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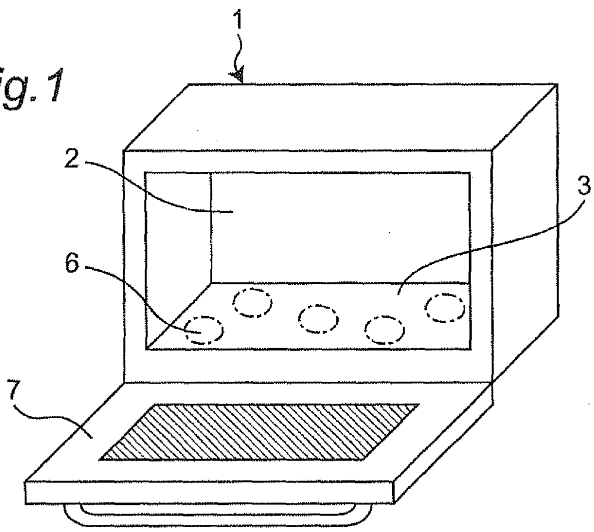
(54) **MICROWAVE HEATER**

(57) According to the present invention, in order to provide a microwave heater capable of performing uniform and efficient microwave heating on objects to be heated, without using a rotational mechanism, a plurality of microwave radiating portions (6) for radiating circularly-polarized waves within a heating chamber are provided in a waveguide (5) for propagating microwaves from a microwave generating portion (4), in its surface faced to the heating chamber (2), wherein the plurality of the microwave radiating portions are adapted to radiate substantially the same amount of microwaves.

Fig.1



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Description

Technical Field

[0001] The present invention relates to microwave heaters such as microwave ovens and, more particularly, relates to microwave heaters including microwave radiating portions with characteristic structures.

Background Art

[0002] As representative devices as microwave heaters for performing heating processes on objects through microwaves, there have been microwave ovens. Microwave ovens are adapted to radiate microwaves generated from a microwave generating portion, within a heating chamber made of a metal, thereby performing heating processes on objects to be heated within the heating chamber, through microwaves radiated therein.

[0003] As microwave generating portions in conventional microwave ovens, magnetrons have been employed. A magnetron creates microwave, and the microwave is radiated within a heating chamber through a waveguide. When there is a non-uniform microwave electromagnetic-field distribution within the heating chamber, it is impossible to perform uniform microwave heating on objects to be heated.

[0004] Conventionally, ordinary microwave heaters have included structures for rotating tables which place objects to be heated thereon for rotating the objects to be heated, structures for rotating antennas which radiate microwaves while fixing objects to be heated, or structures for causing phase shifts in microwaves generated from microwave generating portions, as means for uniformizing heating of objects to be heated.

[0005] For example, conventional microwave heater has been provided with a rotational antenna, an antenna shaft and the like within a waveguide and, further, have been adapted to drive a magnetron while rotating the rotational antenna through an antenna motor, in order to alleviate non-uniformity in the microwave distribution within the heating chamber.

[0006] Further, as described in Unexamined Japanese Patent Publication No. S62- 064093 (Patent Literature 1), it has been suggested microwave heater having a rotatable antenna provided to a magnetron. The microwave heater in Patent Literature 1 is adapted to direct cooling air flows from a blower fan to the blades in the rotatable antenna, in order to rotate the antenna by wind power from the blower fan, thereby changing the microwave distribution within the heating chamber.

[0007] On the other hand, as an example of provision of a phase shifter, there has been a microwave heater described in U.S. Patent No. 4,301,347 (Patent Literature 2), which attains cost reduction and reduction of the space of feeding portions, in addition to alleviation of heating unevenness in objects to be heated during microwave heating. As described in Patent Literature 2, there have been suggested microwave heaters provided with a rotational mechanism for causing phase shifts and with a single microwave radiating portion for radiating circularly-polarized waves within a heating chamber.

Citation List

Patent Literatures

[0008]

Patent Literature 1: Unexamined Japanese Patent Publication No. S62-064093
Patent Literature 2: U.S. Patent No. 4301347
Patent Literature 3: Unexamined Japanese Patent Publication No. 2007-225186

Summary of Invention

Technical Problem

[0009] Microwave heaters such as microwave ovens have been required to perform heating on objects to be heated with simple structures and with higher efficiency, and without inducing heating unevenness. However, conventional structures which have been suggested in the past as described above have had various problems.

