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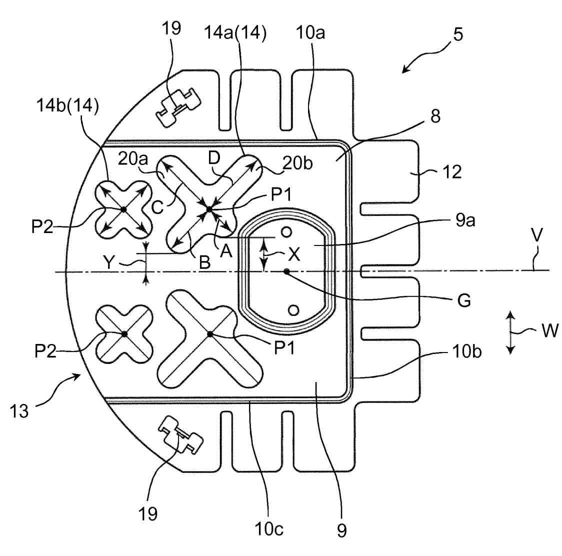
(54) **MICROWAVE HEATING DEVICE**

(57) Waveguide structure antenna (5) has ceiling surface (9) and side wall surfaces (10a, 10b, 10c) defining waveguide structure section (8), as well as has front opening (13) to emit microwaves from front opening (13) toward a heating-target object. Waveguide structure section (8) includes a coupling part joined to ceiling surface (9) to couple microwaves into an internal space of waveguide structure section (8). Waveguide structure section (8) includes at least one microwave extraction opening (14) formed on ceiling surface (9) to emit circularly polarized waves from microwave extraction opening (14) into a heating chamber. Waveguide structure section (8) has, at a portion of ceiling surface (9), which is closer to the coupling part than to microwave extraction openings (14), step area (9a) having a height that differs from heights of other portions of ceiling surface (9). According to this configuration, a heating-target object loaded on a central area of a loading surface can uniformly be heated.

FIG. 11



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a microwave heating device such as a microwave oven for microwave-heating using microwaves a heating-target object such as a food product.

BACKGROUND ART

[0002] A microwave oven that is a typical microwave heating device supplies microwaves generated by a magnetron that is a typical microwave generating unit into a metallic heating chamber to microwave-heat a heating-target object loaded in the heating chamber.

[0003] A microwave oven in which a flat bottom surface in a heating chamber can be used as a loading stand has been utilized in recent years. In such a microwave oven, a rotating antenna is provided under a loading stand to uniformly heat a whole heating-target object loaded on the loading stand (for example, see PTL 1). The rotating antenna disclosed in PTL 1 has a waveguide structure that is magnetic-field coupled to a waveguide that transmits microwaves generated by a magnetron.

[0004] FIG. 12 is a front cross-sectional view illustrating a configuration of microwave oven 100 disclosed in PTL 1. As shown in FIG. 12, in microwave oven 100, microwaves generated by magnetron 101 transmit in waveguide 102 and reach coupling shaft 109.

[0005] Rotating antenna 103 has a fan shape when viewed from top in plane, is coupled via coupling shaft 109 to waveguide 102, and is driven by motor 105 to rotate. Coupling shaft 109 couples microwaves transmitted in waveguide 102 to rotating antenna 103 having a waveguide structure, and functions as a center of rotation of rotating antenna 103.

[0006] Rotating antenna 103 has emission port 107 for emitting microwaves, and low impedance portion 106. Microwaves emitted from emission port 107 are supplied into heating chamber 104 to microwave-heat a heating-target object (not shown) loaded on loading stand 108 in heating chamber 104.

[0007] Rotating antenna 103 is rotated under loading stand 108 so that uniform heating distribution can be achieved in heating chamber 104.

[0008] In addition to a function for wholly and uniformly heating inside a heating chamber (uniform heating), for example, in order to simultaneously heat a frozen food product and a food product at a room temperature loaded in a heating chamber, a function for locally and intensively emitting microwaves (local heating) toward an area in which the frozen food product is loaded is required.

[0009] To achieve such local heating, a microwave oven that controls a stop position of a rotating antenna based on a temperature distribution in a heating chamber, which is detected by an infrared sensor, has been proposed (for example, see PTL 2).

[0010] FIG. 13 is a front cross-sectional view illustrating a configuration of microwave oven 200 disclosed in PTL 2. As shown in FIG. 13, in microwave oven 200, microwaves generated by magnetron 201 reach rotating antenna 203 having a waveguide structure via waveguide 202.

[0011] When viewed from top in plane, rotating antenna 203 has emission port 207 formed on a side of rotating antenna 203 to emit microwaves, and low impedance portions 206 formed on other three sides of rotating antenna 203. Microwaves emitted from emission port 207 are supplied, via power feeding chamber 209, into heating chamber 204 to microwave-heat a heating-target object loaded in heating chamber 204.

[0012] The microwave oven disclosed in PTL 2 includes infrared sensor 210 for detecting a temperature distribution in heating chamber 204. Based on the temperature distribution detected by infrared sensor 210, controller 211 controls rotation and a position of rotating antenna 203, and a direction of emission port 207.

[0013] The rotating antenna 203 disclosed in PTL 2 is configured to move on a circular arc orbit, while being rotated, by motor 205, inside power feeding chamber 209 formed under loading stand 208 in heating chamber 204. According to microwave oven 200, since emission port 207 of rotating antenna 203 simultaneously moves and rotates, a cold portion of a heating-target object, which is detected by infrared sensor 210, can intensively be heated.

Citation List

Patent Literature

[0014]

PTL 1: Japanese Examined Patent Publication No. 63-53678
PTL 2: Japanese Patent No. 2,894,250

SUMMARY OF THE INVENTION

[0015] In microwave oven 100 disclosed in PTL 1, rotating antenna 103 is configured to rotate around coupling shaft 109 disposed under loading stand 108. Microwaves are emitted from emission port 107 at a tip of rotating antenna 103.

[0016] With this configuration, microwaves cannot directly be radiated toward a heating-target object loaded on a central area of loading stand 108, thus uniform heating cannot always be achieved.

[0017] According to microwave oven 200 disclosed in PTL 2, a heating-target object can uniformly and locally be heated. However, this configuration involves a mechanism for simultaneously moving and rotating rotating antenna 203 under loading stand 208, thus making a structure complicated and increasing a device in size.

[0018] The present disclosure has been aimed to solve the above described problems in the background art, and has an object to provide a further small-sized microwave heating device capable of uniformly heating a loading surface in a heating chamber, in particular, a heating-target object loaded on its central area.

[0019] A microwave heating device according to a first aspect of the present disclosure includes a heating chamber for accommodating a heating-target object, a microwave generating unit for generating microwaves, and a waveguide structure antenna having a ceiling surface and side wall surfaces defining a waveguide structure section, as well as having a front opening to emit microwaves from the front opening into the heating chamber. The waveguide structure section includes a coupling part joined to the ceiling surface to couple microwaves into an internal space of the waveguide structure section.

[0020] The waveguide structure section includes at least one microwave extraction opening formed on the ceiling surface to emit circularly polarized waves from the microwave extraction opening into the heating chamber. The waveguide structure section has, at a portion of the ceiling surface, which is closer to the coupling part than to the microwave extraction opening, a step area having a height that differs from heights of other portions of the ceiling surface.

[0021] According to this aspect, a further small-sized microwave heating device capable of uniformly heating a loading surface in a heating chamber, in particular, a heating-target object loaded on its central area can be configured.

BRIEF DESCRIPTION OF DRAWINGS

[0022]

FIG. 1 is a cross-sectional view illustrating a schematic configuration of a microwave heating device according to an exemplary embodiment of the present disclosure.

FIG. 2A is a perspective view illustrating a power feeding chamber in the microwave heating device according to this exemplary embodiment.

FIG. 2B is a plan view illustrating the power feeding chamber in the microwave heating device according to this exemplary embodiment.

FIG. 3 is an exploded perspective view illustrating a rotating antenna in the microwave heating device according to this exemplary embodiment.

FIG. 4 is a perspective view illustrating an ordinary rectangular waveguide.

FIG. 5A is a plan view illustrating surface H of a waveguide having a rectangular slot-shaped opening for emitting linearly polarized waves.

FIG. 5B is a plan view illustrating surface H of a waveguide having cross slot-shaped openings for emitting circularly polarized waves.

FIG. 5C is a front view illustrating a positional relationship between a waveguide and a heating-target object.

FIG. 6A is a characteristic graph illustrating a result of experiment on the waveguide shown in FIG. 5A.

FIG. 6B is a characteristic graph illustrating a result of experiment on the waveguide shown in FIG. 5B.

FIG. 7 is a characteristic graph illustrating results of experiments in "food product" cases.

FIG. 8A is a cross-sectional view schematically illustrating an extraction effect according to this exemplary embodiment.

FIG. 8B is a cross-sectional view schematically illustrating an extraction effect according to this exemplary embodiment.

FIG. 9A is a schematic view illustrating an exemplary flat-shaped rotating antenna used in an experiment.

FIG. 9B is a schematic view illustrating another exemplary flat-shaped rotating antenna used in another experiment.

FIG. 9C is a schematic view illustrating still another exemplary flat-shaped rotating antenna used in still another experiment.

FIG. 10A is a schematic view illustrating still another exemplary flat-shaped rotating antenna used in still another experiment.

FIG. 10B is a schematic view illustrating still another exemplary flat-shaped rotating antenna used in still another experiment.

FIG. 11 is a plan view illustrating a waveguide structure section according to this exemplary embodiment.
FIG. 12 is a front cross-sectional view illustrating the microwave oven disclosed in PTL 1.
FIG. 13 is a front cross-sectional view illustrating the microwave oven disclosed in PTL 2.

DESCRIPTION OF EMBODIMENT

[0023] A microwave heating device according to a first aspect of the present disclosure includes a heating chamber for accommodating a heating-target object, a microwave generating unit for generating microwaves, and a waveguide structure antenna having a ceiling surface and side wall surfaces defining a waveguide structure section, as well as having a front opening to emit microwaves from the front opening into the heating chamber. The waveguide structure section includes a coupling part joined to the ceiling surface to couple microwaves into an internal space of the waveguide structure section.

[0024] The waveguide structure section includes at least one microwave extraction opening formed on the ceiling surface to emit circularly polarized waves from the microwave extraction opening into the heating chamber. The waveguide structure section has, at a portion of the ceiling surface, which is closer to the coupling part than to the microwave extraction opening, a step area having a height that differs from heights of other portions of the ceiling surface.

[0025] According to this aspect, a further small-sized microwave heating device capable of uniformly heating a loading surface in a heating chamber, in particular, a heating-target object loaded on its central area can be configured.

[0026] In addition to the first aspect, with a microwave heating device according to a second aspect, a step area includes a joining area corresponding to a joining portion between a coupling part and a waveguide structure section.

[0027] According to this aspect, a heating-target object loaded on a central area of a loading surface can uniformly be heated.

[0028] In addition to the first aspect, with a microwave heating device according to a third aspect, a step area is provided at a portion of a ceiling surface, which is closer to a coupling part than to a microwave extraction opening, and has a height lower than heights of other portions of the ceiling surface. According to this aspect, circularly polarized waves can securely be emitted from the microwave extraction openings.

[0029] In addition to the first aspect, with a microwave heating device according to a fourth aspect, a driving unit for rotating a waveguide structure antenna is further included. A coupling part includes a coupling shaft coupled to the driving unit to include a center of rotation of the waveguide structure antenna, and a flange provided around the coupling shaft to configure a joining portion. The flange has a shorter length in a direction of a pipe axis than a length in a direction orthogonal to the direction of the pipe axis.

[0030] According to this aspect, a heating-target object loaded on a central area of a loading surface can uniformly be heated.

[0031] In addition to the first aspect, with a microwave heating device according to a fifth aspect, a microwave extraction opening has a cross slot shape where two slits intersect, and is provided at a position shifted from a pipe axis. According to this aspect, a heating-target object loaded on a central area of a loading surface can uniformly be heated.

[0032] In addition to the first aspect, with a microwave heating device according to a sixth aspect, a waveguide structure section includes at least two microwave extraction openings that are symmetrical with respect to a pipe axis. A distance between the two microwave extraction openings on an area around a coupling part is longer than a distance between the two microwave extraction openings on an area away from the coupling part. According to this aspect, a heating-target object loaded on a central area of a loading surface can uniformly be heated.

[0033] A preferred exemplary embodiment of a microwave heating device according to the present disclosure will now be described herein with reference to the accompanying drawings.

