom portion 224 and a side wall portion 225. The bottom portion 224 is a plate-shaped portion and may have a disc shape. The shaft 232 is connected to the center of the body portion 221. The bottom portion 224 has a drop surface 224a. The drop surface 224a is a surface of the bottom portion 224 opposite to the shaft 232 and is a surface where the liquid droplets D of the plasma raw material 101 are added dropwise as shown in Fig. 12. The drop surface 224a is, for example, a surface perpendicular to the rotation axis M, i.e., a horizontal surface.

[0098] The side wall portion 225 is a cylindrical wall portion continuous to the peripheral edge of the bottom portion 224. The side wall portion 225 may be a cylindrical wall portion provided at a predetermined distance from the rotation axis M. The side wall portion 225 has a holding surface 225a. The holding surface 225a is a surface of the side wall portion 225 on the inner peripheral side.

[0099] When the liquid droplets D of the plasma raw material 101 are added dropwise into the drop surface 224a as shown in Fig. 12, the plasma raw material 101 flows from the drop surface 224a to the holding surface 225a due to centrifugal force caused by the rotation of the rotation body 220, and the plasma raw material 101 is held on the holding surface 225a as shown by an arrow in Fig. 16. The holding surface 225a is continuous to the peripheral edge of the drop surface 224a and is, for example, a surface perpendicular to the drop surface 224a. The holding surface 225a may be a surface that is inclined to the inner peripheral side or the outer peripheral side from the surface perpendicular to the drop surface 224a.

[0100] The shield portion 222 covers the incident liquid surface 101b described below and forms an irradiation space H between the shield portion 222 and the holding surface 225a as shown in Fig. 14. Note that illustration of the shield portion 222 is omitted in Fig. 10 and Fig. 11. As shown in Fig. 14, the shield portion 222 includes a ceiling portion 226 that is continuous to the side wall portion 225 and an inner wall portion 227 that is continuous to the ceiling portion 226. The ceiling portion 226 is a plate-shaped member that is parallel to the bottom portion 224, and the inner wall portion 227 is a wall-shaped member that is parallel to the side wall portion 225. The shield portion 222 may have another shape as long as the irradiation space H is formed between the shield portion 222 and the holding surface 225a.

[0101] As shown in Fig. 16, the disturbance prevention portion 223 separates the supply liquid surface 101a and the incident liquid surface 101b, which are the liquid surfaces of the plasma raw material 101, from each other. The supply liquid surface 101a is a liquid surface to which a new plasma raw material 101 is supplied, of the liquid surfaces of the plasma raw material 101, and is a liquid surface that is continuous to the drop surface 224a, of the liquid surfaces of the plasma raw material 101 on the holding surface 225a. The incident liquid surface 101b is a liquid surface that the energy beam EB enters, of the liquid surfaces of the plasma raw material 101, and is a liquid surface in the irradiation space H, of the liquid surfaces of the plasma raw material 101 on the holding surface 225a.

[0102] Specifically, the disturbance prevention portion 223 includes a partition wall 228. The partition wall 228 is a partition wall that is provided in a liquid of the plasma raw material 101 via the liquid surfaces of the plasma raw material

101 from the inner wall portion 227. The partition wall 228 is spaced apart from the holding surface 225a and has a gap 228a between the partition wall 228 and the holding surface 225a.

[0103] Fig. 17 is a schematic diagram showing supply of the plasma raw material 101 and application of the energy beam EB to the rotation body 220 from the raw material supply device 130. When the liquid droplets D of the plasma raw material 101 are added dropwise into the drop surface 224a, the liquid droplets D flows from the drop surface 224a to the supply liquid surface 101a due to centrifugal force caused by rotation of the rotation body 220, as shown in the figure. As shown by a broken arrow in Fig. 17, the plasma raw material 101 flows from the side of the supply liquid surface 101a to the side of the incident liquid surface 101b via the gap 228a.

[0104] Further, as shown in Fig. 17, the energy beam EB enters the incident liquid surface 101b via the shield portion 222 to generate the plasma P. Since the plasma raw material 101 is consumed due to transformation into plasma by application of the energy beam EB, the liquid droplets D are continuously added dropwise into the drop surface 224a also during the application of the energy beam EB. Note that the shield portion 222 is provided with a through path (not shown) through which the energy beam EB and the radiation R pass. The through path is a gap or opening provided in the inner wall portion 227.

[Effects of disturbance prevention portion]

[0105] When the liquid droplets D of the plasma raw material 101 are added dropwise into the drop surface 224a, the liquid droplets D flow from the drop surface 224a to the supply liquid surface 101a as shown in Fig. 17. At this time, wavefront fluctuations are caused in the supply liquid surface 101a due to a collision of the plasma raw material 101 with the supply liquid surface 101a. Here, the disturbance prevention portion 223 includes the partition wall 228 that separates the supply liquid surface 101a and the incident liquid surface 101b from each other, and the partition wall 228 prevents the wavefront fluctuations from being transmitted to the incident liquid surface 101b. As a result, the incident liquid surface 101b becomes stable, the irradiation position I does not fluctuate, and the intensity of the radiation R is also stable.

[Other configurations of rotation body]

[0106] Fig. 18 to Fig. 20 are each a schematic diagram showing another configuration of the rotation body 220. As shown in Fig. 18, the disturbance prevention portion 223 may further include a flow velocity suppression portion 229. The flow velocity suppression portion 229 is provided in a liquid of the plasma raw material 101 and suppresses the flow velocity of the plasma raw material 101 passing through the disturbance prevention portion 223.

[0107] Specifically, as shown in Fig. 18, the flow velocity suppression portion 229 may be a protruding portion that protrudes from the holding surface 225a toward the liquid surfaces of the plasma raw material 101. This protruding portion blocks the flow of the plasma raw material 101 passing through the gap 228a and changes the flow direction to suppress the flow velocity of the plasma raw material 101. As a result, the disturbance prevention portion 223 is capable of further suppressing the fluctuations of the incident liquid surface 101b.

[0108] In addition, the flow velocity suppression portion 229 may be a hilly structure provided on the holding surface 225a or a porous structure provided on the holding surface 225a. The flow velocity suppression portion 229 may be provided on the side of the incident liquid surface 101b than the gap 228a. Further, the disturbance prevention portion 223 may also include one or more partition walls 228 and one or more flow velocity suppression portions 229.

[0109] As shown in Fig. 19, the holding surface 225a may include a first region 225b and a second region 225c. The first region 225b is located at a first distance from the rotation axis M (see Fig. 13), and the second region 225c is located at a second distance from the rotation axis M. The second distance is smaller than the first distance, and a depth L1 of the plasma raw material on the first region 225b is deeper than a depth L2 of the plasma raw material on the second region 225c. The supply liquid surface 101a is provided on the first region 225b, and the incident liquid surface 101b is provided on the second region 225c.

[0110] This allows the wavefront fluctuations of the supply liquid surface 101a to be more difficult to transmit to the incident liquid surface 101b. In addition, the depth L2 of the plasma raw material in the incident liquid surface 101b can be adjusted by the depth of the second region 225c (second distance). Note that the second distance may be larger than the first distance, i.e., the depth L2 may be deeper than the depth L1. Also in this configuration, the disturbance prevention portion 223 may include one or more partition walls 228 and one or more flow velocity suppression portions 229.

[0111] Further, as shown in Fig. 20, the rotation body 220 does not necessarily need to include the shield portion 222, and the disturbance prevention portion 223 may include a partition wall 230 that protrudes above the liquid of the plasma raw material 101 from the holding surface 225a. The partition wall 230 has an opening 230a that is located in the liquid of the plasma raw material 101, and the plasma raw material 101 is movable from the side of the supply liquid surface 101a to the side of the incident liquid surface 101b via the opening 230a. The number and shape of openings 230a are not particularly limited.

[0112] Also in this configuration, the disturbance prevention portion 223 may include one or more partition walls 228 and one or more flow velocity suppression portions 229. Further, the holding surface 225a may have the first region 225b and the second region 225c (see Fig. 19). Note that although the rotation body 220 includes the partition wall 228 in the above configurations, the partition wall 228 may be fixed separately from the rotation body 220 and does not necessarily need to rotate together with the rotation body 220.

<Third embodiment>

[Basic configuration of light source apparatus]

[0113] A light source apparatus according to a third embodiment of the present invention will be described.

[Configuration of plasma generation mechanism]

[0114] Fig. 21 is a schematic diagram showing a configuration example of a light source apparatus 300 according to the third embodiment of the present invention, and Fig. 22 is a schematic enlarged view of part of the light source apparatus 300. Fig. 23 is a schematic diagram of a plasma generation mechanism 306 included in the light source apparatus 300. Of the configurations of the light source apparatus 300, configurations other than the plasma generation mechanism 306 are similar to those in the first embodiment. As shown in Fig. 21 and Fig. 23, the plasma generation mechanism 306 includes a rotation body 320, a rotational drive source 331, a shaft 332, and a reservoir tank 333.

[0115] The rotational drive source 331 is disposed outside the vacuum chamber 103 and generates rotational power of the rotation body 320. The rotational drive source 331 is, for example, a motor. The shaft 332 penetrates the chamber body 109 and the enclosure 102 to connect the rotational drive source 331 and the rotation body 320, and transmits the rotational power generated by the rotational drive source 331 to the rotation body 320. The reservoir tank 333 is located below the rotation body 320 and reserves the plasma raw material 101. As shown in Fig. 23, the liquid droplets D of the plasma raw material 101 are added dropwise from the raw material supply device 130 into the reservoir tank 333.

[0116] The rotation body 320 is disposed inside the vacuum chamber 103 and is connected to the shaft 332. As shown by an arrow S in Fig. 23, the rotation body 320 rotates by the rotation of the shaft 332. Hereinafter, the rotation axis of the rotation body 320 and the shaft 332 will be referred to as the rotation axis M. The rotation axis M is disposed along the horizontal direction (X-Y direction) such that the rotation surface is in the vertical direction. Part of the rotation body 320 is immersed in the plasma raw material 101 reserved in the reservoir tank 333, and the plasma raw material 101 adheres to the rotation body 320 along with the rotation.

[0117] Fig. 24 is a cross-sectional view of the rotation body 320, Fig. 25 is an enlarged view of Fig. 24, and Fig. 26 is a plan view of the rotation body 320. Fig. 24 shows the cross section of the rotation body 320 taken along the line C-C in Fig. 26. Fig. 27 is a schematic diagram showing the rotation body 320 and the plasma raw material 101. As shown in these figures, the rotation body 320 includes a body portion 321 and a disturbance prevention portion 322.