[0010] Further, technical developments have been advanced for attaining higher outputs with microwave heaters, particularly microwave ovens, and commercial products with rated high- frequency outputs of 1000 W have been on sale in Japan. A striking feature of microwave heaters, as commercial products, is convenience of directly heating food through induction heating, rather than heating food through heat conduction. However, if microwave ovens are adapted to generate higher outputs in states where heating unevenness has not overcome, this makes the problem of heating unevenness more obvious.

[0011] As problems of the structures of conventional microwave heaters, there have been two points as follows. The first point is that there is a need for a mechanism for rotating a table or an antenna for alleviating heating unevenness. Therefore, conventional microwave heaters have been required to secure a rotation space for rotating the table or the antenna, and an installation space for a driving mechanism such as a motor for rotating the table or the antenna, which has obstructed size reduction of microwave heaters.

[0012] The second point is that, in order to stably rotate the table or the antenna, it is necessary to provide this rotational antenna at an upper portion or a lower portion in the heating chamber, which has imposed restrictions on the structure.

[0013] In a microwave heater, when a rotational mechanism for a table or a phase shifter is installed in the space for microwave irradiation, the reliability is degraded. Accordingly, there has been a need for microwave heaters which do not necessitate such mechanisms.

[0014] Further, microwave heaters adapted to radiate circularly- polarized waves within a heating chamber from a single microwave radiating portion, in order to attain cost reduction and reduction of the space of feeding portions in addition to alleviation of heating unevenness in objects to be heated during microwave heating, as described in Patent Literature 2, have the advantage of having no rotational mechanism for a table or an antenna, but have the problem of necessity of a rotational mechanism for causing phase shifts, and the problem of impossibility of realization of sufficiently-uniform heating on objects to be heated through microwave radiation from the single microwave radiating portion.

[0015] The present invention was made to overcome the aforementioned problems in conventional microwave heaters and to provide a microwave heater capable of performing uniform and efficient microwave heating on objects to be heated, without using a rotational mechanism.

Solution to Problem

[0016] In order to attain the aforementioned objects, according to the present invention, there are provided: a heating chamber adapted to house an object to be heated; a placement portion which forms a bottom surface of the heating chamber and is adapted to accommodate and place, thereon, the object to be heated within the heating chamber; a microwave generating portion adapted to generate a microwave; a waveguide adapted to propagate the microwave from the microwave generating portion; and a plurality of microwave radiating portions which are provided in a surface of the waveguide which is faced to the heating chamber and are adapted to radiate a circularly-polarized wave within the heating chamber.

[0017] The microwave heater having the aforementioned structure according to the present invention is enabled to suppress the occurrence of standing waves due to interference of microwaves radiated within the heating chamber with microwaves having been reflected by the inner walls and the like of the heating chamber, which has been regarded as a problem in microwave heating through conventional microwave heaters. This can realize uniform microwave heating.

Advantageous Effects of Invention

[0018] The microwave heater according to the present invention is capable of performing uniform and efficient microwave heating on objects to be heated with a simple structure and without using a rotational mechanism and, also, is capable of having a feeding portion with a reduced size and having improved reliability.

Brief Description of Drawings

[0019]

Fig. 1 is a perspective view illustrating a microwave heater according to a first embodiment of the present invention.
Fig. 2 is a cross-sectional view of the microwave heater according to the first embodiment.
Fig. 3 is a top view of a waveguide, illustrating microwave radiation portions in the microwave heater according to the first embodiment.
Fig. 4 is a view illustrating concrete shapes of the microwave radiating portions for use in the microwave heater according to the first embodiment.
Fig. 5 is a perspective view illustrating a microwave heater according to a second embodiment of the present invention.
Fig. 6 is a top view of a waveguide, illustrating microwave radiation portions in the microwave heater according to the second embodiment.
Fig. 7 is a perspective view illustrating an ordinary rectangular waveguide.
Fig. 8 is a perspective view illustrating a microwave heater according to a third embodiment of the present invention.
Fig. 9 is a top view of a waveguide, illustrating microwave radiation portions in the microwave heater according to the third embodiment.

Fig. 10 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to a fourth embodiment of the present invention.

Fig. 11 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to a fifth embodiment of the present invention.

Fig. 12 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to a sixth embodiment of the present invention.

Fig. 13 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to a seventh embodiment of the present invention.