[0034] Although the exemplary embodiment described below uses a microwave oven as an exemplary microwave heating device according to the present disclosure, the present disclosure is not limited to such a microwave oven for application, but is applicable to microwave-heating devices, garbage treatment machines, and semiconductor manufacturing machines. The present disclosure is not limited to a specific configuration illustrated in the exemplary embodiment described below, but includes various configurations conforming to similar or identical technical ideas.

[0035] Similar or identical components are added with identical reference marks in the drawings described below, and some descriptions might be omitted in order to avoid duplications.

[0036] FIG. 1 is a front cross-sectional view illustrating a schematic configuration of a microwave oven that is a microwave heating device according to an exemplary embodiment of the present disclosure. In below descriptions, a left-right direction of the microwave oven means a left-right direction in FIG. 1, while a front-back direction means a deep direction in FIG. 1.

[0037] As shown in FIG. 1, microwave oven 1 according to this exemplary embodiment includes heating chamber 2a, power feeding chamber 2b, magnetron 3, waveguide 4, rotating antenna 5, and loading stand 6. Loading stand 6 has a flat upper surface for loading a heating-target object (not shown) such as a food product. Heating chamber 2a is a space above loading stand 6, while power feeding chamber 2b is a space under loading stand 6.

[0038] Loading stand 6 covers power feeding chamber 2b provided with rotating antenna 5 to divide heating chamber 2a and power feeding chamber 2b, as well as to configure a bottom surface of heating chamber 2a. Due to the flat upper surface (loading surface 6a) of loading stand 6, a heating-target object can easily be loaded and unloaded, and dirt adhered on loading surface 6a can easily be cleaned.

[0039] Since loading stand 6 is made of a material into which microwaves can easily transmit, such as glass and ceramic, microwaves emitted by rotating antenna 5 transmit loading stand 6, and are supplied to heating chamber 2a.

[0040] Magnetron 3 is an exemplary microwave generating unit for generating microwaves. Waveguide 4 is provided under power feeding chamber 2b, and is an exemplary transmission unit for transmitting microwaves generated by magnetron 3 to coupling part 7. Rotating antenna 5 is provided in an internal space of power feeding chamber 2b to emit microwaves transmitted by waveguide 4 and coupling part from front opening 13 into power feeding chamber 2b.

[0041] Rotating antenna 5 is a waveguide structure antenna including waveguide structure section 8 having a box-shaped waveguide structure where microwaves transmit into its internal space, and coupling part 7 for coupling microwaves in waveguide 4 into the internal space of waveguide structure section 8. Coupling part 7 includes coupling shaft 7a coupled to motor 15 that is a driving unit, and flange 7b joining waveguide structure section 8 and coupling part 7.

[0042] Motor 15 is driven in accordance with a control signal sent from controller 17 to rotate rotating antenna 5 around coupling shaft 7a of coupling part 7, and to stop rotating antenna 5 in a desired direction. Therefore, a direction toward which microwaves are emitted from rotating antenna 5 is changed. Coupling part 7 is made of a metal such as an aluminized steel sheet, while a coupling portion of motor 15, which is coupled to coupling part 7, is made of, for example, fluorocarbon resin.

[0043] Coupling shaft 7a of coupling part 7 passes through an opening communicating waveguide 4 and power feeding chamber 2b so as to create a predetermined clearance (for example, at least 5 mm) from the opening into which coupling shaft 7a passes through. Coupling shaft 7a couples waveguide 4 and the internal space of waveguide structure section 8 of rotating antenna 5, thus microwaves can effectively transmit from waveguide 4 to waveguide structure section 8.

[0044] Infrared sensor 16 is provided at an upper portion of a side surface of heating chamber 2a. Infrared sensor 16 is an exemplary state detecting unit for detecting a temperature inside heating chamber 2a, in other words, a surface temperature of a heating-target object loaded on loading stand 6, as a state of the heating-target object. Infrared sensor 16 detects temperatures in areas of heating chamber 2a separated into plural in a virtual manner, and sends these detected signals to controller 17.

[0045] Based on the signals detected by infrared sensor 16, controller 17 oscillation-controls magnetron 3 and drive-controls motor 15.

[0046] Although this exemplary embodiment includes infrared sensor 16 as an exemplary state detecting unit, state detecting unit is not limited to infrared sensor 16. For example, a weight sensor for detecting a weight of a heating-target object and an image sensor for capturing an image of the heating-target object may be used as state detecting units. In a configuration where no state detecting unit is provided, controller 17 may oscillation-control magnetron 3 and drive-control motor 15 in accordance with a program stored beforehand and a selection made by a user.

[0047] FIG. 2A is a perspective view illustrating power feeding chamber 2b where loading stand 6 is removed. FIG. 2B is a plan view illustrating power feeding chamber 2b in a situation identical to a situation of FIG. 2A.

[0048] As shown in FIGS. 2A and 2B, power feeding chamber 2b disposed under heating chamber 2a and separated by loading stand 6 from heating chamber 2a is provided with rotating antenna 5. Center of rotation G of coupling shaft 7a provided to rotating antenna 5 lies at a center of power feeding chamber 2b in both front-back and left-right directions, in other words, under a center of loading stand 6 in both front-back and left-right directions.

[0049] Power feeding chamber 2b has the internal space configured by its bottom surface 11 and a lower surface of loading stand 6. The internal space of power feeding chamber 2b includes center of rotation G of coupling part 7, and has a shape that is symmetrical with respect to center line J (see FIG. 2B) extending in a left-right direction of power feeding chamber 2b. On side wall surfaces of the internal space of power feeding chamber 2b, protrusions 18 are formed to protrude inwardly. Protrusions 18 include protrusion 18a provided on the side wall surface on a left side, and protrusion 18b provided on the side wall surface on a right side.

[0050] Under protrusion 18b, magnetron 3 is provided. Microwaves emitted from antenna 3a of magnetron 3 transmit into waveguide 4 provided under power feeding chamber 2b, and then transmit, via coupling part 7, to waveguide structure section 8.

[0051] Side wall surfaces 2c of power feeding chamber 2b are inclined so as to upwardly reflect microwaves emitted in a horizontal direction from rotating antenna 5 toward heating chamber 2a.

[0052] FIG. 3 is an exploded perspective view illustrating a specific example of rotating antenna 5. As shown in FIG. 3, waveguide structure section 8 has ceiling surface 9 and side wall surfaces 10a, 10b, and 10c defining its internal space.

[0053] Ceiling surface 9 has three linear edge portions, one circular-arc edge portion, and recess 9a to which coupling part 7 joins, and is disposed to face loading stand 6 (see FIG. 1). From the three linear edge portions of ceiling surface 9, side wall surfaces 10a, 10b, and 10c are formed to each bend downwardly.

[0054] The circular arc edge portion is not provided with a side wall surface, but an opening is formed underneath.

This opening functions as front opening 13 for emitting microwaves transmitted through the internal space of waveguide structure section 8. That is, side wall surface 10b is provided to face front opening 13, while side wall surfaces 10a, 10c are provided to face each other.

[0055] At a lower edge portion of side wall surface 10a, low impedance portion 12 extending outwardly from waveguide structure section 8 and in a direction perpendicular to side wall surface 10a is provided. Low impedance portion 12 is formed in parallel to bottom surface 11 of power feeding chamber 2b, but separated with a small gap. With low impedance portion 12, microwaves are prevented from being leaked as much as possible in the direction perpendicular to side wall surface 10a.

[0056] In order to secure a constant gap between power feeding chamber 2b and bottom surface 11, retaining portion 19 may be formed for attaching a spacer (not shown) made of insulating resin to a lower surface of low impedance portion 12.

[0057] On low impedance portion 12, a plurality of slits 12a is provided periodically at a constant interval so as to extend in the direction perpendicular to side wall surface 10a. The plurality of slits 12a can prevent microwaves from being leaked as much as possible in a direction parallel to side wall surface 10a. The interval between slits 12a is appropriately determined in accordance with a wavelength of microwaves transmitting waveguide structure section 8.

[0058] As for side wall surface 10b and side wall surface 10c, low impedance portions 12 having a plurality of slits 12a at lower edge portions are respectively provided.

[0059] Although rotating antenna 5 according to this exemplary embodiment includes front opening 13 formed in a circular arc shape, the present disclosure is not limited to this shape, but may include linear or curved front opening 13.

[0060] As shown in FIG. 3, ceiling surface 9 includes a plurality of microwave extraction openings 14, in other words, first openings 14a, and second openings 14b that are smaller than first openings 14a. Microwaves transmitted through the internal space of waveguide structure section 8 emit from front opening 13 and the plurality of microwave extraction openings 14.

[0061] Flange 7b formed on coupling part 7 joins to a lower surface of ceiling surface 9 of waveguide structure section 8 by means of, for example, caulking, spot welding, screw tightening, or, welding, to fasten rotating antenna 5 with coupling part 7.

[0062] With this exemplary embodiment, since rotating antenna 5 includes waveguide structure section 8 described later, a heating-target object loaded on loading stand 6 can uniformly be heated. In particular, on a central area of loading surface 6a, which lies above center of rotation G (see FIGS. 2A, 2B) of rotating antenna 5, a heating-target object can effectively and uniformly be heated. A waveguide structure according to this exemplary embodiment will now be described herein in detail.

[Waveguide structure]

[0063] First, to understand features of waveguide structure section 8, ordinary waveguide 300 will now be described herein with reference to FIG. 4. As shown in FIG. 4, simplest, ordinary waveguide 300 is a rectangular waveguide having rectangular cross section 303 having width a, height b, and a depth along pipe axis V of waveguide 300. Pipe axis V is a center line of waveguide 300, which passes through a center of cross section 303 and extends in microwave transmission direction Z.

[0064] It is known that, when a wavelength of a microwave in a free space is specified to λ_0, and width a and height b are respectively selected from ranges of $\lambda_0 > a > \lambda_0/2$ and $b < \lambda_0/2$, the microwave transmits in waveguide 300 in mode TE10.

[0065] Mode TE10 is referred to as a transmission mode on wave H (Transverse Electric Wave (TE wave)) where, in waveguide 300, a magnetic field component exists, but no electric field component exists in microwave transmission direction Z.

[0066] Wavelength λ_0 of a microwave in a free space can be obtained through Equation (1).

[Equation 1]

$$\lambda_0 = c / f \quad \cdots (1)$$

[0067] In Equation (1), velocity of light c is approximately 2.998×10^8 [m/s], while oscillating frequency f is, in a case of a microwave oven, in a range from 2.4 to 2.5 [GHz] (ISM band) inclusive. Since oscillating frequency f fluctuates due to unevenness in a magnetron and a load condition, wavelength λ_0 in a free space fluctuates in a range from a minimum of 120 [mm] (at 2.5 GHz) to a maximum of 125 [mm] (at 2.4 GHz).

[0068] When waveguide 300 is used for a microwave oven, by taking into account a range of wavelength λ_0 in a free space and other factors, width a of waveguide 300 is often designed to a value in a range from 80 mm to 100 mm inclusive, as well as height b is often designed to a value in a range from 15 mm to 40 mm inclusive.

[0069] Generally, in waveguide 300 shown in FIG. 4, wide width surfaces 301 that are its upper and lower surfaces are referred to as surfaces H in a sense that, on the surfaces, a magnetic field swirls in parallel, while narrow width surfaces 302 that are left and right side surfaces are referred to as surfaces E in a sense that the surfaces are in parallel to an electric field. For a simplified description, in plan views shown below, a straight line on surface H, which is pipe axis V projected onto surface H, is sometimes referred to as pipe axis V.

[0070] When a wavelength of a microwave emitted from a magnetron is defined to wavelength λ_0, while a wavelength of a microwave transmitting a waveguide is defined to in-pipe wavelength λg, λg can be obtained through Equation (2).

[Equation 2]

$$\lambda g = \frac{\lambda_0}{\sqrt{1-(\lambda_0/(2\cdot a))^2}} \quad \cdots (2)$$

[0071] Therefore, in-pipe wavelength λg changes in accordance with width a of waveguide 300, but has no relation to height b. In mode TE10, at both edges of waveguide 300 in width direction W (surfaces E), in other words, narrow width surfaces 302, an electric field becomes 0, while, at a center in width direction W, an electric field becomes maximum.

[0072] In this exemplary embodiment, a principle similar or identical to a principle of waveguide 300 shown in FIG. 4 is applied to rotating antenna 5 shown in FIGS. 1 and 3. On rotating antenna 5, ceiling surface 9 and bottom surface 11 of power feeding chamber 2b are regarded as surfaces H, while side wall surfaces 10a, 10c are regarded as surfaces E.