[0118] The body portion 321 includes a bottom portion 323, a side wall portion 324, and a ceiling portion 325. The bottom portion 323 is a plate-shaped portion and may have a disc shape. The shaft 332 is connected to the center of the body portion 321. The bottom portion 323 has an adhesion surface 323a. The adhesion surface 323a is a surface of the bottom portion 323 opposite to the shaft 332, and is a surface to which the plasma raw material 101 of the reservoir tank 333 adheres, as shown in Fig. 23. The adhesion surface 323a is, for example, a surface perpendicular to the rotation axis M, i.e., a vertical surface.

[0119] The side wall portion 324 is a cylindrical wall portion continuous to the peripheral edge of the bottom portion 323. The side wall portion 324 may be a cylindrical wall portion provided at a predetermined distance from the rotation axis M. The ceiling portion 325 is a plate-shaped portion that is parallel to the bottom portion 323 and may have an annular shape. The ceiling portion 325 is connected to the end of the side wall portion 324 opposite to the bottom portion 323. As shown in Fig. 25, in the peripheral edge of the rotation body 320, the bottom portion 323, the side wall portion 324, the ceiling portion 325, and a partition wall 326 described below form a channel 327.

[0120] When the rotation body 320 rotates while the plasma raw material 101 adheres to the adhesion surface 323a, the plasma raw material 101 flows from the adhesion surface 323a to the channel 327 due to centrifugal force caused by the rotation of the rotation body 320, as shown by an arrow in Fig. 27. While the rotation body 320 rotates, the plasma raw material 101 is held inside the channel 327.

[0121] As shown in Fig. 27, the disturbance prevention portion 322 separates the supply liquid surface 101a and the incident liquid surface 101b, which are the liquid surfaces of the plasma raw material 101, from each other. The supply liquid surface 101a is a liquid surface to which the plasma raw material 101 is newly supplied, of the liquid surfaces of the plasma raw material 101, and is a liquid surface of the plasma raw material 101 in the channel 327. As shown in Fig. 27, the supply liquid surface 101a is a liquid surface that is parallel to the rotation axis M. The incident liquid surface 101b is a liquid surface that the energy beam EB enters, of the liquid surfaces of the plasma raw material 101, and is a

liquid surface perpendicular to the rotation axis M, as shown in Fig. 27.

[0122] Specifically, as shown in Fig. 25, the disturbance prevention portion 322 includes the partition wall 326. The partition wall 326 is located between the supply liquid surface 101a and the incident liquid surface 101b and forms the channel 327 in a gap between the partition wall 326 and the opposing members, i.e., the bottom portion 323, the side wall portion 324, and the ceiling portion 325. The channel 327 includes an entrance 327a between the partition wall 326 and the bottom portion 323 and an exit 327b between the partition wall 326 and the ceiling portion 325.

[0123] Fig. 28 is a schematic diagram showing supply of the plasma raw material 101 and application of and the energy beam EB to the rotation body 320. When the plasma raw material 101 adheres from the reservoir tank 333 to the adhesion surface 323a, the plasma raw material 101 flows from the adhesion surface 323a to the channel 327 via the entrance 327a due to centrifugal force caused by rotation of the rotation body 320, as shown in the figure. As shown by a broken arrow in Fig. 28, the plasma raw material 101 flows through the channel 327.

[0124] Further, as shown in Fig. 28, the energy beam EB enters the incident liquid surface 101b to generate the plasma P. Since the plasma raw material 101 is consumed due to transformation into plasma by application of the energy beam EB, the liquid droplets D are continuously added dropwise into the reservoir tank 333 (see Fig. 23) also during the application of the energy beam EB.

[Effects of disturbance prevention portion]

[0125] When the plasma raw material 101 adheres to the adhesion surface 323a, the plasma raw material 101 flows from the adhesion surface 323a to the supply liquid surface 101a, as shown in Fig. 28. At this time, wavefront fluctuations are caused in the supply liquid surface 101a due to a collision of the plasma raw material 101 with the supply liquid surface 101a. Here, the disturbance prevention portion 223 includes the partition wall 326 that separates the supply liquid surface 101a and the incident liquid surface 101b from each other, and the partition wall 326 prevents the wavefront fluctuations from being transmitted to the incident liquid surface 101b. As a result, the incident liquid surface 101b becomes stable, the irradiation position I does not fluctuate, and the intensity of the radiation R is also stable.

[Other configurations of rotation body]

[0126] Fig. 29 and Fig. 30 are each a schematic diagram showing another configuration of the rotation body 320. As shown in Fig. 29, the disturbance prevention portion 322 may form the channel 327 that passes through the position that is spaced apart from the rotation axis M than the incident liquid surface 101b, i.e., the outer periphery side of the rotation body 320 than the incident liquid surface 101b. Fig. 31 shows a state in which the supply liquid surface 101a is located on the outer periphery side than the partition wall 326 in the above-mentioned configuration, as comparison. In this case, since the supply liquid surface 101a and the incident liquid surface 101b are not separated from each other, wavefront fluctuations of the supply liquid surface 101a are transmitted to the incident liquid surface 101b.

[0127] On the other hand, in the configuration shown in Fig. 29, the channel 327 passing through the position that is spaced apart from the rotation axis M than the incident liquid surface 101b is provided. As a result, the partition wall 326 separates the supply liquid surface 101a and the incident liquid surface 101b from each other even if the supply liquid surface 101a is located on the outer periphery side than the partition wall 326, and it is possible to prevent the wavefront fluctuations of the supply liquid surface 101a from being transmitted to the incident liquid surface 101b.

[0128] As shown in Fig. 30, the channel 327 may be provided to be inclined in a direction parallel to the rotation axis M (Y direction) with respect to the adhesion surface 323a, and the supply liquid surface 101a may be spaced apart from the adhesion surface 323a in the same direction (Y direction). In this case, since the flow velocity of the plasma raw material 101 flowing through the channel 327 is reduced, it is possible to make the incident liquid surface 101b further stable. Note that although the channel 327 extends downward with respect to the adhesion surface 323a in Fig. 30, the channel 327 may extend upward with respect to the adhesion surface 323a.

[0129] In addition, the disturbance prevention portion 322 may include a flow velocity suppression portion such as a hilly structure and a porous structure provided in the channel 327. Note that although the rotation body 320 includes the partition wall 326 in the above configurations, the partition wall 326 may be fixed separately from the rotation body 220 and does not necessarily need to rotate together with the rotation body 220.

[0130] In the present disclosure, words such as "substantially" are used to readily understand the explanation. There is no clear difference between the cases where these words "substantially" are used and the cases where they are not used. In other words, in the present disclosure, concepts that define shapes, sizes, position relationships, and states, such as "center", "middle", "uniform", "equal", "same", "orthogonal", "parallel", "symmetrical", "extending", "axial direction", "circular shape", "arc shape", "rectangular shape", "polygonal shape", "ring shape", "cubic shape", "rectangular parallelepiped shape", "columnar shape", "disc shape", and "cone shape", are concepts including "substantially center", "substantially middle", "substantially uniform", "substantially equal", "substantially the same", "substantially orthogonal", "substantially parallel", "substantially symmetrical", "substantially extending", "substantially axial direction", "substantially

circular shape", "substantially arc shape", "substantially rectangular shape", "substantially polygonal shape", "substantially ring shape", "substantially cubic shape", "substantially rectangular parallelepiped shape", "substantially columnar shape", "substantially disc shape", and "substantially cone shape". The concepts also include concepts having states in a predetermined range (e.g., $\pm 10\%$ range) with respect to, for example, "exactly center", "exactly middle", "exactly uniform", "exactly equal", "exactly the same", "exactly orthogonal", "exactly parallel", "exactly symmetrical", "exactly extending", "exactly axial direction", "exactly circular shape", "exactly arc shape", "exactly rectangular shape", "exactly polygonal shape", "exactly ring shape", "exactly cubic shape", "exactly rectangular parallelepiped shape", "exactly columnar shape", "exactly disc shape", and "exactly cone shape". Hence, even when the words "substantially" are not added, the concepts may include those that are expressed by adding so-called "substantially". Conversely, states expressed by adding "substantially" do not necessarily exclude their exact states.

[0131] In the present disclosure, expressions using the term "than" such as "greater than A" and "less than A" are expressions that comprehensively include both concepts that include the case that is equal to A and concepts that do not include the case that is equal to A. For example, "greater than A" is not limited to the case where it does not include "equal to A", and it also includes "equal to or greater than A". Further, "less than A" is not limited to "less than A", and it also includes "equal to or less than A". Upon the implementation of the present technology, specific settings and other settings only need to be appropriately adopted from the concepts that are included in "greater than A" and "less than A" to achieve the effects described above.

[0132] Among the characteristic portions according to the present technology described above, it is also possible to combine at least two of the characteristic portions. In other words, the various characteristic portions described in the respective embodiments may be arbitrarily combined with each other without distinguishing from each other in the respective embodiments. The various effects described above are merely examples and are not limitative, and other effects may also be achieved.

Reference Signs List

[0133]

100, 200, 300	light source apparatus
101	plasma raw material
102	enclosure
106, 206, 306	plasma generation mechanism
120	raw material container
121	reservoir tank
122	lid portion
123, 223, 322	disturbance prevention portion
126, 128, 228, 230, 326	partition wall
127, 229	flow velocity suppression portion
220, 320	rotation body
221	body portion
222	shield portion
224a	drop surface
323a	adhesion surface
327	channel

Claims

1. A plasma generation mechanism included in a light source apparatus that transforms a liquid plasma raw material into plasma by irradiation of an energy beam to extract radiation, comprising:
a disturbance prevention portion that separates a supply liquid surface to which the plasma raw material is newly supplied, of liquid surfaces of the plasma raw material, and an incident liquid surface that the energy beam enters, of the liquid surfaces of the plasma raw material, from each other and communicates the plasma raw material between a side of the supply liquid surface and a side of the incident liquid surface.
2. The plasma generation mechanism according to claim 1, further comprising
a reservoir tank that reserves the plasma raw material,
the supply liquid surface being a liquid surface where the plasma raw material is added dropwise, of liquid

surfaces of the plasma raw material reserved in the reservoir tank.

3. The plasma generation mechanism according to claim 1, further comprising

a rotation body that has a drop surface where the plasma raw material is added dropwise and a holding surface that holds the plasma raw material flowed from the drop surface due to centrifugal force caused by rotation, the supply liquid surface being a liquid surface continuous to the drop surface, of liquid surface of the plasma raw material on the holding surface.