Fig. 14 is a view illustrating concrete shapes of the microwave radiating portions according to the sixth and seventh embodiments.

Fig. 15 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to an eighth embodiment of the present invention.

Fig. 16 is a view illustrating another structure of microwave radiating portions in the microwave heater according to the eighth embodiment.

Fig. 17 is a perspective view illustrating a microwave heater according to a ninth embodiment of the present invention.

Fig. 18 is a top view of a waveguide, illustrating microwave radiation portions in the microwave heater according to the ninth embodiment.

Fig. 19 is a perspective view illustrating a microwave heater according to a tenth embodiment of the present invention.

Fig. 20 is a top view of a waveguide, illustrating microwave radiation portions in the microwave heater according to the tenth embodiment.

Fig. 21 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to an eleventh embodiment of the present invention.

Fig. 22 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to a twelfth embodiment of the present invention.

Fig. 23 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to a thirteenth embodiment of the present invention.

Fig. 24 is a top view of a waveguide, illustrating microwave radiation portions in a microwave heater according to a fourteenth embodiment of the present invention.

Fig. 25 is a perspective view illustrating a microwave heater according to a fifteenth embodiment of the present invention.

Fig. 26 is a front cross-sectional view of the microwave heater according to the fifteenth embodiment.

Fig. 27 is a plan cross-sectional view illustrating a bottom-surface portion of a heating chamber, in the microwave heater according to the fifteenth embodiment.

Fig. 28 is a front cross-sectional view of a microwave heater according to a sixteenth embodiment of the present invention.

Fig. 29 is a plan cross-sectional view illustrating a bottom-surface portion of a heating chamber, in the microwave heater according to the sixteenth embodiment.

Fig. 30 is a cross-sectional view illustrating a conventional microwave heater.

Description of Embodiments

[0020] A first invention comprises a heating chamber adapted to house an object to be heated;
a placement portion which forms a bottom surface of the heating chamber and is adapted to accommodate and place, thereon, the object to be heated within the heating chamber;
a microwave generating portion adapted to generate a microwave;
a waveguide adapted to propagate the microwave from the microwave generating portion; and
a plurality of microwave radiating portions which are provided in a surface of the waveguide which is faced to the heating chamber and are adapted to radiate a circularly-polarized wave within the heating chamber.

[0021] The microwave heater having the aforementioned structure according to the first invention is enabled to suppress the occurrence of standing waves due to interference of microwaves radiated within the heating chamber with microwaves having been reflected by the inner walls and the like of the heating chamber, which has been regarded as a problem in microwave heating through conventional microwave heaters. This can realize uniform microwave heating.

[0022] A second invention is configured that the plurality of the microwave radiating portions are placed just under the placement portion. The microwave heater having the structure according to the second invention is enabled to perform uniform microwave heating on the object to be heated.

[0023] A microwave heater of a third invention is configured that the respective plurality of the microwave radiating portions are adapted to radiate substantially the same amount of microwaves. The microwave heater having the structure according to the third invention is enabled to perform uniform microwave heating on the object to be heated.

[0024] A fourth invention is configured that, especially in the third invention, the plurality of the microwave radiating portions are placed, in such a way as to be arranged at least in a direction of propagation in the waveguide. The microwave heater having the structure according to the fourth invention is enabled to perform uniform and efficient microwave heating on the object to be heated, since the microwave radiating portions are properly placed at desired positions.

[0025] A fifth invention is configured that, especially in the third invention, the plurality of the microwave radiating portions are placed, in such a way as to be arranged at least in a direction orthogonal to a direction of an electric field and to a direction of propagation in the waveguide. The microwave heater having the structure according to the fifth invention is enabled to perform uniform and efficient microwave heating on the object to be heated.

[0026] A sixth invention is configured that, especially in the fourth or the fifth invention, the plurality of the microwave radiating portions comprise two slits intersected with each other, and each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide. The microwave heater having the structure according to the sixth invention is enabled to perform uniform and efficient microwave heating on the object to be heated.

[0027] A seventh invention is configured that, especially in the fourth or the fifth invention, the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the longer sides of the slits have lengths which are varied depending on their positions in the direction of propagation in the waveguide. The microwave heater having the structure according to the seventh invention is enabled to control the amount of microwave radiations and, thus, is enabled to perform uniform and efficient microwave heating on the object to be heated, by varying the respective lengths of the slits in the microwave radiating portions, as well as through the placement of the microwave radiating portions.