[0073] Side wall surface 10b is regarded as a reflecting edge for reflecting all microwaves inside rotating antenna 5 toward a direction of front opening 13. In this exemplary embodiment, specifically, width a of waveguide 300 is 106.5 mm.

[0074] Ceiling surface 9 is formed with a plurality of microwave extraction openings 14. Microwave extraction openings 14 include two first openings 14a and two second openings 14b. Two first openings 14a are symmetrical with respect to pipe axis V of waveguide structure section 8 of rotating antenna 5. Similarly, two second openings 14b are symmetrical with respect to pipe axis V. First openings 14a and second openings 14b are formed so as not to cross pipe axis V.

[0075] With a structure where first openings 14a and second openings 14b are disposed at positions shifted from pipe axis V of waveguide structure section 8 (precisely, a line on ceiling surface 9, which is pipe axis V projected onto ceiling surface 9), microwave extraction openings 14 can securely emit circularly polarized waves. With emitted circularly polarized microwaves, the central area of loading surface 6a can uniformly be heated.

[0076] Depending on whether first openings 14a and second openings 14b are provided on an area on either left or right of pipe axis V, a rotation direction of an electric field is determined, that is, a right handed polarized wave (Clockwise: CW) or a left handed polarized wave (Counterclockwise: CCW).

[0077] In this exemplary embodiment, microwave extraction openings 14 are each provided so as not to cross pipe axis V. However, the present disclosure is not limited to this configuration, but, in a configuration where these openings partially cross pipe axis V, circularly polarized waves can be emitted. In this case, deformed circularly polarized waves are emitted.

[Circularly polarized wave]

[0078] Next, a circularly polarized wave will now be described herein. A circularly polarized wave is a technology widely used in fields of mobile communications and satellite communications. For example, an Electronic Toll Collection System (ETC), in other words, a non-stop automatic toll collection system, is one of familiar applications.

[0079] A circularly polarized wave is a microwave where a polarized wave surface of an electric field rotates with respect to a travelling direction as time passes by, and has a feature that a direction of the electric field keeps changing as time passes by, but a magnitude of a field intensity does not change.

[0080] With a microwave heating device applied with the circularly polarized waves, it is expected that a heating-target object can uniformly be heated with respect to in particular a circumferential direction of the circularly polarized waves, compared with microwave-heating through conventional linearly polarized waves. In either of right handed polarized waves and left handed polarized waves, a similar or identical effect can be achieved.

[0081] Circularly polarized waves have originally and mainly been used in a field of communications in which circularly polarized waves are emitted into an open space, thus, circularly polarized waves are normally discussed to serve as travelling waves that are free from reflected waves. On the other hand, in this exemplary embodiment, reflected waves could be generated in heating chamber 2a that is a closed space, and the generated reflected waves might be composed with travelling waves to generate stationary waves.

[0082] However, it can be thought that, in addition to reduced reflected waves since a food product can absorb microwaves, at a moment when microwaves are emitted from microwave extraction openings 14, stationary waves are unbalanced, thus travelling waves will be generated until stationary waves will be generated again. Therefore, according to this exemplary embodiment, the features of the circularly polarized waves described above can be utilized, thus heating chamber 2a can uniformly be heated internally.

[0083] Differences between the field of communications in an open space and a field of dielectric heating in a closed space will now be described herein.

[0084] In the field of communications, in order to achieve precise information communications, either right handed polarized waves or left handed polarized waves are used, and, on a receiving side, a receiving antenna having directivity conforming to the used polarized waves is used.

[0085] On the other hand, in the field of microwave heating, instead of a receiving antenna having directivity, a heating-target object without having directivity, such as a food product, receives microwaves, thus, microwaves should be radiated toward the whole heating-target object. Therefore, in the field of microwave heating, whether right handed polarized waves or left handed polarized waves should be used is not so important, and right handed polarized waves and left handed polarized waves may be mixed.

[Microwave extraction effect]

[0086] A microwave extraction effect provided by a rotating antenna, which is a feature of this exemplary embodiment, will now be described herein. In this exemplary embodiment, the microwave extraction effect is referred to as a phenomenon where, when a heating-target object such as a food product is placed near microwave extraction openings 14, microwaves inside a waveguide structure are emitted from microwave extraction openings 14.

[0087] FIG. 5A is a plan view of waveguide 400 having surface H provided with an opening for generating linearly polarized waves. FIG. 5B is a plan view of waveguide 500 having surface H provided with openings for generating circularly polarized waves. FIG. 5C is a front view illustrating a positional relationship between waveguide 400 or 500 and heating-target object 22.

[0088] As shown in FIG. 5A, opening 401 is a rectangular slit provided to cross pipe axis V of waveguide 400. Opening 401 emits linearly polarized microwaves. As shown in FIG. 5B, two openings 501 are openings each having a cross slot shape configured by two rectangular slits crossing at a right angle. Two openings 501 are symmetrical with respect to pipe axis V of waveguide 500.

[0089] Both openings are symmetrical with respect to pipe axis V of the waveguide, and each have a width of 10 mm, and a length of L mm. In these configurations, a "no food product" case where no heating-target object 22 is disposed, and a "food product" case where a heating-target object 22 is disposed have been analyzed through computer assisted engineering (CAE).

[0090] In the "food product" case, as shown in FIG. 5C, heating-target objects 22 each having a constant height of 30 mm, each having either two different types of bottom areas (100 mm square, 200 mm square), and each made of either three different types of materials (frozen beef, refrigerated beef, water) are measured for distances D, as a parameter, from waveguides 400, 500 to bottom surfaces of heating-target objects 22.

[0091] To regard radiation power from an opening in the "no food product" case as reference power, relationships between lengths from the opening and radiation power in the "no food product" case are shown in FIGS. 6A and 6B.

[0092] FIG. 6A shows a characteristic when opening 401 shown in FIG. 5A is used, while FIG. 6B shows a characteristic when openings 501 shown in FIG. 5B are used. In FIGS. 6A and 6B, horizontal axes represent length of opening L [mm], while vertical axes represent electric power [W] of microwaves emitted from openings 401, 501 when electric power transmitting in a waveguide is specified to 1.0 W.

[0093] To compare with the "food product" case, length L at which radiation power becomes 0.1 W in the "no food product" case, in other words, a case in which length L becomes 45.5 mm is selected in the graph shown in FIG. 6A, while a case in which length L becomes 46.5 mm is selected in the graph shown in FIG. 6B.

[0094] FIG. 7 includes, when two lengths L are specified, which are the above described lengths (45.5 mm, 46.5 mm), and in the "food product" case, six graphs showing results of analyses performed for three types of food products (frozen beef, refrigerated beef, water) each prepared with two types of bottom areas (100 mm square, 200 mm square).

[0095] In the graphs shown in FIG. 7, horizontal axes each represent distance D [mm] from heating-target object 22 to a waveguide, while vertical axes each represent relative radiation power when radiation power in the "no load" case is specified to 1.0. That is, compared with the "no food product" case, in the "food product" case, the graphs show how degrees waveguides 400, 500 extract microwaves toward heating-target object 22.

[0096] In the graphs shown in FIG. 7, broken lines show characteristics when opening 401 has a straight shape (I-shape) (shown with "I" in the graphs), while solid lines show characteristics when opening 501 has two cross slot shapes (X-shapes) (shown with "2X" in the graphs).

[0097] In all the six graphs, it can be recognized that radiation power of opening 401 is greater than radiation power of opening 501, and, in particular, with a distance equivalent to a distance in an actual microwave oven, which is a distance D of 20 mm or shorter, there is a difference of approximately twice. Therefore, regardless of types of heating-target objects 22 and bottom areas, an opening that generates circularly polarized waves obviously demonstrates a higher microwave extraction effect than a microwave extraction effect of an opening that generates linearly polarized waves.

[0098] As results of detailed investigations, among various types of heating-target objects 22, in particular, with a distance D of 10 mm or shorter, an extraction effect is greater in frozen beef where a dielectric constant and a dielectric loss are smaller, while an extraction effect is smaller in water where a dielectric constant and a dielectric loss are greater.

[0099] In a case of refrigerated beef or water, as distance D extends, in particular, in linearly polarized waves, radiation power lowers to a value equal to or below 1. This can be thought that electric power reflected by heating-target object 22 offsets radiation power. As for the bottom areas of heating-target objects 22, since radiation power is almost identical between the heating-target object with the bottom area of 100 mm square and the heating-target object with the bottom area of 200 mm square, it can be thought that a microwave extraction effect has not significantly been affected.

[0100] The inventors have studied, through experiments using various opening shapes, conditions for openings that can emit circularly polarized waves. As a result, the inventors have concluded as described below. An advantageous condition for generating circularly polarized waves is to dispose an opening away from pipe axis V of a waveguide, and an opening shape includes a cross slot shaped opening. A cross slot shaped opening can most effectively emit circularly polarized microwaves, in other words, can achieve a higher extraction effect.

[0101] FIGS. 8A and 8B are cross-sectional views schematically illustrating extraction effects according to this exemplary embodiment. Front opening 13 of rotating antenna 5 faces leftward in both FIGS. 8A and 8B. Heating-target object 22 is disposed, in FIG. 8A, above coupling part 7, while, in FIG. 8B, loaded to a left end of loading surface 6a. That is, in two states shown in FIGS. 8A and 8B, distances from coupling part 7 to heating-target object 22 differ.

[0102] In the state shown in FIG. 8A, heating-target object 22 lies near microwave extraction openings 14, in particular, near first opening 14a, thus an extraction effect from first opening 14a can be expected. As a result, most of microwaves travelling from coupling part 7 toward front opening 13 are emitted, as circularly polarized microwaves emitted from first opening 14a, toward heating-target object 22 to heat heating-target object 22.

[0103] On the other hand, in the state shown in FIG. 8B, since heating-target object 22 lies away from microwave extraction openings 14, an extraction effect from microwave extraction openings 14 cannot fully be expected. As a result, most of microwaves travelling from coupling part 7 toward front opening 13 are emitted, as linearly polarized microwaves, from front opening 13 toward heating-target object 22 to heat heating-target object 22.

[0104] As described above, with microwave extraction openings 14 according to this exemplary embodiment, it can be thought that a special phenomenon is observed, where, when a food product is disposed near microwave extraction openings 14, radiation power increases, while, when a food product is disposed away from microwave extraction openings 14, radiation power reduces.

[Uniform heating by waveguide structure section]

[0105] Uniformly heating a heating-target object by a waveguide structure section according to this exemplary embodiment will now be described herein. The inventors have performed experiments using rotating antennas having variously shaped waveguide structures, and have found a waveguide structure optimum for uniform heating.

[0106] FIGS. 9A, 9B, and 9C are schematic views of three exemplary flat shaped rotating antennas used in the experiments.

[0107] As shown in FIG. 9A, waveguide structure section 600 includes two first openings 614a and two second openings 614b. First openings 614a each have a cross slot shape, where rectangular slits are provided near coupling part 7 so as to form an angle of 45 degrees relative to pipe axis V of waveguide structure section 600. Second openings 614b are smaller than first openings 614a, and provided away from coupling part 7.

[0108] As shown in FIG. 9B, different from waveguide structure section 600, waveguide structure section 700 includes one first opening 714a having a cross slot shape similar or identical to the cross slot shapes of first openings 614a.

[0109] As shown in FIG. 9C, different from waveguide structure section 600, waveguide structure section 800 includes two first openings 814a each having a T-shape. That is, different from first openings 614a, first openings 814a each do not have a portion extending, on either of two rectangular slits, from an intersecting portion in a direction toward coupling part 7.

[0110] In common to the waveguide structure sections shown in FIGS. 9A to 9C, a plurality of cross slot shaped microwave extraction openings is provided, and a first opening or first openings similar in size is/are provided at a similar location or similar locations, as well as second openings similar in size are provided at similar locations. In particular, second openings 614b, second openings 714b, and second openings 814b are identical.

[0111] Using rotating antennas having the waveguide structures shown in FIGS. 9A to 9C, experiments have been performed under identical heating conditions to heat a frozen okonomiyaki loaded on the central area of loading surface 6a, and verifications have been performed through CAE. An okonomiyaki is a savory pancake with various ingredients.

[0112] When waveguide structure section 600 shown in FIG. 9A is used, an abnormal phenomenon has been observed, where circularly polarized waves output from these openings interfere, accordingly a temperature at a portion of a heating-target object that lies on the central area of loading surface 6a above coupling part 7 does not fully rise, compared with an area around the portion (hereinafter referred to as a decrease in temperature around coupling part 7).