4. The plasma generation mechanism according to claim 1, further comprising:

a reservoir tank that reserves the plasma raw material; and
a rotation body that is immersed in the reservoir tank, has an adhesion surface to which the plasma raw material adheres, and includes a channel where the plasma raw material flows from the adhesion surface due to centrifugal force caused by rotation,
the supply liquid surface being a liquid surface in the channel, of liquid surfaces of the plasma raw material.

5. The plasma generation mechanism according to any one of claims 2 to 4, wherein
the disturbance prevention portion includes a partition wall that is provided in a liquid of the plasma raw material via the liquid surfaces of the plasma raw material from above the liquid surfaces.

6. The plasma generation mechanism according to claim 5, wherein
the partition wall has an opening or a gap that communicates the plasma raw material between a side of the supply liquid surface and a side of the incident liquid surface of the partition wall.

7. The plasma generation mechanism according to claim 2, further comprising

a lid portion that faces the liquid surfaces of the plasma raw material above the liquid surfaces,
the disturbance prevention portion including a partition wall that is provided in a liquid of the plasma raw material via the liquid surfaces from the lid portion.

8. The plasma generation mechanism according to claim 3, further comprising

a shield portion that covers the incident liquid surface,
the disturbance prevention portion including a partition wall that is provided in a liquid of the plasma raw material via the liquid surfaces from the shield portion.

9. The plasma generation mechanism according to claim 8, wherein

the holding surface has a first region that is located at a first distance from a rotation axis of the rotation body and a second region that is located at a second distance from the rotation axis of the rotation body, the second distance being smaller than the first distance, and
the supply liquid surface is located on the first region and the incident liquid surface is located on the second region.

10. The plasma generation mechanism according to claim 4, wherein

the supply liquid surface is a liquid surface that is parallel to the rotation axis of the rotation body,
the incident liquid surface is a liquid surface that is perpendicular to the rotation axis of the rotation body, and
the disturbance prevention portion is a partition wall that is located between the supply liquid surface and the incident liquid surface and forms the channel between the partition wall and an opposing member.

11. The plasma generation mechanism according to claim 10, wherein
the supply liquid surface is spaced apart from the adhesion surface in a direction parallel to the rotation axis.

12. The plasma generation mechanism according to claim 1, wherein
the disturbance prevention portion includes a flow velocity suppression portion that is provided in a liquid of the plasma raw material and suppresses flow velocity of the plasma raw material passing through the disturbance

prevention portion.

13. The plasma generation mechanism according to claim 1, wherein the radiation is extreme ultraviolet light or X-rays.

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14. The plasma generation mechanism according to claim 1, wherein the plasma raw material is tin, lithium, gadolinium, terbium, gallium, bismuth, or an alloy including at least one of these materials.

15. A light source apparatus that transforms a liquid plasma raw material into plasma by irradiation of an energy beam to extract radiation, comprising:

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a plasma generation mechanism including a disturbance prevention portion that separates a supply liquid surface to which a new plasma raw material is supplied, of liquid surfaces of the plasma raw material, and an incident liquid surface that the energy beam enters, of the liquid surfaces of the plasma raw material, from each other and communicates the plasma raw material between a side of the supply liquid surface and a side of the incident liquid surface; and

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a beam source that causes the energy beam to enter the incident liquid surface.

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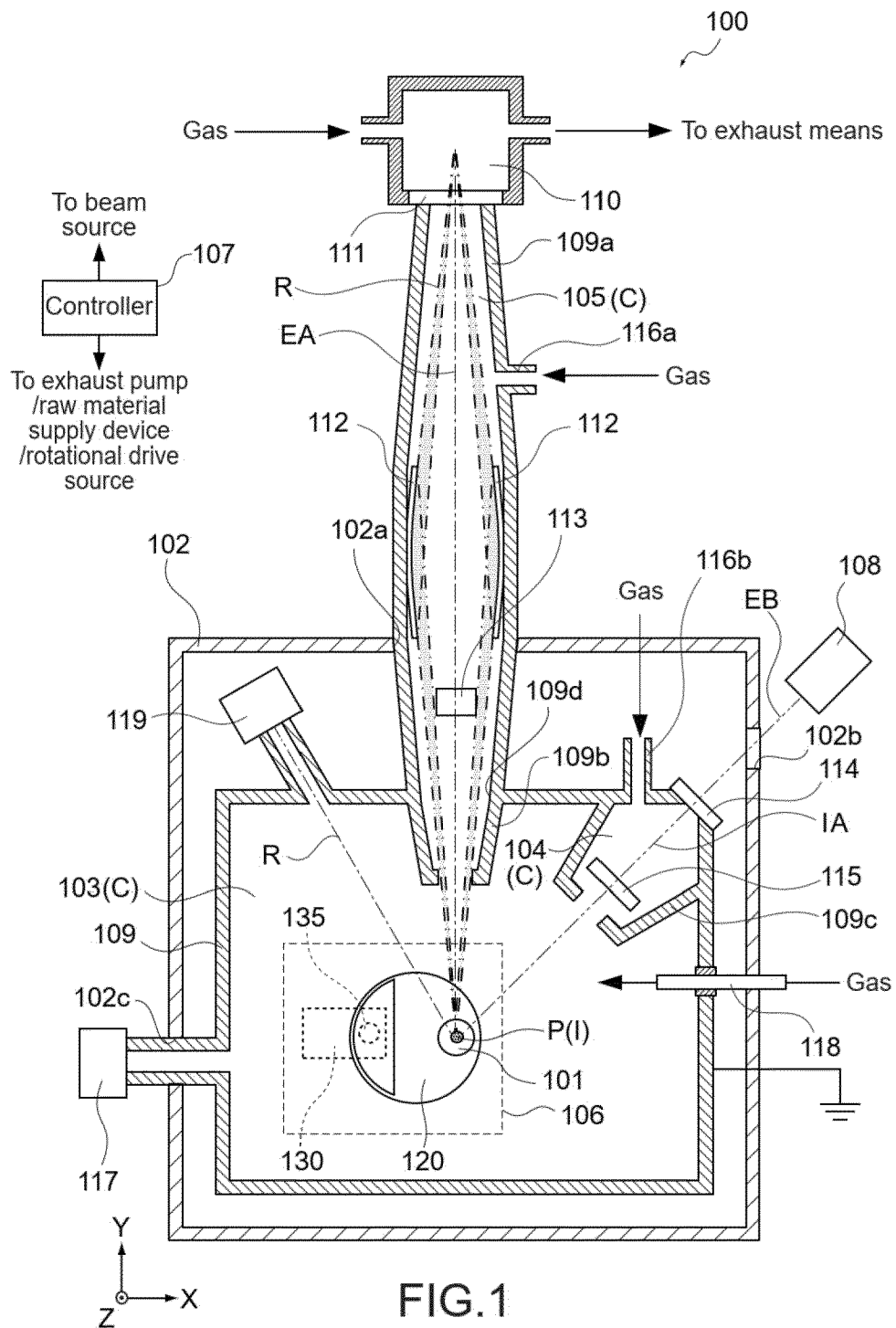
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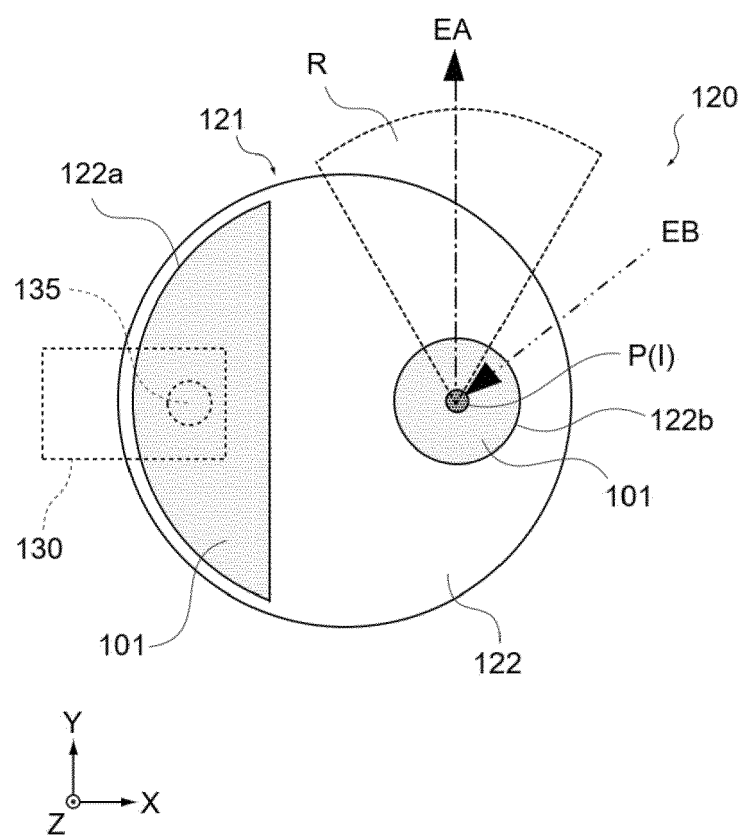


FIG.2

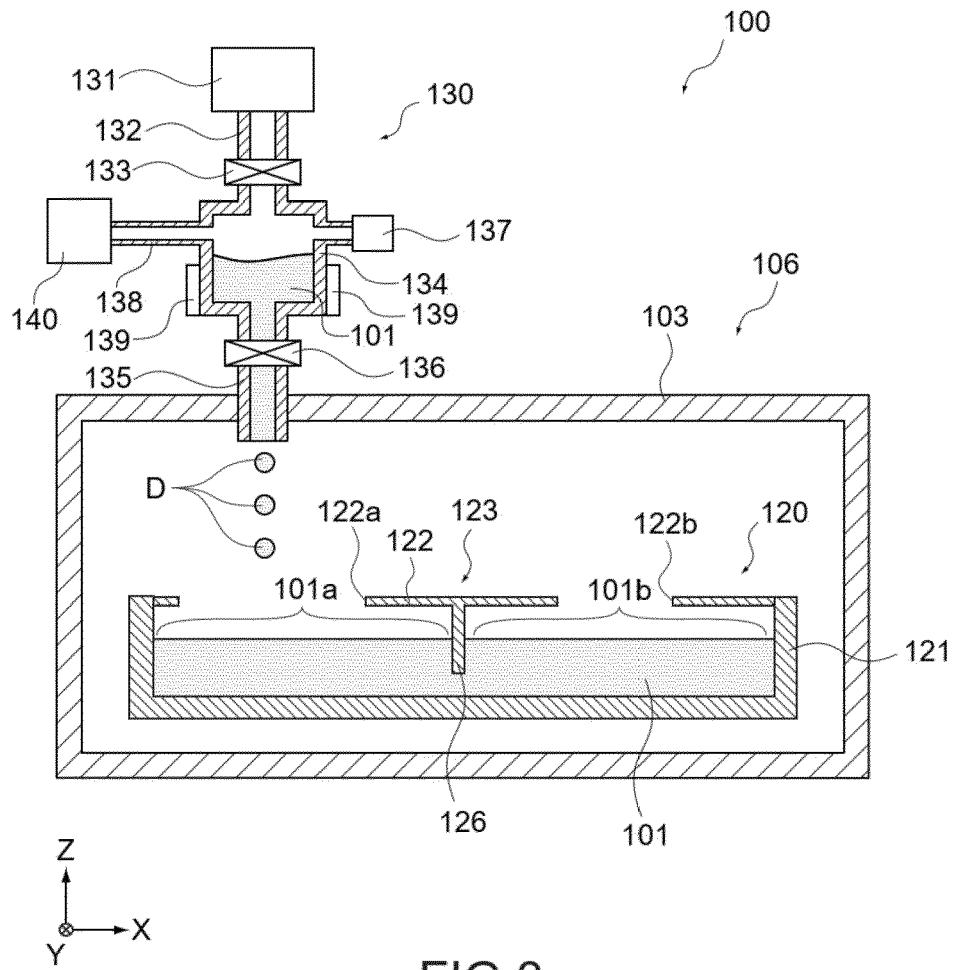


FIG.3

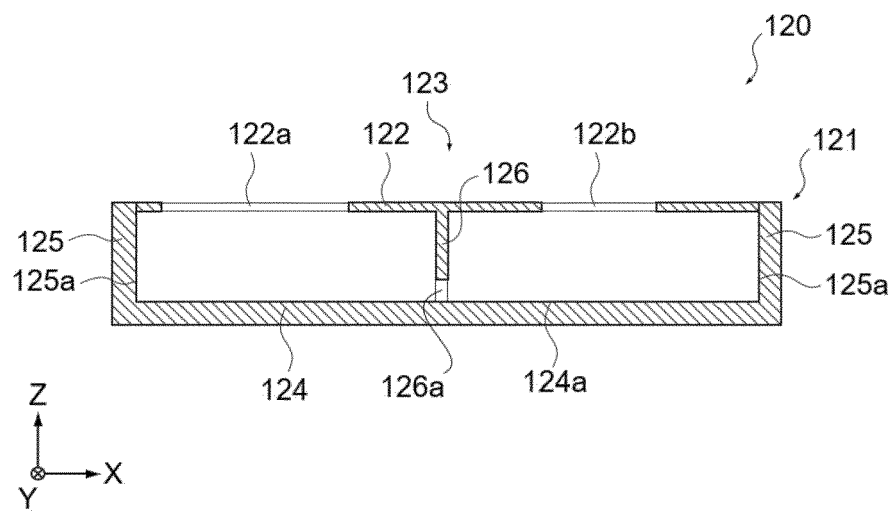


FIG.4

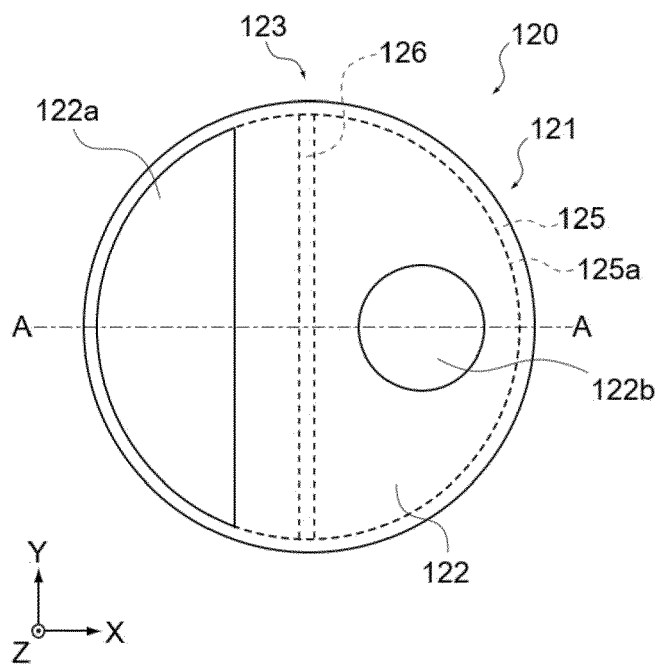


FIG.5

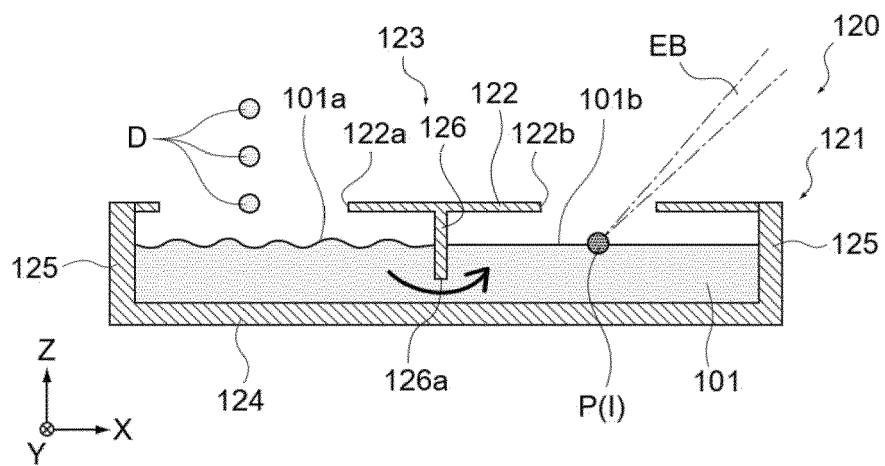


FIG.6

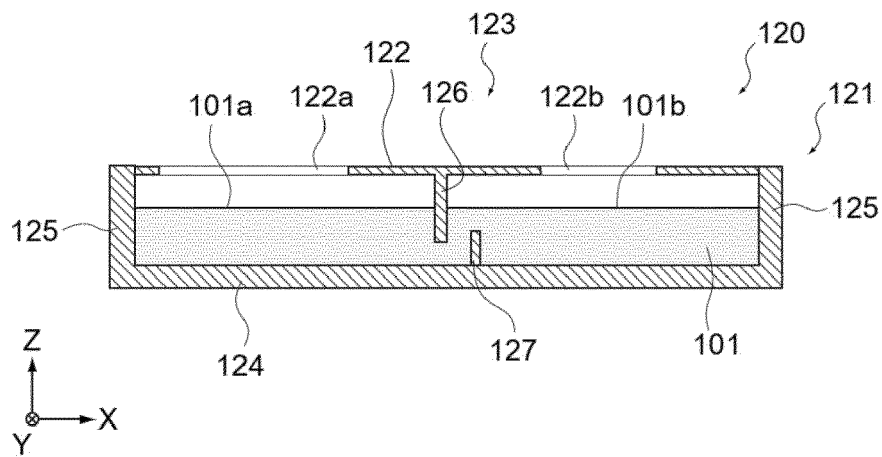


FIG.7