[0113] When waveguide structure section 700 shown in FIG. 9B is used, the decrease in temperature around coupling part 7 could have been prevented as much as possible. Similarly, when waveguide structure section 800 shown in FIG. 9C is used, the decrease in temperature around coupling part 7 could have been prevented as much as possible.

[0114] As described above, it has been confirmed that, with a waveguide structure where no opening is provided around coupling part 7, or only one opening is provided around coupling part 7, the decrease in temperature around coupling part 7 could have been prevented as much as possible, and heating chamber 2a could have uniformly been heated internally.

[0115] In addition, the inventors have experimented for shapes of microwave extraction openings, and have found a waveguide structure that can achieve a further uniform heating distribution.

[0116] Since, first openings 814a of waveguide structure section 800 shown in FIG. 9C emit deformed circularly polarized waves, different from circularly polarized waves that are formed in a circular shape by cross slot shaped openings, an advantageous result in a viewpoint of achieving uniform heating in heating chamber 2a could have not been obtained.

[0117] To prevent two circularly polarized waves from being interfered, as well as to form circularly polarized waves that are as much as possible close to a circular shape, first openings 914a having shapes shown in FIGS. 10A, 10B have been investigated.

[0118] Waveguide structure sections having first openings 914a will now be described herein with reference to the drawings.

[0119] FIGS. 10A, 10B are schematic views illustrating flat shapes of waveguide structure section 900A, waveguide structure section 900B, each provided with first openings 914a as described above.

[0120] As shown in FIGS. 10A, 10B, waveguide structure sections 900A, 900B each have identical first openings 914a and second openings 914b.

[0121] First openings 914a each have a cross slot shape where, on either of two rectangular slits, a portion extending from an intersecting portion in a direction toward coupling part 7 has a shorter length than a length of a portion extending from the intersecting portion in a direction opposite to a direction toward coupling part 7. As a result of investigations, it has been confirmed that, according to first openings 914a, in addition to preventing two circularly polarized waves from being interfered as much as possible and to achieving uniform heating, the above described extraction effect can be improved, compared with first openings 814a shown in FIG. 9C.

[0122] Lengths of the portions of first openings 914a, which extend from the intersecting portions in directions toward coupling part 7, are set as appropriate in accordance with specifications so as not to cause two circularly polarized waves to interfere.

[0123] Waveguide structure section 900A wholly has a flat ceiling surface. On the other hand, waveguide structure section 900B is formed with a joining area having a recess shape recessed downwardly (recess 909a that is a step area) at joining portion at which flange 7b joins to a ceiling surface (for example, see FIG. 3). Accordingly, on the ceiling surface of waveguide structure section 900B, a distance between the joining area and a loading stand is longer than a distance of other portions.

[0124] Similarly, using rotating antennas having the above described waveguide structures, experiments have been performed under identical heating conditions to heat a frozen okonomiyaki loaded on the central area of loading surface 6a, and verifications have been performed through CAE.

[0125] As a result, with waveguide structure section 900A, since first openings 914a substantially have cross slot shapes, two circularly polarized waves can be prevented from being interfered, and circularly polarized waves can be generated in an almost circular shape.

[0126] With first openings 914a, an extraction effect can also be improved, while the decrease in temperature around coupling part 7 can be prevented as much as possible. In addition, it has been observed that, with the joining area formed in a recess shape on the ceiling surface of waveguide structure section 900B, the decrease in temperature around coupling part 7 can be prevented as much as possible.

[0127] Based on knowledge obtained from various experiments as described above, a specific example configuration of a rotating antenna according to this exemplary embodiment will now be described herein. Based on the above described knowledge, variously modified microwave heating devices are available in accordance with specifications.

[0128] FIG. 11 is a plan view illustrating a rotating antenna having waveguide structure section 8 according to this exemplary embodiment.

[0129] As shown in FIG. 11, waveguide structure section 8 includes a plurality of microwave extraction openings 14 provided on ceiling surface 9. The plurality of microwave extraction openings 14 includes first openings 14a, and second openings 14b that are smaller than first openings 14a. First openings 14a and second openings 14b each substantially have a cross slot shape.

[0130] With a structure where center points P1 of first openings 14a and center points P2 of second openings 14b are disposed at positions shifted from pipe axis V of waveguide structure section 8, microwave extraction openings 14 can emit circularly polarized waves. Center points P1 of first openings 14a and center points P2 of second openings 14b are center points of intersection areas of two slits forming each of first openings 14a and second openings 14b.

[0131] In this exemplary embodiment, first openings 14a and second openings 14b are disposed so as not to cross pipe axis V of waveguide structure section 8. Longitudinal directions of rectangular slits of first openings 14a and second openings 14b are substantially inclined at an angle of 45°C relative to pipe axis V.

[0132] As shown in FIG. 11, first openings 14a are formed near recess 9a of ceiling surface 9. Recess 9a is a step area provided to protrude from ceiling surface 9 in a direction (downward direction) opposite to a travelling direction of microwaves emitted from first openings 14a (see FIG. 3). Two first openings 14a are symmetrical with respect to pipe axis V.

[0133] Second openings 14b are formed near front opening 13 so as to lie away from coupling part 7 than first openings 14a. Similar to first openings 14a, two second openings 14b are symmetrical with respect to pipe axis V.

[0134] A feature of each of first openings 14a is that, in two slots, a length of a portion extending from center point P1 in a direction toward pipe axis V is shorter than a length of a portion extending from center point P1 in a direction toward side wall surface 10a.

[0135] As shown in FIG. 3, flange 7b provided on coupling part 7 has a shape where a length in microwave transmission direction Z is shorter than a length in width direction W of waveguide structure section 8. That is, in coupling part 7, the length in microwave transmission direction Z is shorter than the length in a direction orthogonal to transmission direction Z. According to flange 7b, a tip of a slit extending from center point P1 toward coupling part 7 can be formed further near coupling part 7.

[0136] In this exemplary embodiment, since flange 7b joins to a back side of recess 9a, recess 9a is configured deeper than a height of a protrusion such as protruded TOX caulking, a welding mark, and a head of a screw or nut, formed on a front side of recess 9a due to joined flange 7b. According to this exemplary embodiment, any protrusions do not come into contact with the lower surface of loading stand 6.

[0137] Waveguide structure section 8 shown in FIG. 11 includes recess 9a provided on ceiling surface 9 above coupling part 7, and has a configuration similar or identical to the configuration of waveguide structure section 900B shown in FIG. 10B. According to waveguide structure section 8 shown in FIG. 11, similar or identical to waveguide structure section 900B, the decrease in temperature around coupling part 7 can be prevented as much as possible. Two possible reasons are as described below.

[0138] As the first reason, when a heating-target object is loaded above first openings 14a, circularly polarized microwaves emitted from first openings 14a are partially reflected by the heating-target object. The reflected microwaves are repeatedly reflected in a space formed between an upper surface of recess 9a and the lower surface of loading stand 6 to, as a result, further strongly heat the heating-target object.

[0139] As the second reason, in this exemplary embodiment, an internal space of waveguide structure section 8, where recess 9a is formed, is narrower than other portions. Most of microwaves transmitted from coupling shaft 7a into waveguide structure section 8, and travelling from a narrower space near recess 9a toward a wider space away from recess 9a are emitted from first openings 14a through an extraction effect to further strongly heat a heating-target object loaded on the central area of loading surface 6a.

[0140] A shape of first openings 14a according to this exemplary embodiment will now be described herein in detail.

[0141] As shown in FIG. 11, first openings 14a each include slits 20a, 20b that intersect at center point P1 to form a cross slot shape. Longer axes of the slits of first openings 14a are inclined at an angle of 45 degrees relative to pipe axis V.

[0142] Slit 20a extends from lower right of center point P1 to upper left, and has first length A extending from center point P1 to a lower right tip, and third length C extending from center point P1 to an upper left tip. The lower right tip of slit 20a faces coupling part 7, and lies near recess 9a.

[0143] Slit 20b extends from lower left of center point P1 to upper right, and has second length B extending from center point P1 to a lower left tip, and fourth length D extending from center point P1 to an upper right tip. That is, first length A is, among lengths from center point P1 to the tips of slits 20a, 20b, a length to the tip that is nearest to coupling part 7.

[0144] Third length C and fourth length D are identical, and are substantially equivalent to 1/4 of a wavelength of a microwave transmitting in waveguide structure section 8. Second length B is shorter than third length C and fourth length D, and first length A is shortest among the lengths.

[0145] Distance X between slit 20a and pipe axis V is longer than distance Y between slit 20b and pipe axis V. That is, on ceiling surface 9, an area around recess 9a that lies between two first openings 14a is wider than an area away from recess 9a.

[0146] Since, if an area between two first openings 14a is not flat, a disarrayed electromagnetic field is generated in waveguide structure section 8, which adversely affects formation of circularly polarized waves, a wider flat area should advantageously be provided between two first openings 14a. According to this exemplary embodiment, the wider flat area provided between two first openings 14a can form less disarrayed circularly polarized waves to achieve a higher extraction effect.

[0147] In this exemplary embodiment, a distance between two first openings 14a is at least 1/8 of a wavelength of a microwave transmitting in waveguide structure section 8. According to the experiments performed by the inventors, an advantageous result has been obtained when a distance between two first openings 14a substantially matches to a shaft diameter (18 mm) of coupling shaft 7a.

[0148] On the other hand, second openings 14b each have a cross slot shape where two slits having an identical length cross at right angles at a center. Longer axes of the slits of second openings 14b are inclined to an angle of 45 degrees relative to pipe axis V. In this exemplary embodiment, lengths of the longer axes of the slits of second openings 14b are identical to third length C and fourth length D of first openings 14a.

[0149] Although coupling part 7 according to this exemplary embodiment includes flange 7b having the above described shape, the shape of flange 7b is not limited to the above described shape, but may appropriately be changed in accordance with specifications.

[0150] For example, by shortening a portion of flange 7b in a direction along pipe axis V, first openings 14a can be provided at positions further closer to coupling part 7. According to a shape of flange 7b, such as flange 7b having a cut-away portion between first openings 14a, first openings 14a can be provided at positions further closer to coupling part 7.

[0151] With an improved shape of flange 7b, coupling part 7 and waveguide structure section 8 can further securely be joined without reducing an area of a joining portion, thus unevenness in products can be reduced.

[0152] Even when coupling shaft 7a has, for example, a semicircle, oval, or rectangular cross section, or when coupling shaft 7a having such a cross-sectional shape is directly joined to waveguide structure section 8, an effect similar or identical to the effect of this exemplary embodiment can be achieved. According to a configuration where no flange 7b is provided, a space for forming first openings 14a can further be expanded.

[0153] According to this exemplary embodiment, with an achieved higher extraction effect, the decrease in temperature around coupling part 7 can be prevented as much as possible, thus the central area of loading surface 6a can uniformly be heated.

[0154] Although, in this exemplary embodiment, the microwave extraction openings each have a cross slot shape, a shape of each of the microwave extraction openings according to the present disclosure is not limited to the cross slot shape. As long as a shape can generate circularly polarized waves, the microwave extraction openings may each have any shape other than a cross slot shape.

[0155] As results of experiments, it can be thought that an essential condition for generating circularly polarized waves from a waveguide structure section is to dispose a combination of two approximately elongated openings at positions shifted from the pipe axis.

[0156] Slits configuring microwave extraction openings 14 are not limited to rectangular. For example, even an opening having rounded corners and an oval opening can generate circularly polarized waves.

[0157] To avoid a concentrated electric field, it is rather advantageous that an opening has rounded corners. In this exemplary embodiment, as shown in FIGS. 3, 9A to 9C, 10A, 10B, and 11, the slits included in first openings 14a and second openings 14b have rounded corners at tips and intersecting portions. That is, the two slits included in each of microwave extraction openings 14 each have a width, at around an intersecting portion, wider than a width at around edge portions.

[0158] Although, in this exemplary embodiment, recess 9a is formed above coupling part 7 of ceiling surface 9, waveguide structure section 8 according to the present disclosure is not limited to this configuration.

[0159] For example, by taking into account a transmission situation of microwaves emitted from an opening, recess 9a may be provided between microwave extraction openings 14 and a center of rotation of waveguide structure section 8. Protrusions protruding from microwave extraction openings 14, via an internal space of waveguide structure section 8, to ceiling surface 9 on a side close to a center of rotation of waveguide structure section 8 may be provided.

[0160] That is, waveguide structure section 8 is provided on a part of ceiling surface 9 on a side closer to coupling part 7 than microwave extraction openings 14 so as to have a step area having a lower height than a height of other portions of ceiling surface 9.

INDUSTRIAL APPLICABILITY

[0161] In addition to microwave ovens, the present disclosure is applicable to various industry-purpose microwave heating devices including dryers, pottery heaters, garbage treatment machines, and semiconductor manufacturing machines.