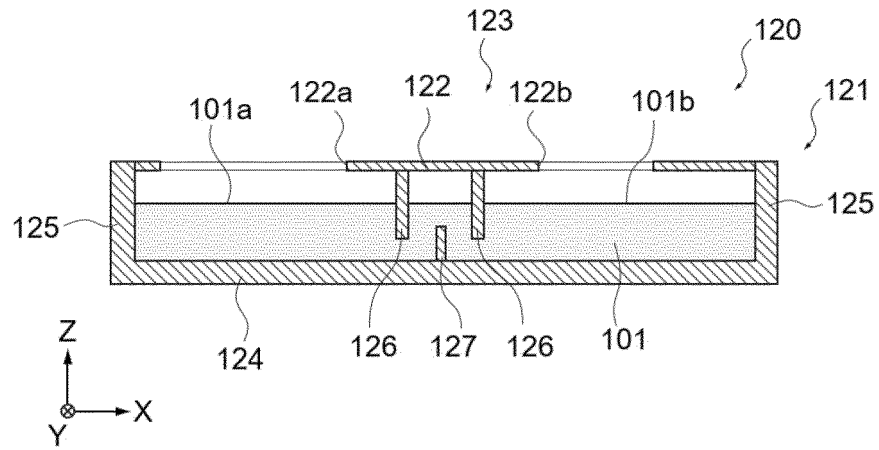


FIG.8

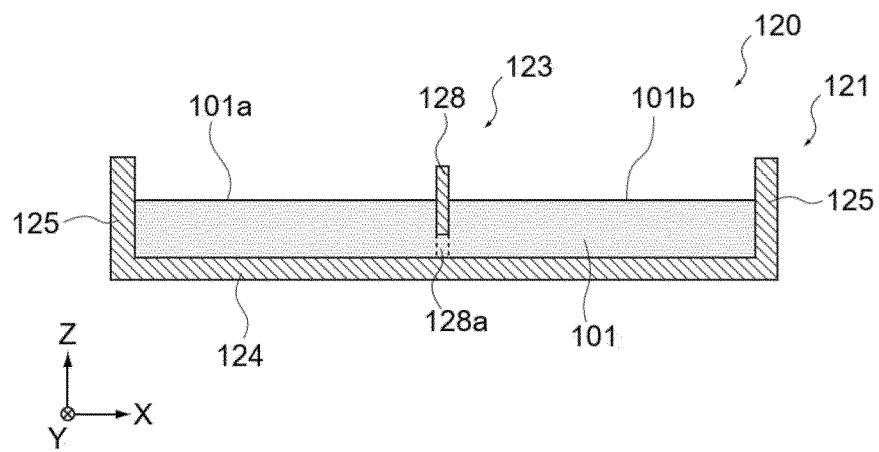


FIG.9

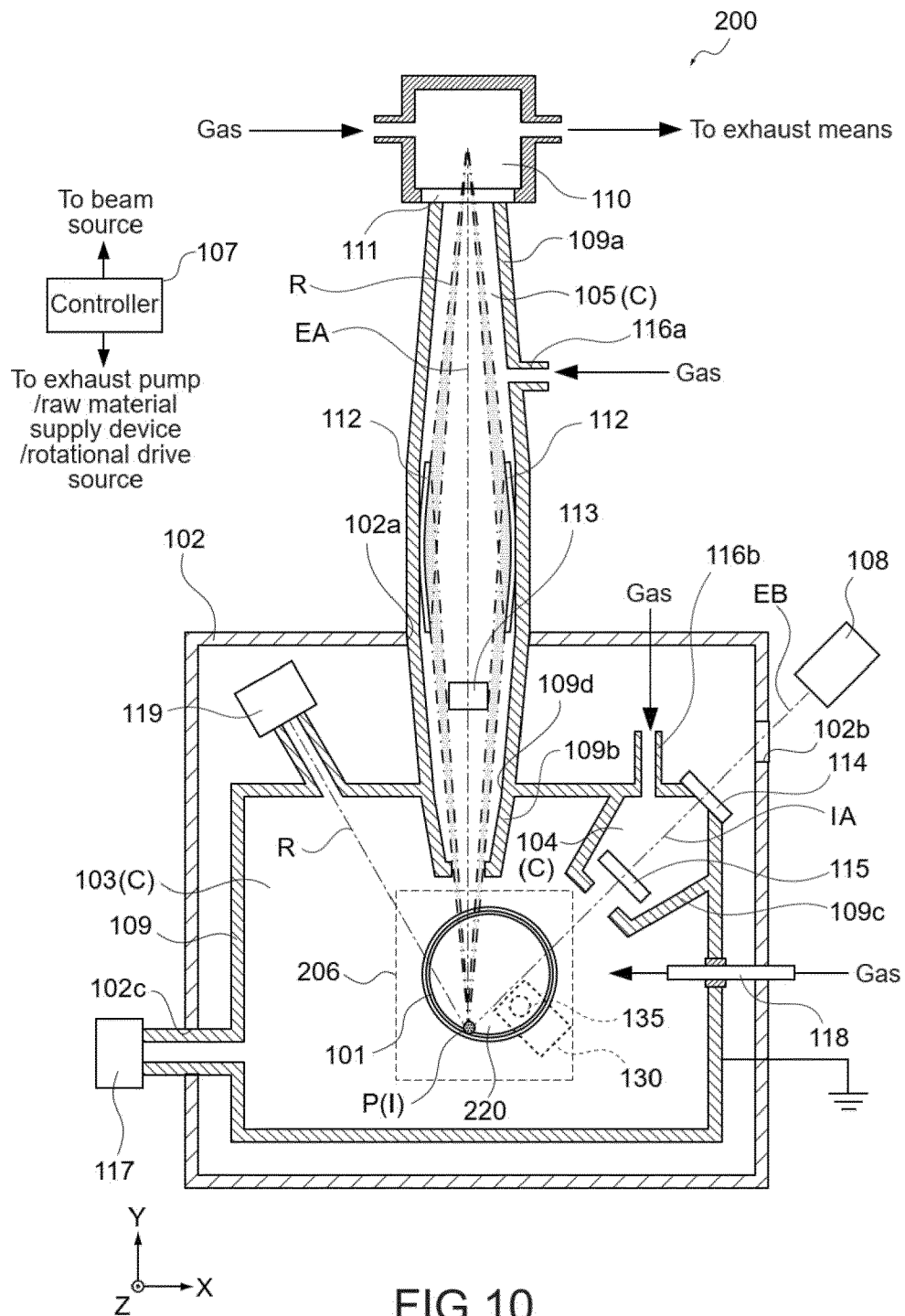


FIG.10

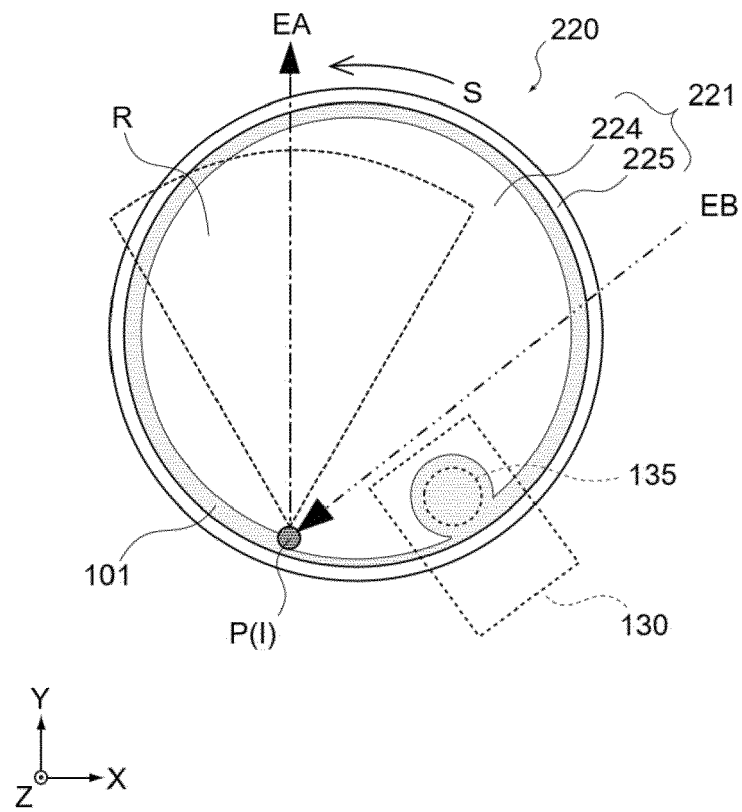


FIG.11

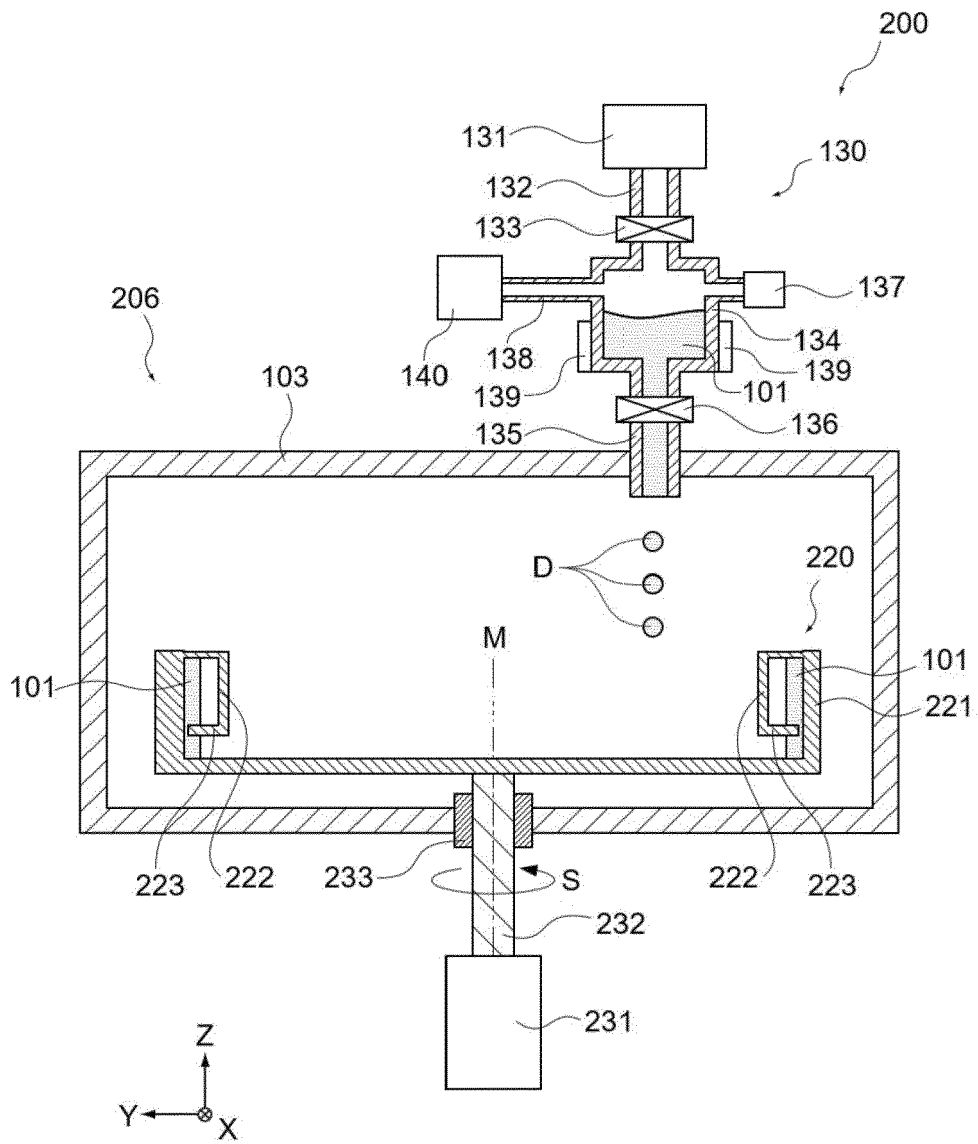


FIG.12

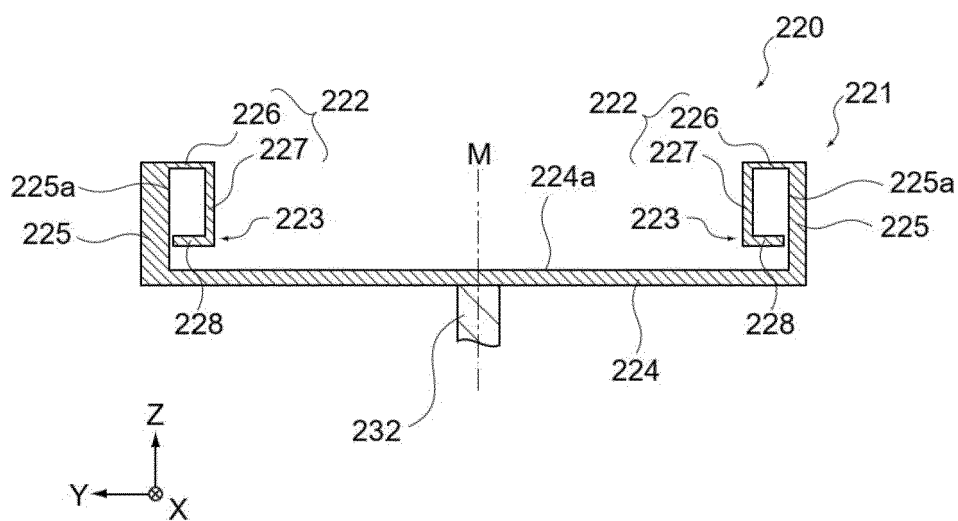


FIG. 13

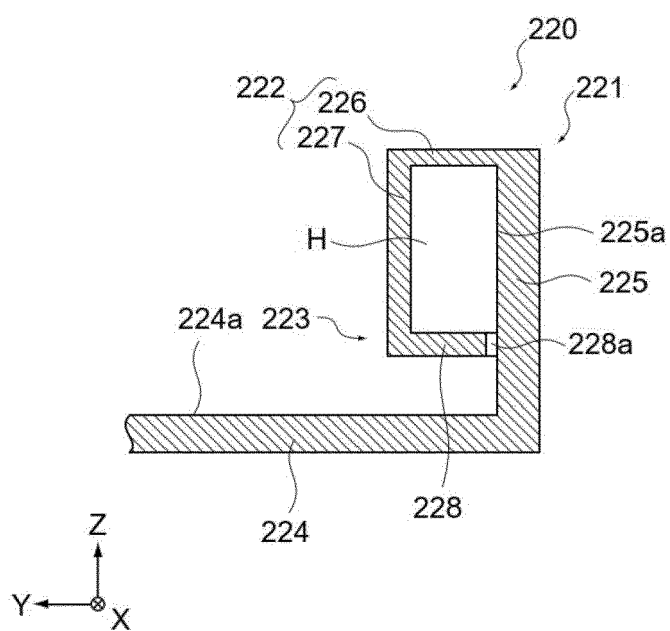


FIG. 14

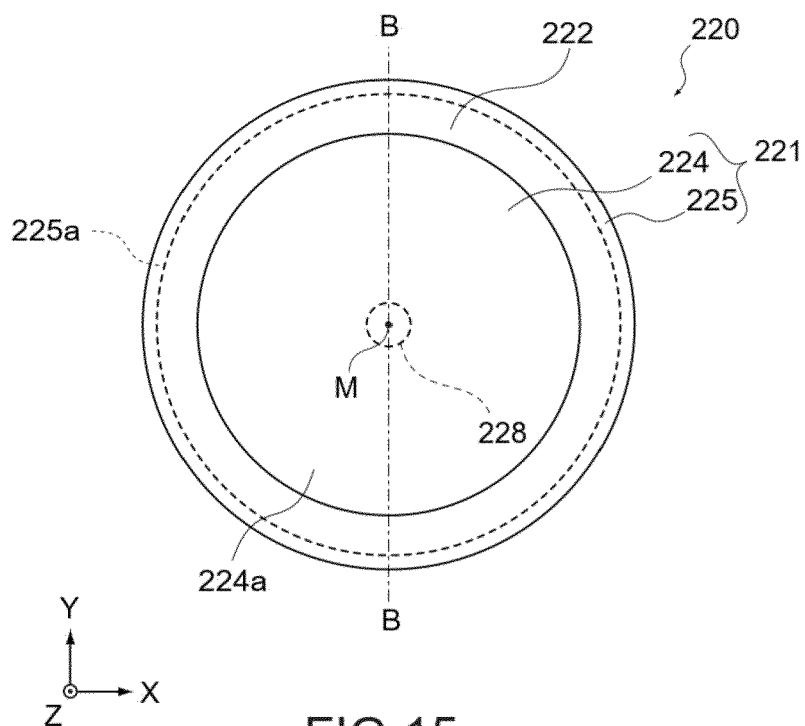


FIG. 15

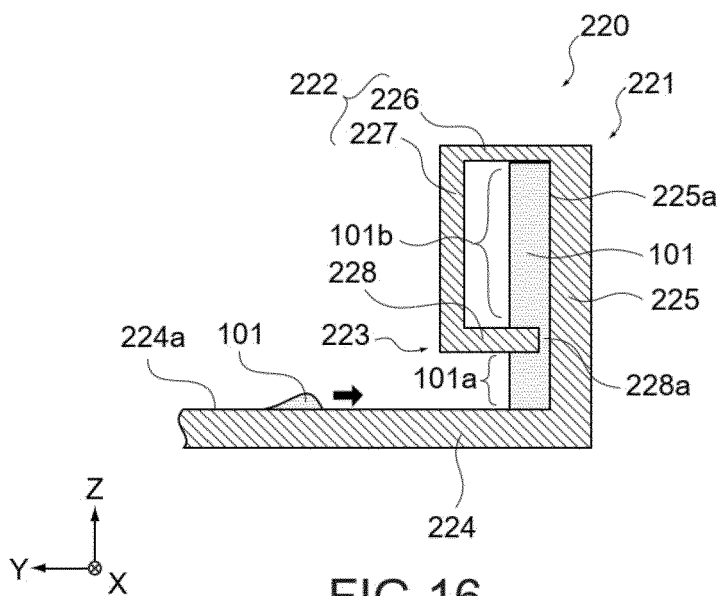
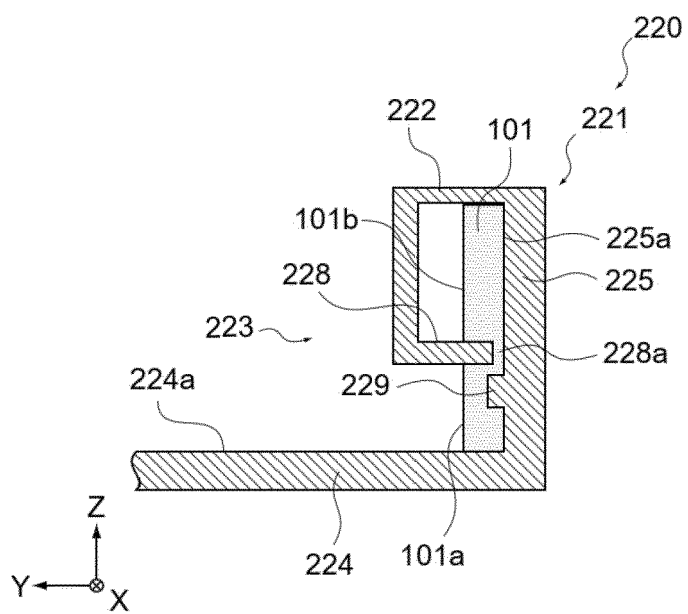
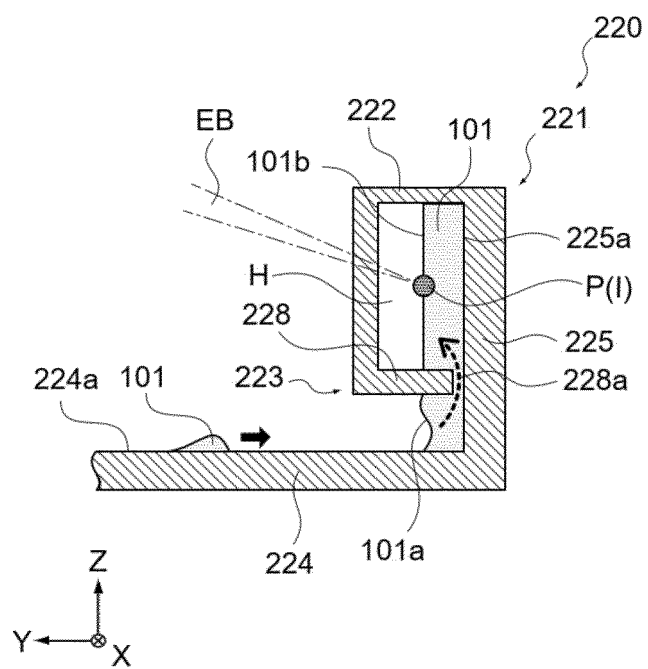