REFERENCE MARKS IN THE DRAWINGS

[0162]

1, 100, 200: microwave oven
2a, 104, 204: heating chamber
2b, 209: power feeding chamber
2c, 10a, 10b, 10c: side wall surface
3, 101, 201: magnetron
3a: antenna
4, 102, 202, 400, 500: waveguide
5, 103, 203: rotating antenna
6, 108, 208: loading stand
6a: loading surface
7: coupling part
7a, 109: coupling shaft
7b: flange
8, 600, 700, 800, 900A, 900B: waveguide structure section
9: ceiling surface
9a, 909a: recess
11: bottom surface
12, 106, 206: low impedance portion
13: front opening
14: microwave extraction opening
14a, 614a, 714a, 814a, 914a: first opening
14b, 614b, 714b, 814b, 914b: second opening
15, 105, 205: motor
16, 210: infrared sensor
17, 211: controller
18, 18a, 18b: protrusion
19: retaining portion
12a, 20a, 20b: slit
107, 207: emission port
300: waveguide
301: wide width surface
302: narrow width surface
303: cross section
401, 501: opening

Claims

1. A microwave heating device comprising:

   a heating chamber for accommodating a heating-target object;
   a microwave generating unit for generating microwaves; and
   a waveguide structure antenna having a ceiling surface and side wall surfaces defining a waveguide structure section, and a front opening, the waveguide structure antenna emitting the microwaves from the front opening into the heating chamber, the waveguide structure section including a coupling part joined to the ceiling surface to couple the microwaves into an internal space of the waveguide structure section, the waveguide structure section including at least one microwave extraction opening formed on the ceiling surface to emit circularly polarized waves from the microwave extraction opening into the heating chamber, the waveguide structure section having, at a portion of the ceiling surface, the portion being closer to the coupling part than to the microwave extraction opening, a step area having a height that differs from heights of other portions of the ceiling surface.

2. The microwave heating device according to claim 1, wherein the step area includes a joining area corresponding to a joining portion between the coupling part and the waveguide structure section.

3. The microwave heating device according to claim 1, wherein the step area is provided at a portion of the ceiling surface, the portion being closer to the coupling part than to the microwave extraction opening, and has a height lower than the heights of other portions of the ceiling surface.

4. The microwave heating device according to claim 1, further comprising a driving unit for rotating the waveguide structure antenna,
wherein the coupling part includes a coupling shaft coupled to the driving unit to include a center of rotation of the waveguide structure antenna, and
a flange provided around the coupling shaft to configure the joining portion, the flange having a shorter length in a direction a pipe axis of the waveguide structure section than a length in a direction orthogonal to the direction of the pipe axis.

5. The microwave heating device according to claim 1, wherein the microwave extraction opening has a cross slot shape where two slits intersect, and is provided at a position shifted from the pipe axis.

6. The microwave heating device according to claim 1, wherein
the waveguide structure section includes at least two microwave extraction openings that are symmetrical with respect to the pipe axis, and
a distance between the two microwave extraction openings on an area around the coupling part is longer than a distance between the two microwave extraction openings on an area away from the coupling part.

FIG. 1

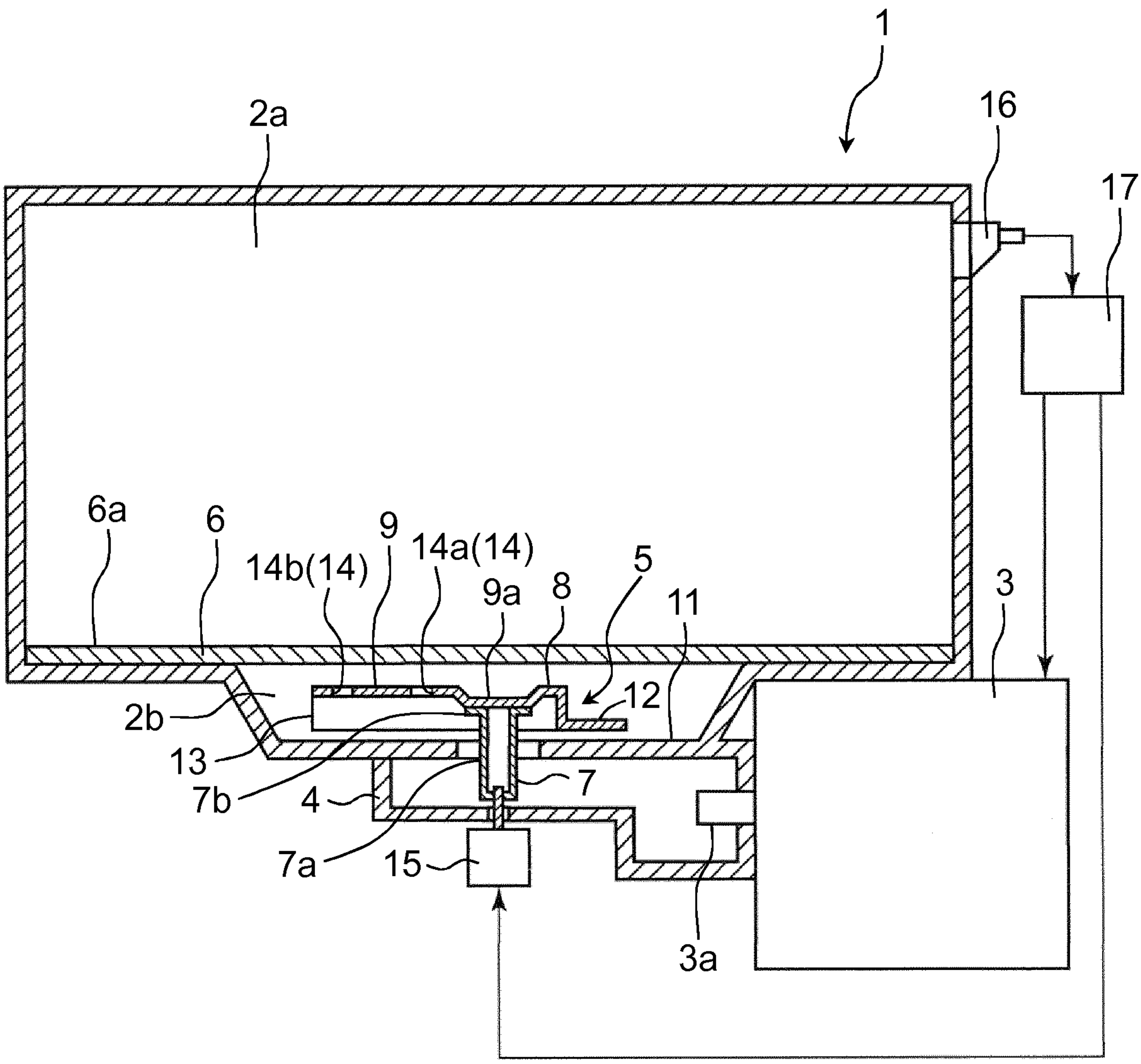


FIG. 2A

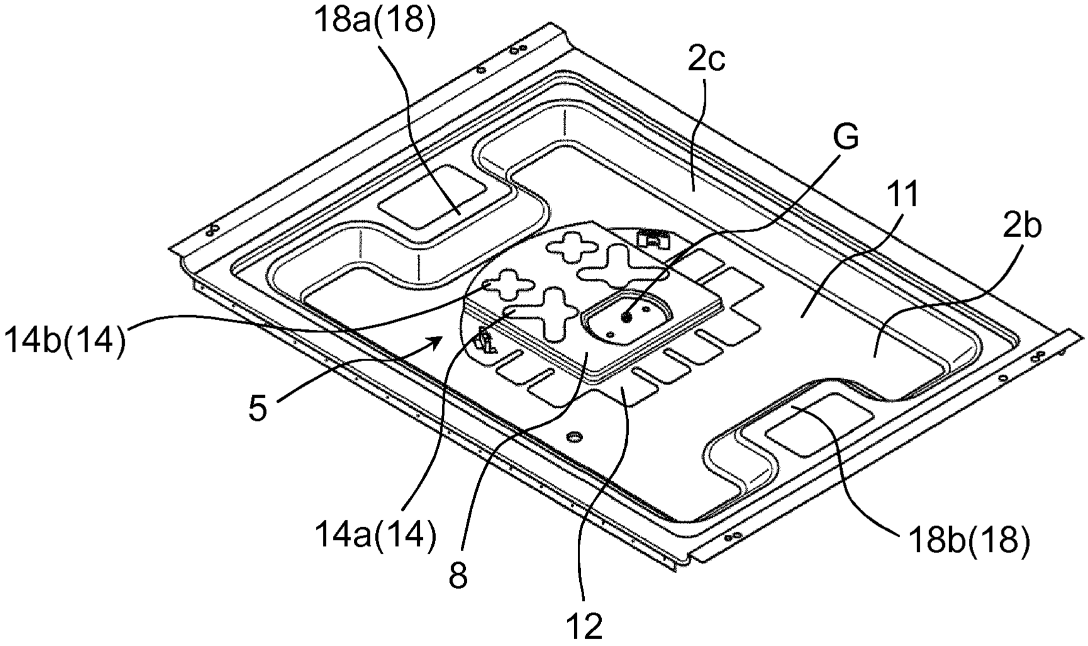

18a(18)
2c
G
11
2b
14b(14)
5
14a(14)
8
12
18b(18)