FIG. 16



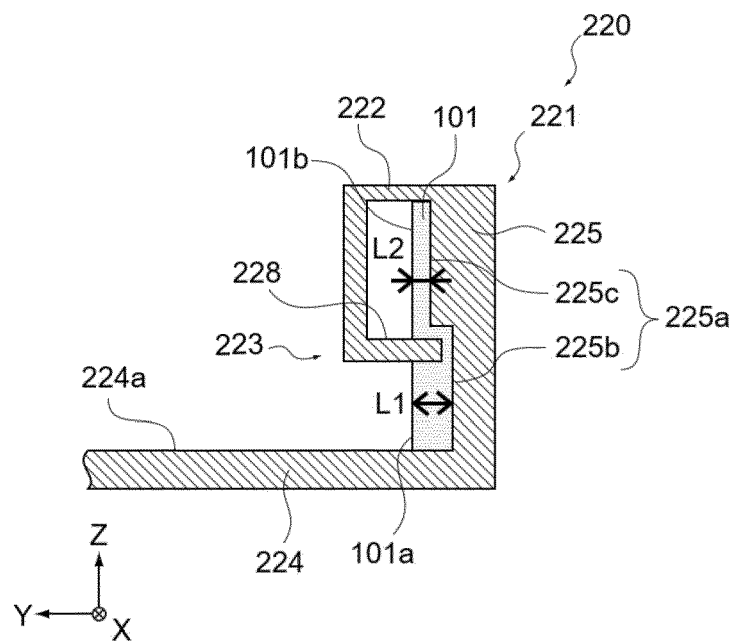


FIG. 19

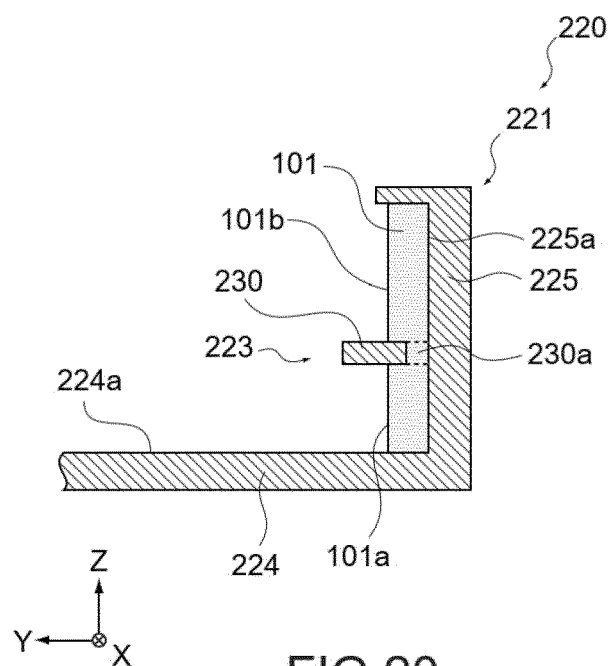


FIG. 20

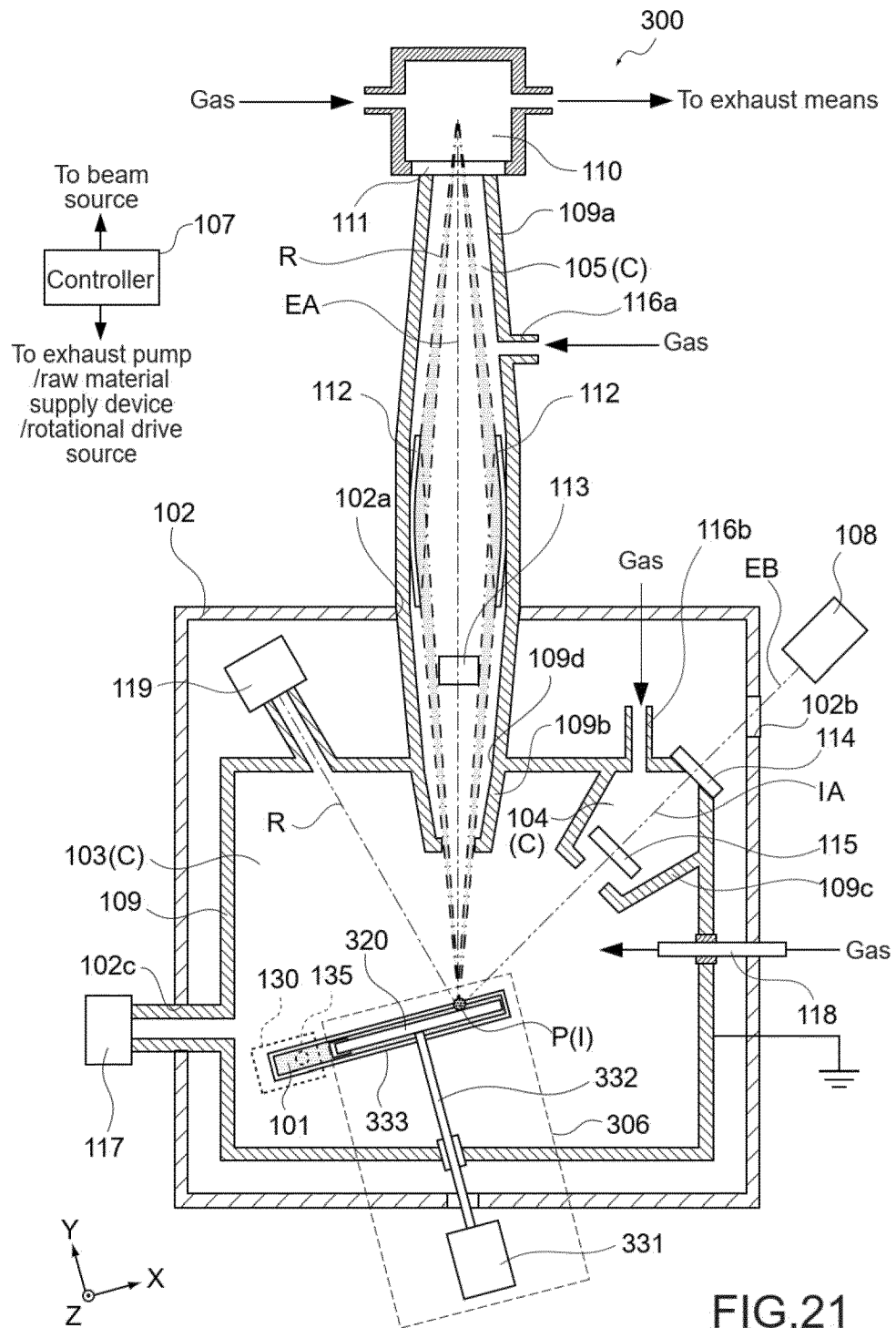


FIG.21

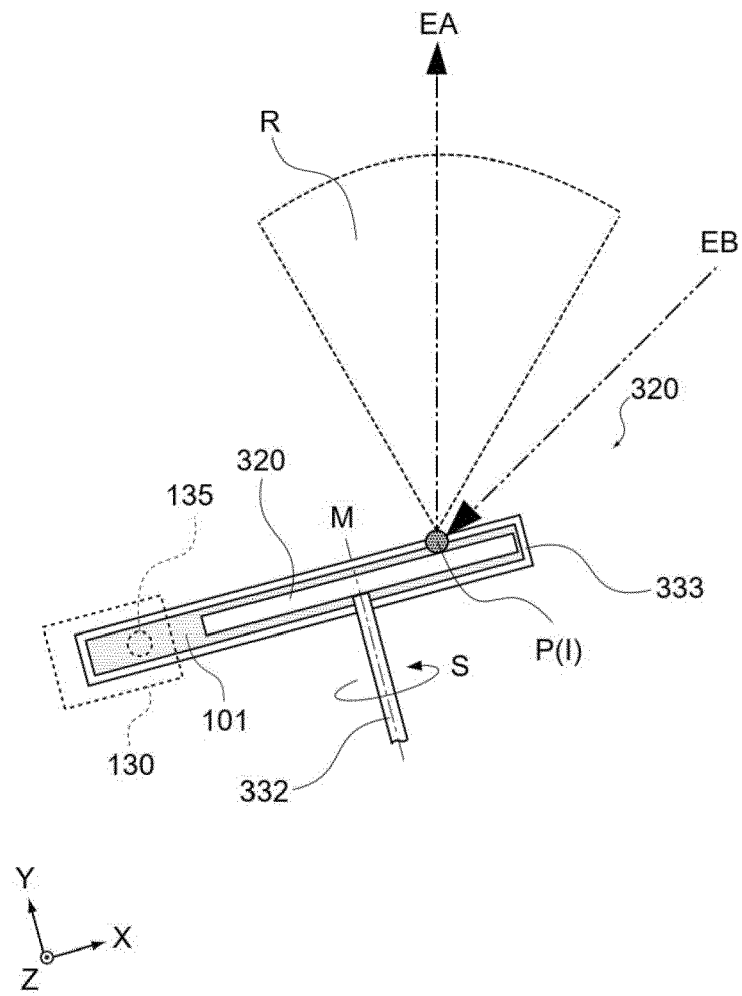


FIG.22

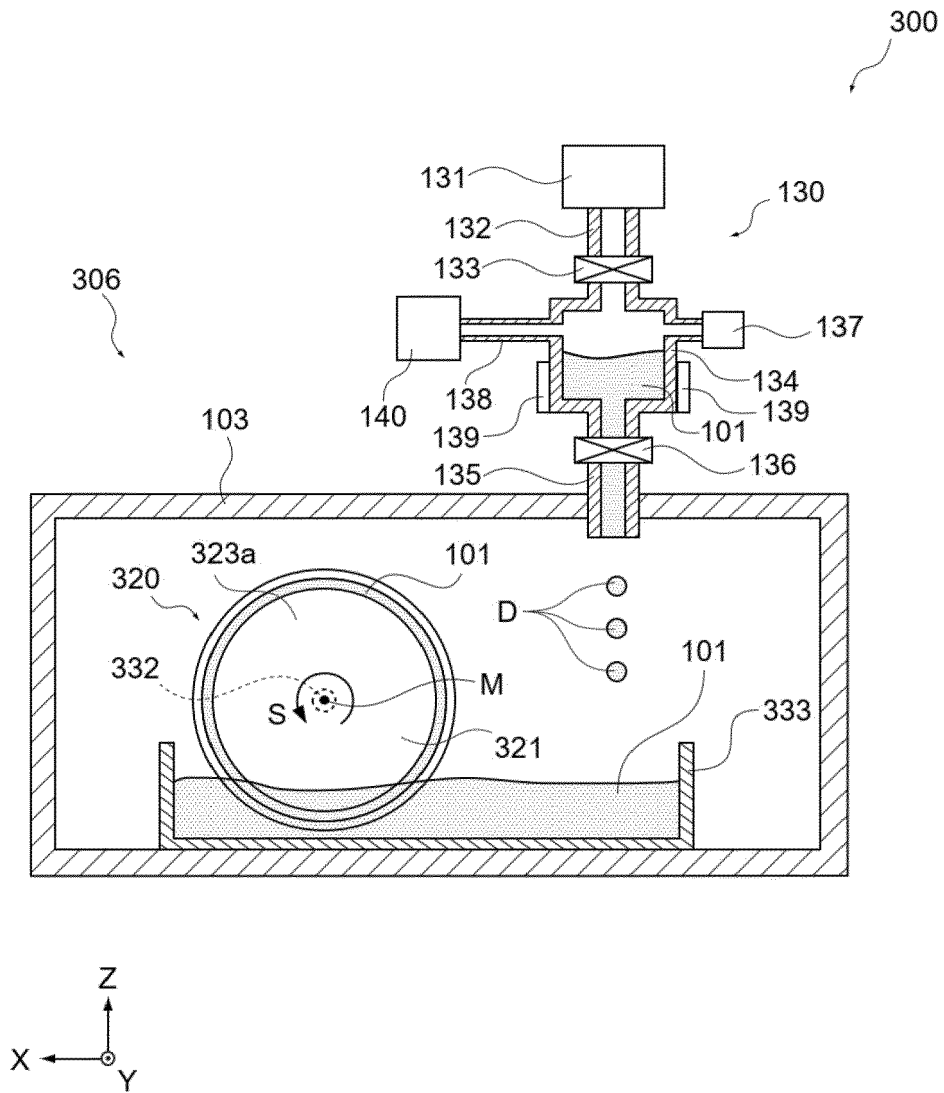


FIG. 23

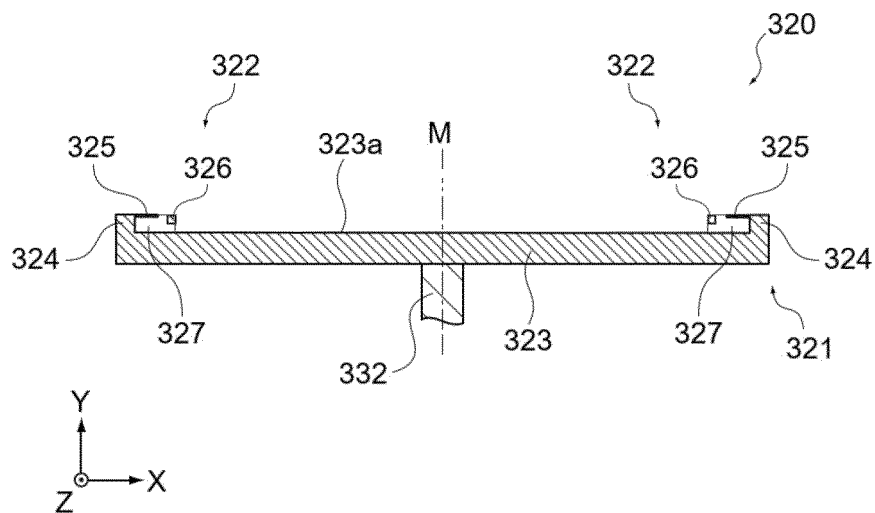


FIG. 24

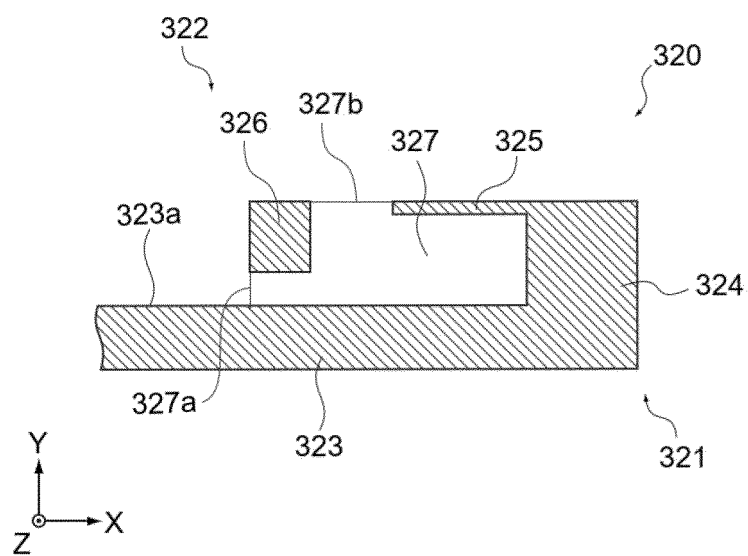


FIG. 25

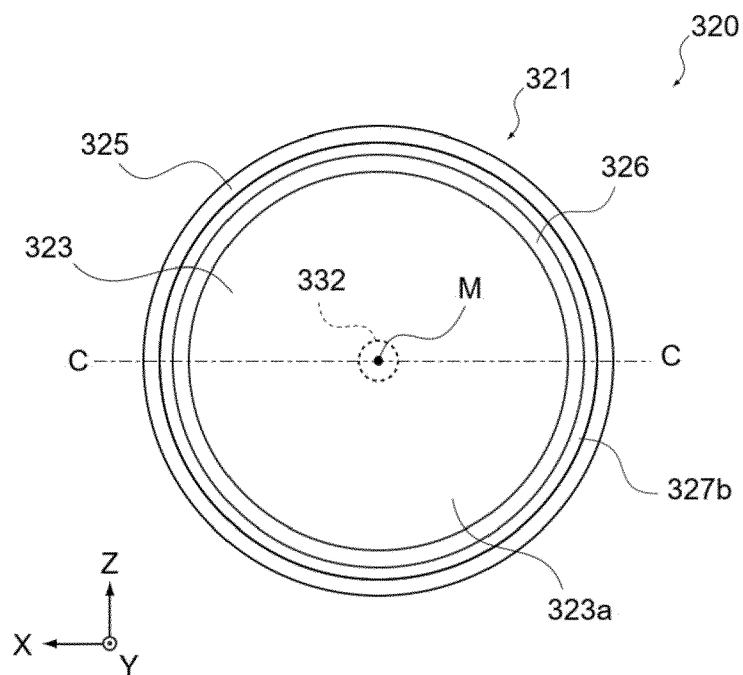


FIG.26

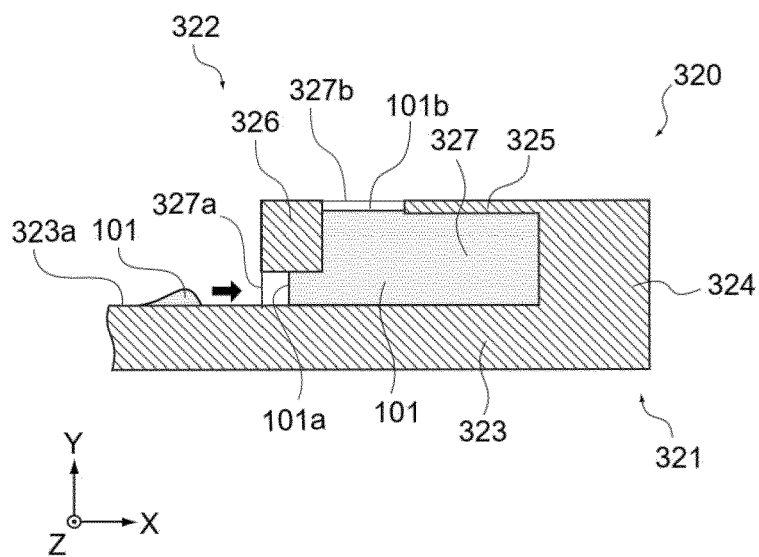


FIG.27

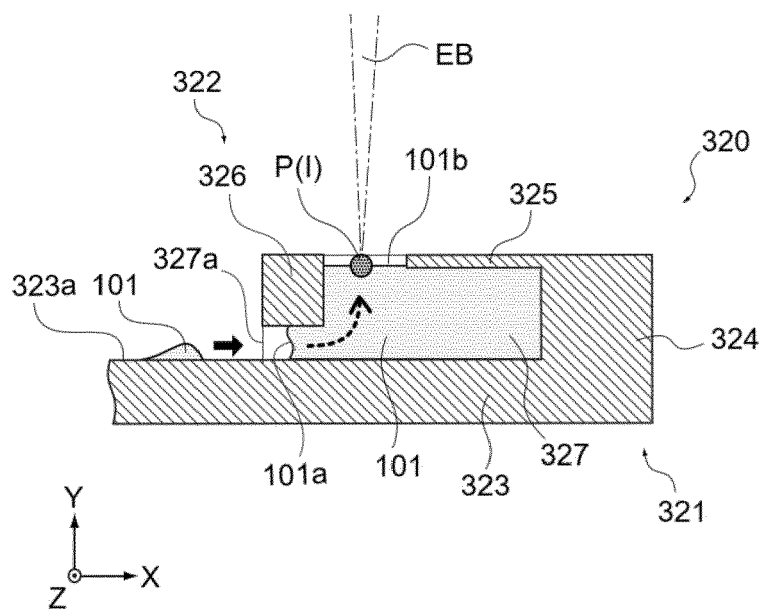


FIG.28

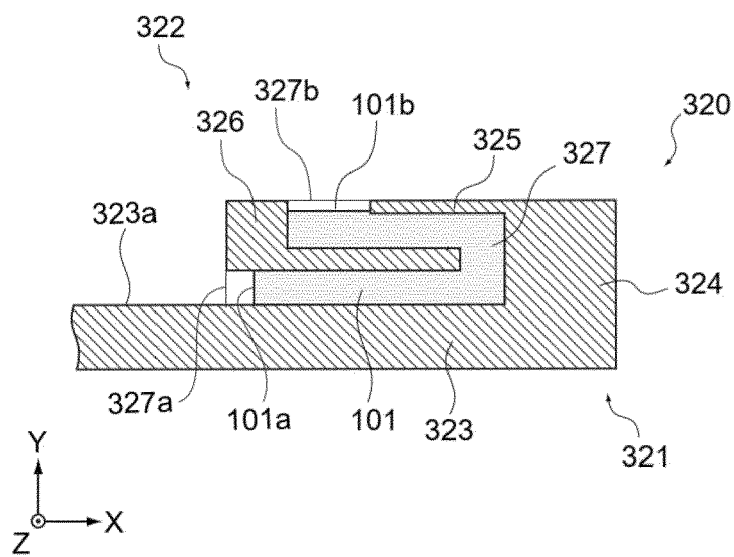


FIG.29

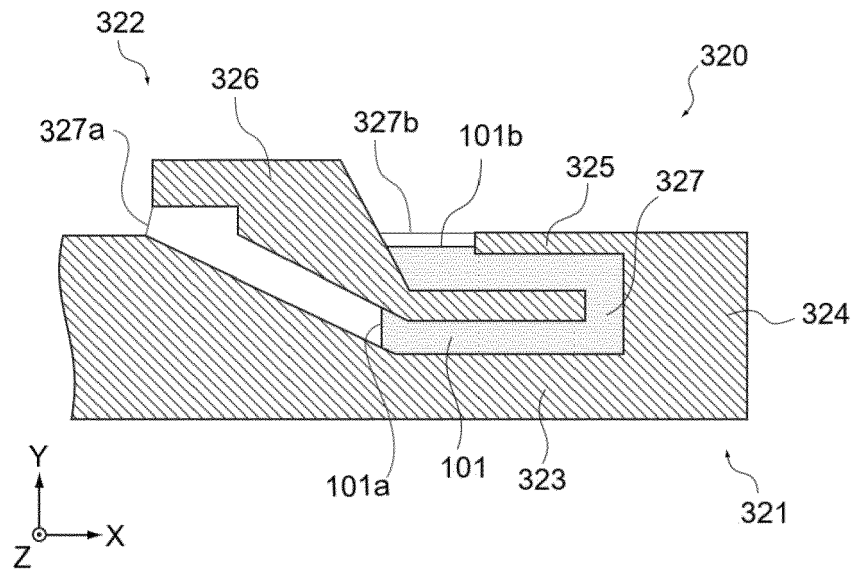


FIG.30

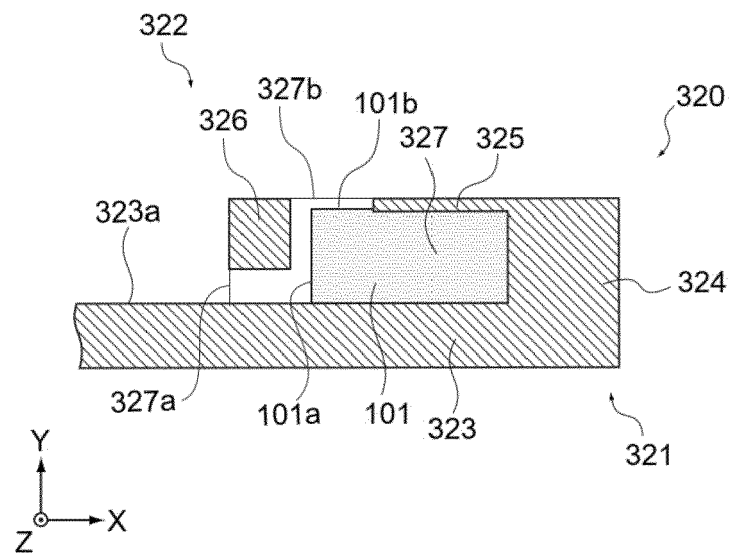


FIG.31

REFERENCES CITED IN THE DESCRIPTION

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- JP 2022530497 A [0005]