FIG. 2B

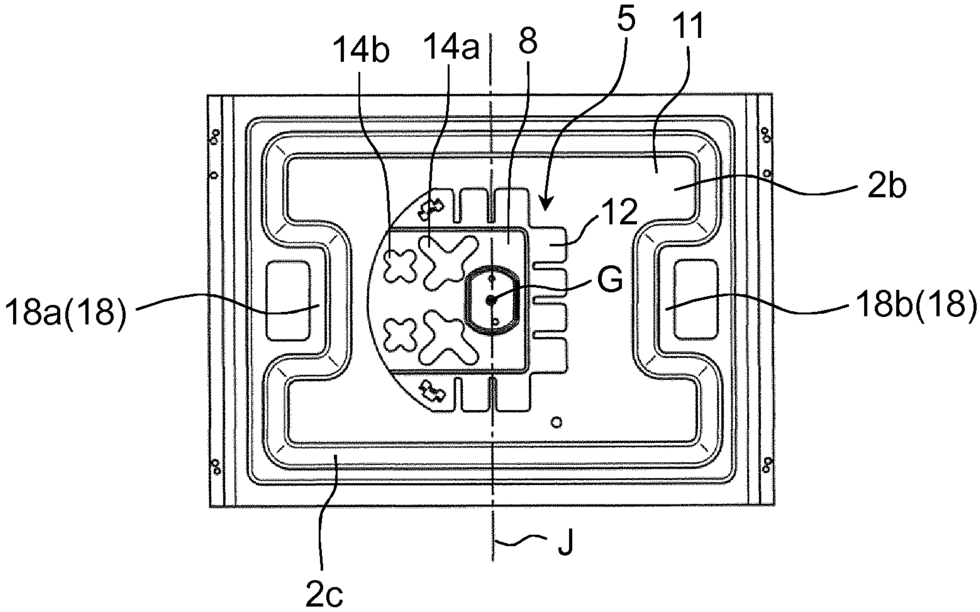

14b
14a
8
5
11
2b
12
G
18a(18)
18b(18)
2c
J

FIG. 3

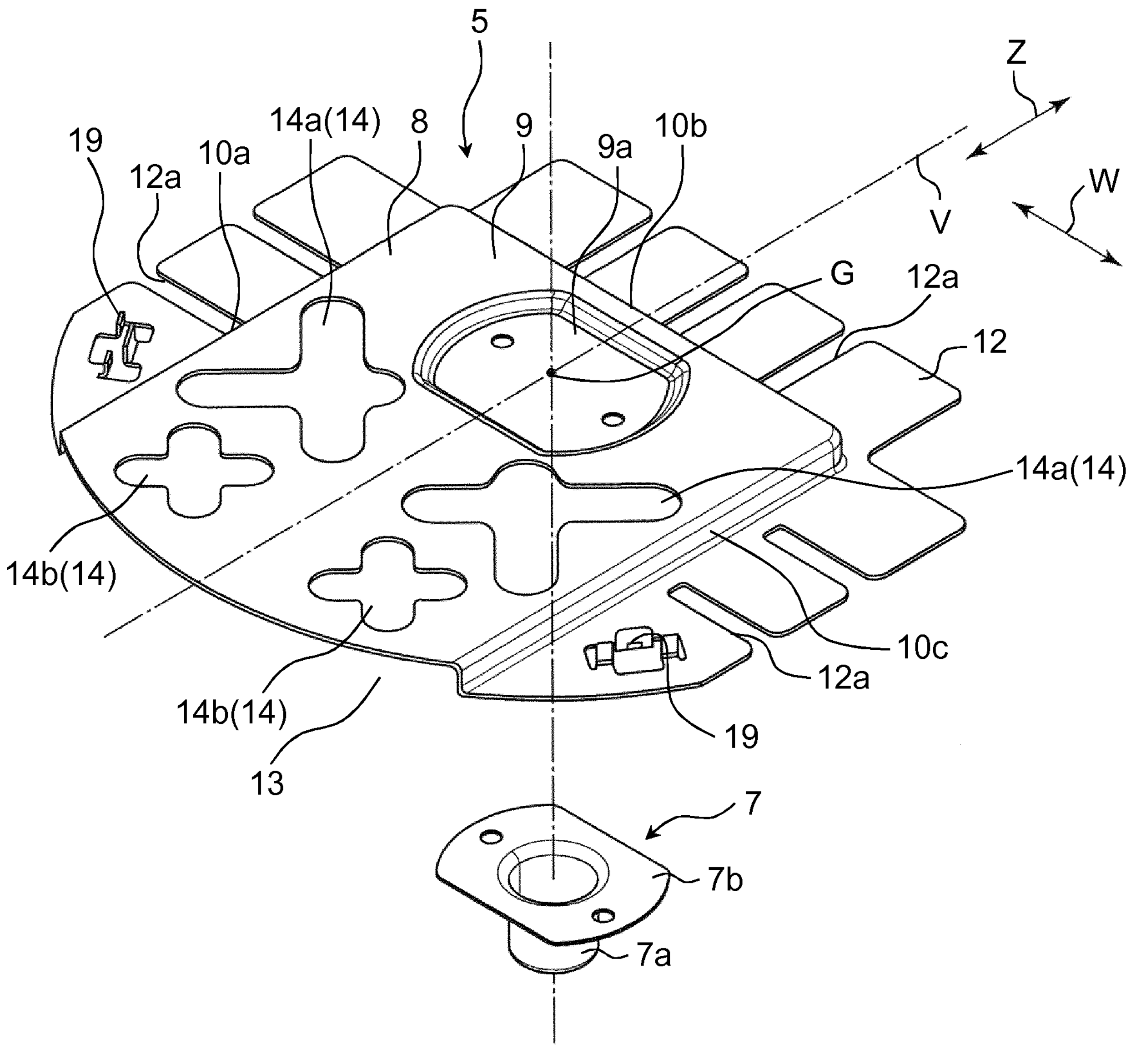

5
Z
19
12a
10a
14a(14)
8
9
9a
10b
V
W
G
12a
12
14a(14)
14b(14)
10c
12a
19
14b(14)
13
7
7b
7a

FIG. 4

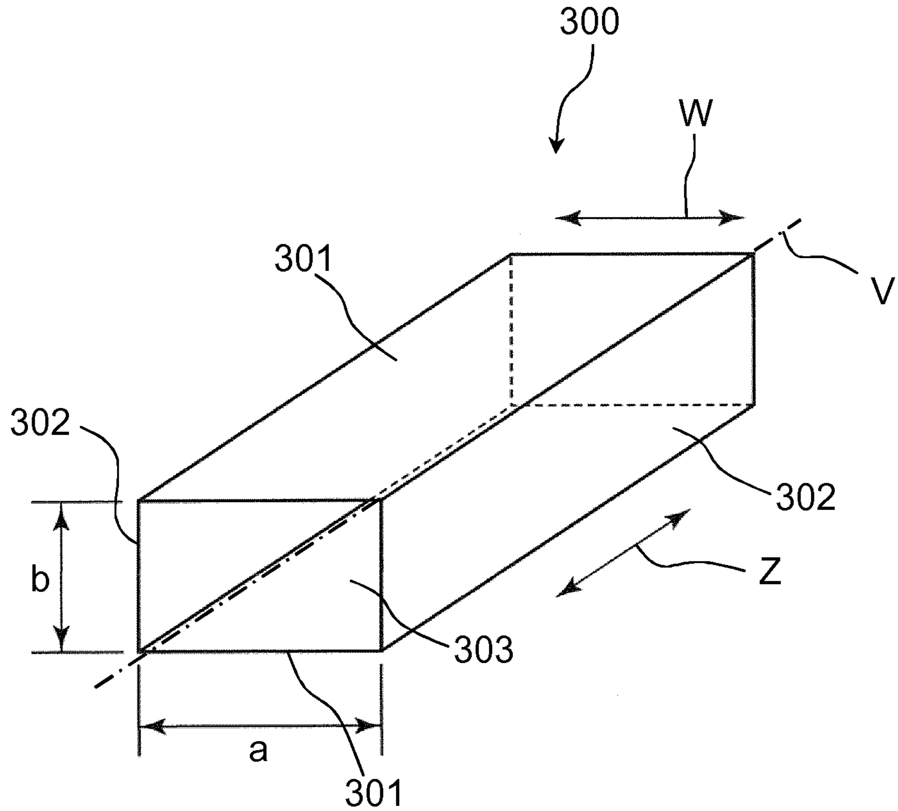


FIG. 5A

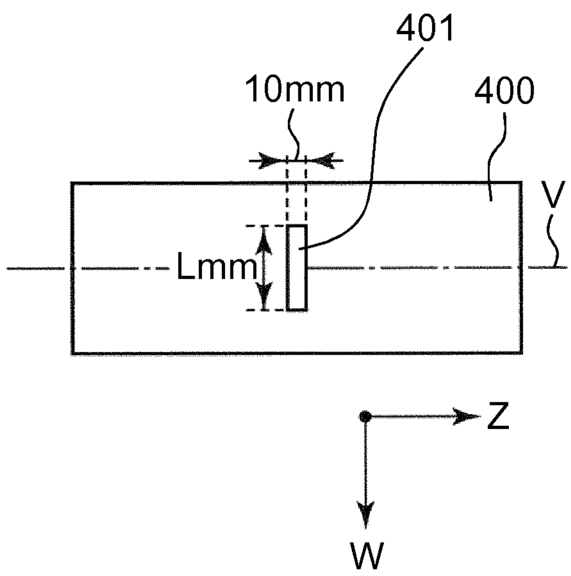


FIG. 5B

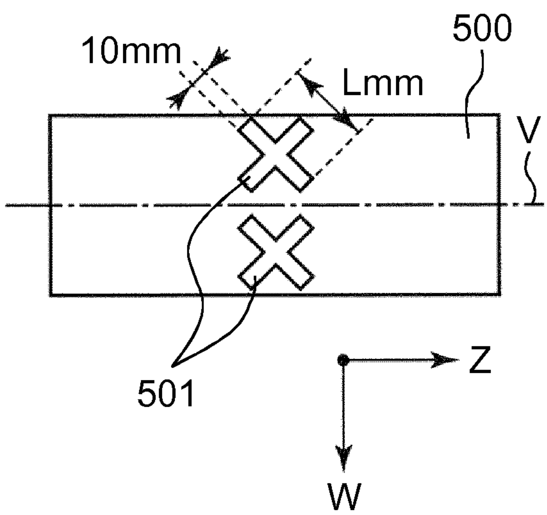


FIG. 5C

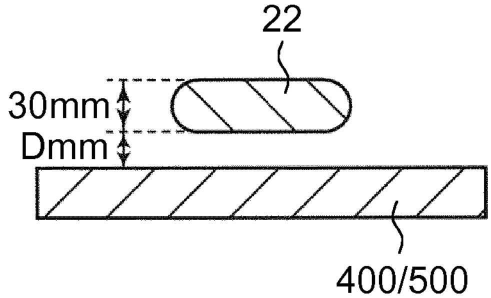


FIG. 6A

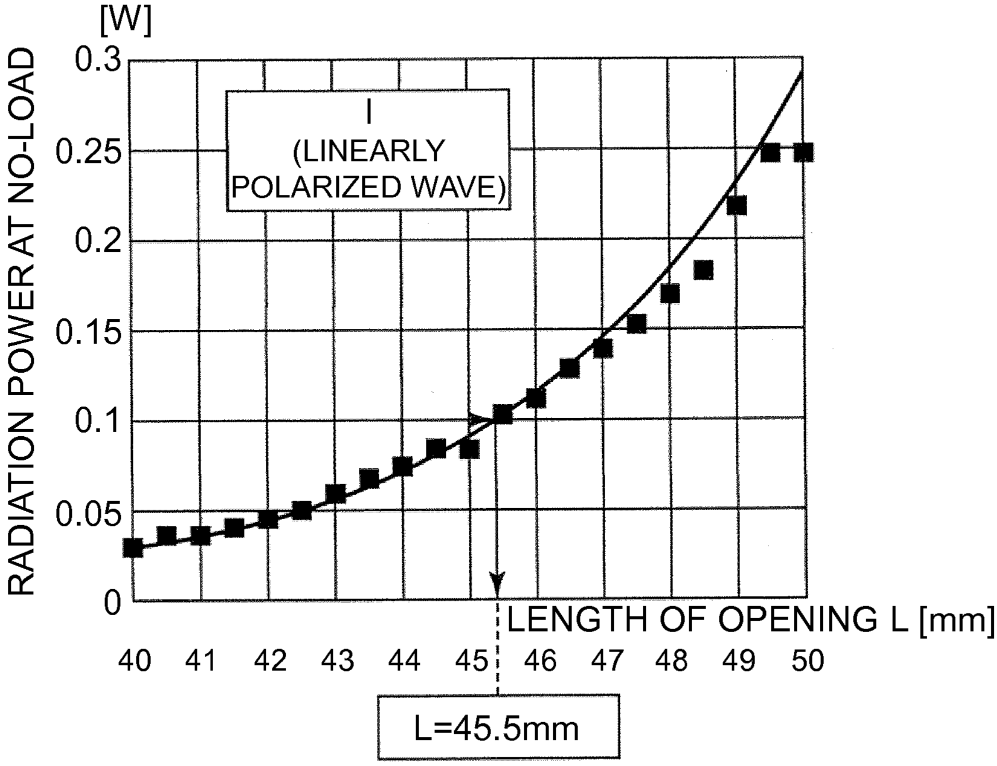

[W]
RADIATION POWER AT NO-LOAD
0.3
0.25
0.2
0.15
0.1
0.05
0
I
(LINEARLY
POLARIZED WAVE)
LENGTH OF OPENING L [mm]
40 41 42 43 44 45 46 47 48 49 50
L=45.5mm

FIG. 6B

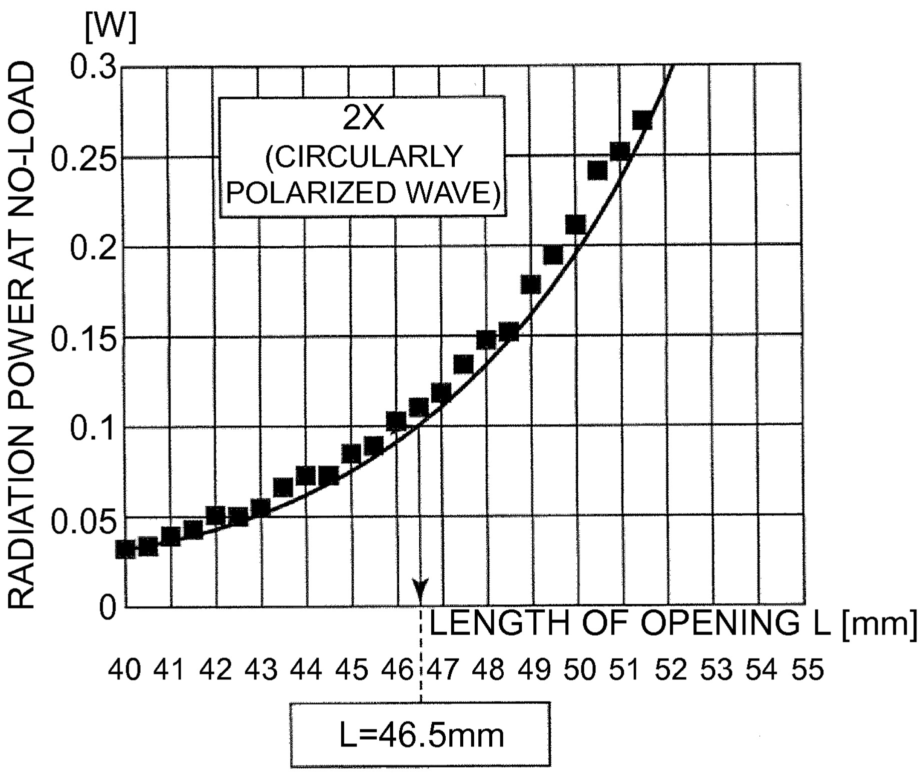

[W]
RADIATION POWER AT NO-LOAD
0.3
0.25
0.2
0.15
0.1
0.05
0
2X
(CIRCULARLY
POLARIZED WAVE)
LENGTH OF OPENING L [mm]
40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55
L=46.5mm

FIG. 7

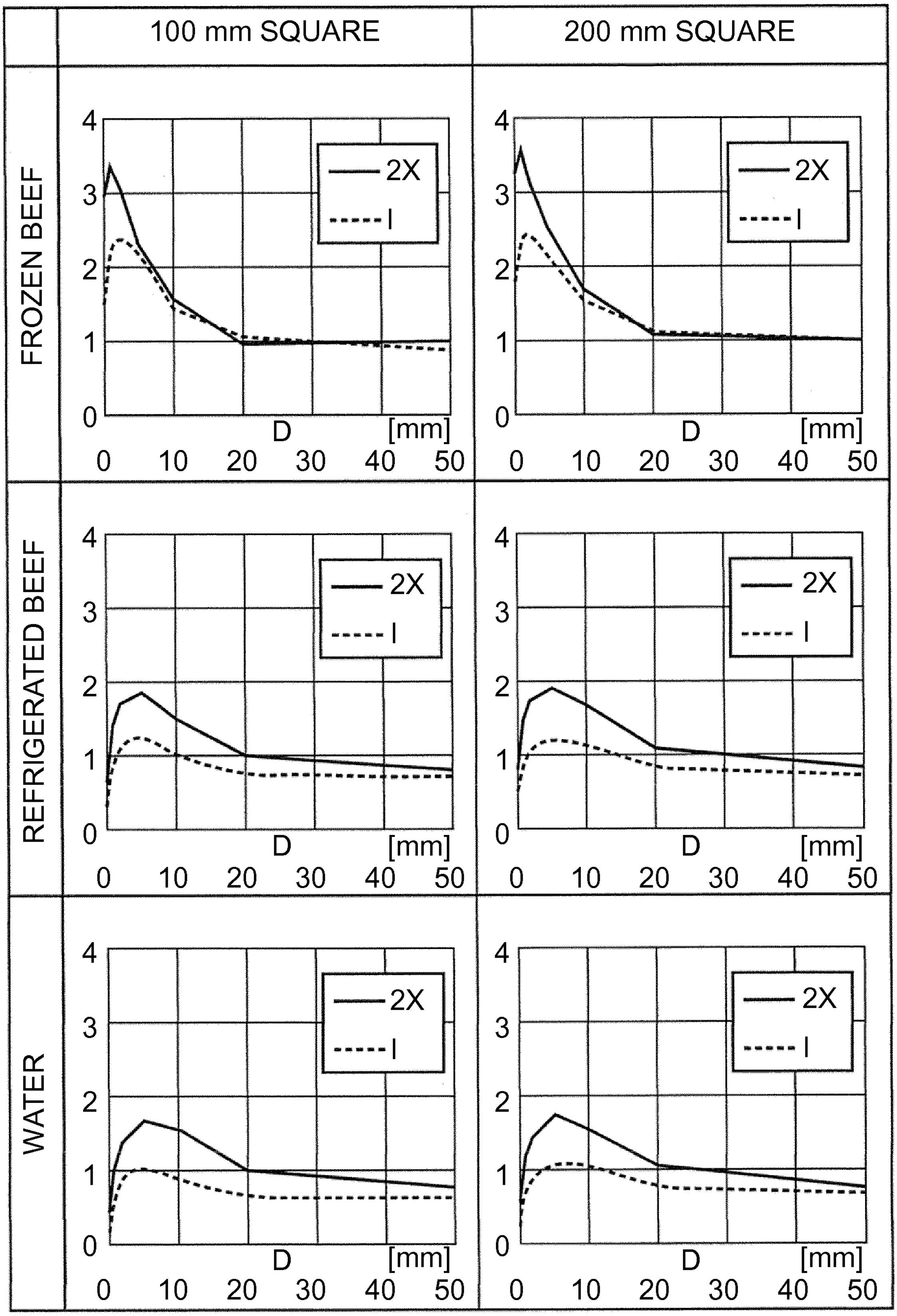

100 mm SQUARE
200 mm SQUARE
FROZEN BEEF
REFRIGERATED BEEF
WATER
2X
I
D
[mm]
0
10
20
30
40
50
0
1
2
3
4

FIG. 8A

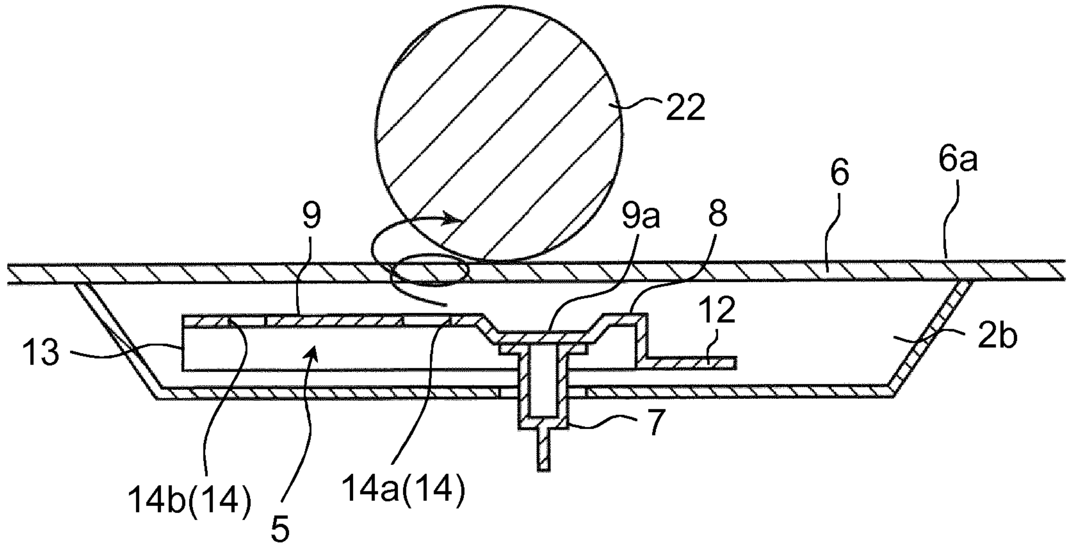

22
6
6a
9
9a
8
12
13
2b
7
14b(14)
5
14a(14)

FIG. 8B

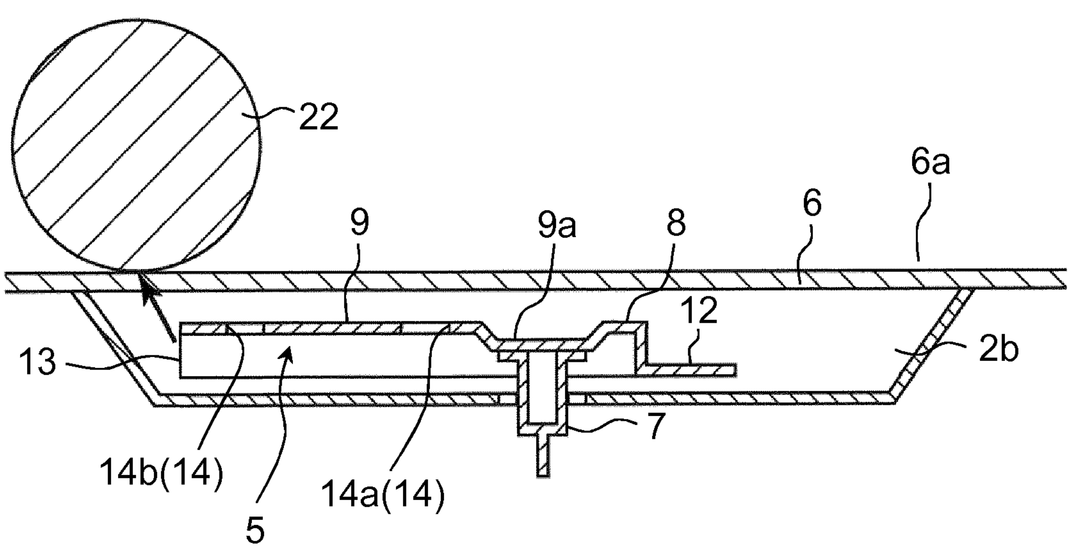

22
6a
6
9
9a
8
12
13
2b
7
14b(14)
14a(14)
5

FIG. 9A

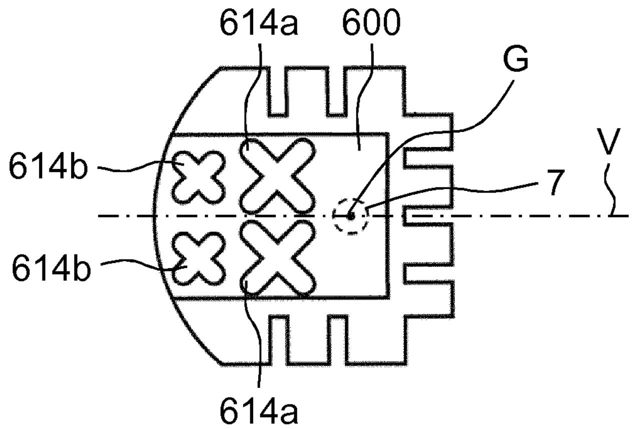


FIG. 9B

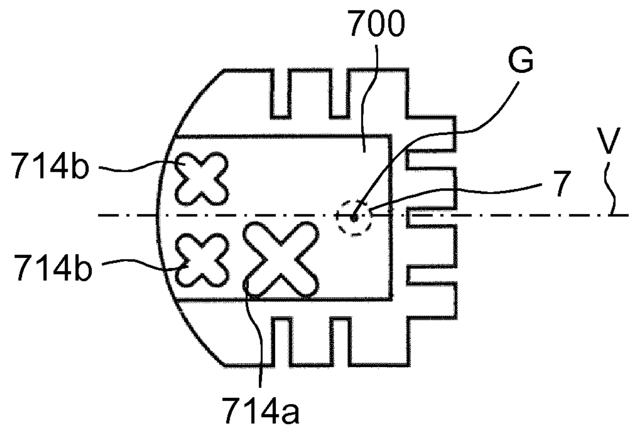


FIG. 9C

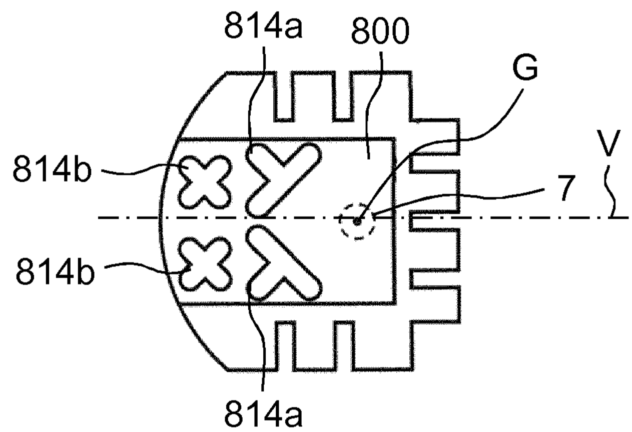


FIG. 10A

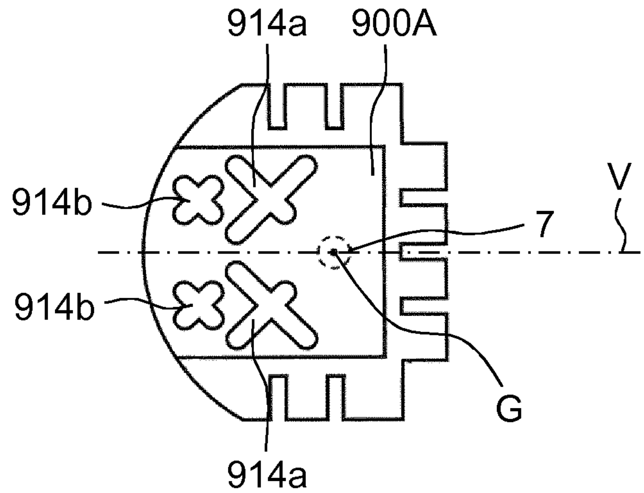


FIG. 10B

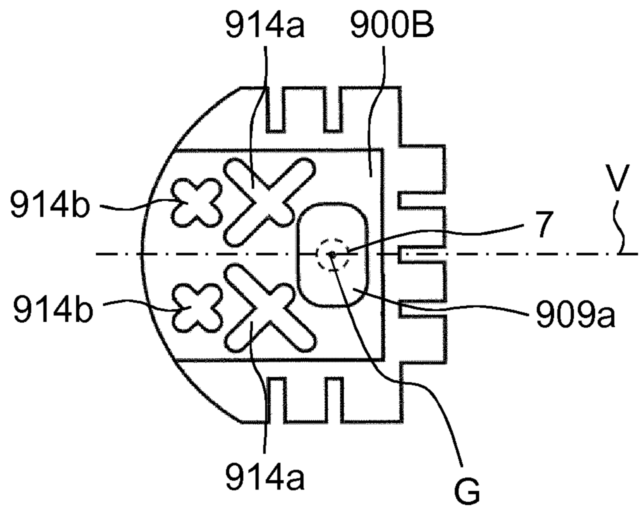


FIG. 11

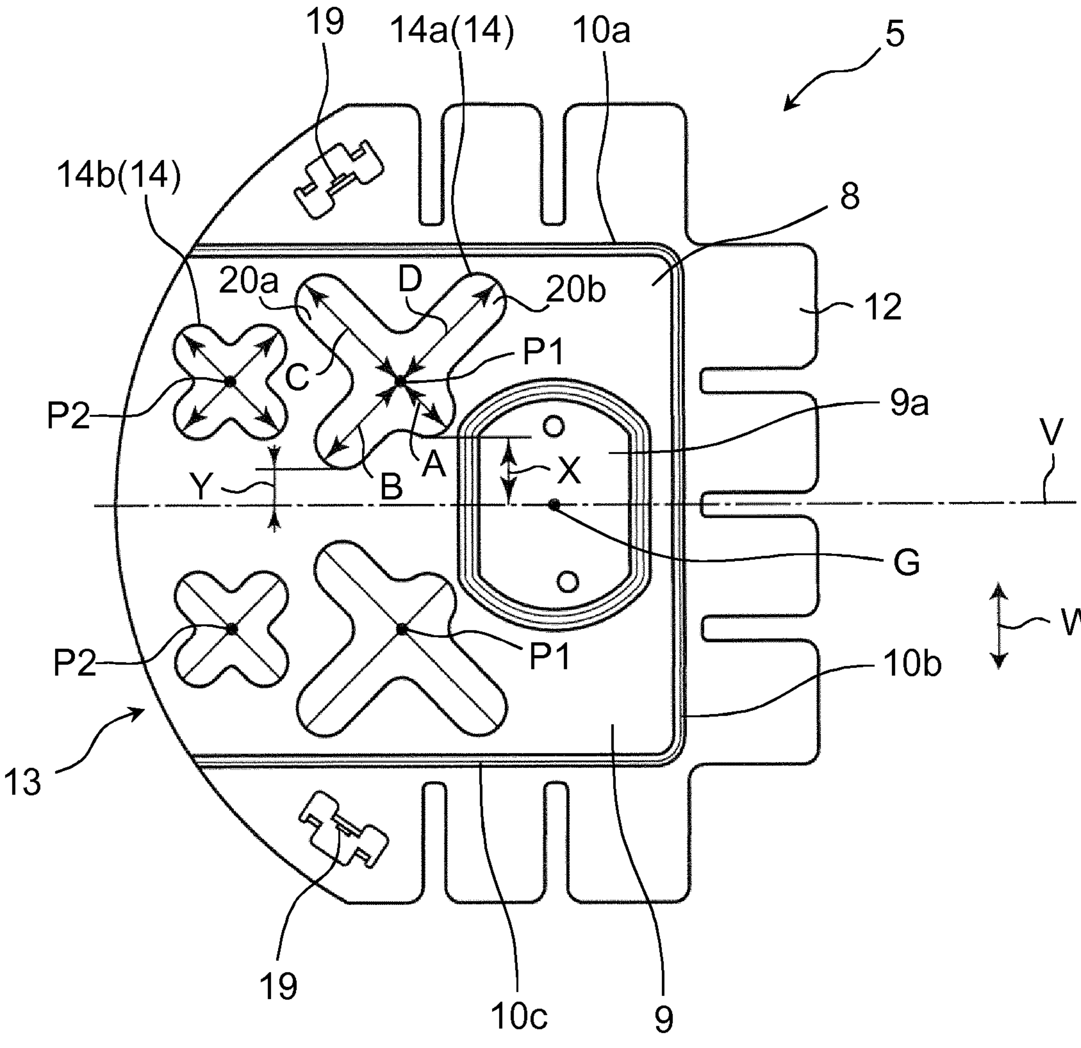

19
14a(14)
10a
5
14b(14)
8
20a
D
20b
12
P1
C
9a
P2
A
V
Y
B
X
G
W
P2
P1
10b
13
19
10c
9

FIG. 12

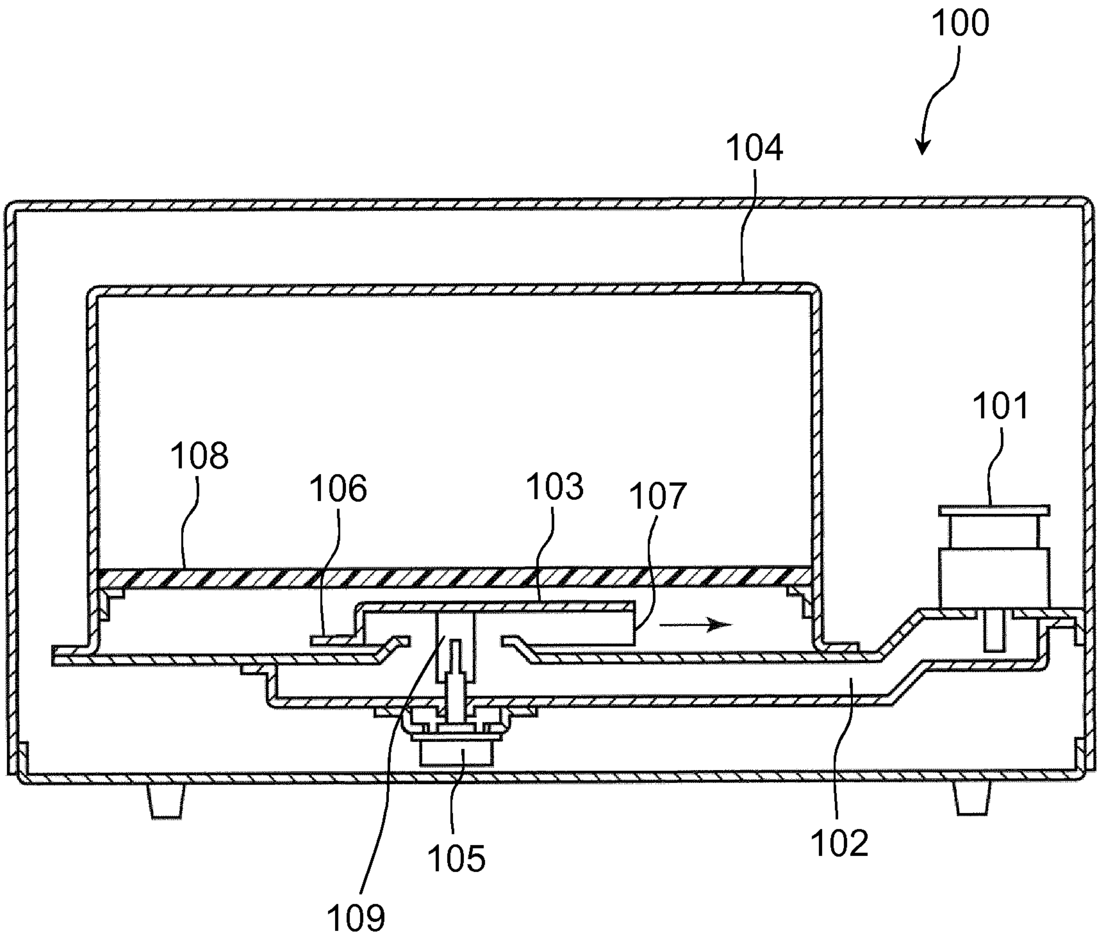
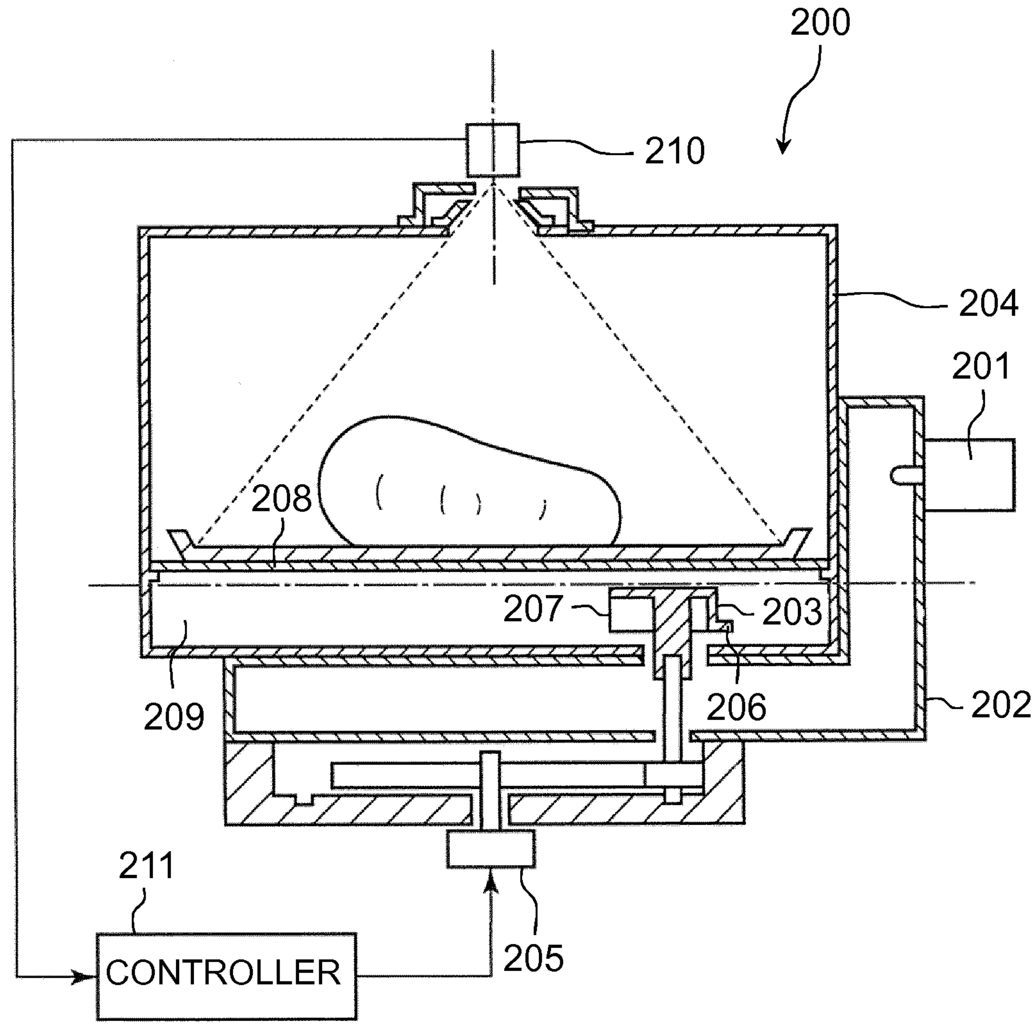


FIG. 13



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/006019

A. CLASSIFICATION OF SUBJECT MATTER
H05B6/72(2006.01)i, *F24C7/02*(2006.01)i, *H05B6/74*(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)
H05B6/72, F24C7/02, H05B6/74

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2014/171152 A1 (Panasonic Corp.), 23 October 2014 (23.10.2014), paragraphs [0028] to [0099] (Family: none)	1-6
A	WO 2013/018358 A1 (Panasonic Corp.), 07 February 2013 (07.02.2013), paragraphs [0045] to [0102] & US 2014/0166645 A1 paragraphs [0061] to [0122] & EP 2741574 A1 & CN 103718644 A	1-6
A	WO 2012/114369 A1 (Mitsubishi Electric Corp.), 30 August 2012 (30.08.2012), entire text; all drawings & TW 201236513 A & SG 192170 A & CN 103392378 A	1-6

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 January 2016 (07.01.16)	19 January 2016 (19.01.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 63053678 A **[0014]**
- JP 2894250 B **[0014]**