[0028] An eighth invention is configured that, especially in the fourth or the fifth invention, the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the longer sides of the slits have lengths which are varied depending on their positions in a direction orthogonal to the direction of the electric field and to the direction of propagation in the waveguide. The microwave heater having the structure according to the eighth invention is enabled to perform uniform and efficient microwave heating on the object to be heated.

[0029] A ninth invention is configured that, especially in the fourth or the fifth invention, the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the slits have widths which are varied depending on their positions in the direction of propagation in the waveguide. The microwave heater having the structure according to the ninth invention is enabled to change the microwave distribution within the heating chamber, thereby ensuring uniformity of the microwave distribution within the heating chamber, by varying the widths of the slits in the microwave radiating portions, as well as through the placement of the microwave radiating portions.

[0030] A tenth invention is configured that, especially in the fourth or the fifth invention, the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the slits have widths which are varied depending on their positions in a direction orthogonal to the direction of the electric field and to the direction of propagation in the waveguide. The microwave heater having the structure according to the tenth invention is enabled to perform uniform and efficient microwave heating on the object to be heated.

[0031] An eleventh invention is configured that, especially in the fourth or the fifth invention, the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the slits have been subjected to round chamfering (R) or chamfering (C) at their intersection portions. The microwave heater having the structure according to the eleventh invention is enabled to reduce microwave losses in the microwave radiating portions and, thus, is enabled to perform efficient microwave heating on the object to be heated.

[0032] A twelfth invention is configured that, especially in the fourth or the fifth invention, the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the slits have been subjected to round chamfering (R) or chamfering (C) at their distal end portions. The microwave heater having the structure according to the twelfth invention is enabled to reduce microwave losses in the microwave radiating portions and, thus, is enabled to perform efficient microwave heating on the object to be heated.

[0033] A thirteenth invention is configured that, especially in the fourth or the fifth invention, the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and

in terms of the positions of the intersection portions of the slits, a microwave radiating portion at a larger propagation distance from the position at which the microwave generating portion is installed is shaped to have a higher rate of radiation of a microwave to the heating chamber through the waveguide, than that of a microwave radiating portion at a smaller propagation distance from the position at which the microwave generating portion is installed. The microwave heater having the structure according to the thirteenth invention is enabled to perform uniform and efficient microwave heating on the object to be heated.

[0034] A fourteenth invention is configured that, especially in the third invention, the placement portion adapted to accommodate and place, thereon, the object to be heated within the heating chamber includes a microwave transmission portion which is penetrated by microwaves, the microwave transmission portion is placed oppositely to the microwave radiating portions, and the microwave transmission portion is provided at least just above the microwave radiating portions. With the microwave heater having the structure according to the fourteenth invention, the placement portion can be formed to have a smaller area which is penetrated by microwaves. As a result thereof, the microwave heater is enabled to reduce the amount of microwave energy losses caused by absorption of microwaves in the placement portion, which can increase the efficiency of heating of the object to be heated through microwaves, thereby realizing excellent energy saving performance.

[0035] Further, this microwave heater is of a type for radiating circularly- polarized microwaves within the heating chamber, which eliminates the necessity of providing a rotational antenna, and a motor for driving the rotational antenna. This can eliminate the necessity of providing a driving space and an installation space for such mechanisms, which can attain size reduction of the microwave heater, thereby making the installation space smaller.

[0036] A fifteenth invention is configured that, especially in the fourteenth invention, the microwave transmission portion has a shape conforming to the microwave radiating portions. The microwave heater having the structure according to the fifteenth invention is enabled to have a minimum necessary area which is penetrated by microwaves, which further reduces microwave absorption losses in the microwave transmission portion. As a result thereof, the microwave heater is enabled to have an increased efficiency of supply of microwaves to the heating chamber.

[0037] A sixteenth invention is configured that, especially in the fifteenth invention, the placement portion includes the microwave transmission portion, and a microwave reflection portion for reflecting microwaves. With the microwave heater having the structure according to the sixteenth invention, the microwave reflection portion is structured to reflect microwaves which have not been absorbed by the object to be heated, which facilitates absorption of microwaves by the object to be heated, thereby further increasing the efficiency of heating through microwaves.

[0038] A seventeenth invention is configured that, especially in the sixteenth invention, the microwave transmission portion is made of a crystallized glass containing at least one material, out of silicon oxide, aluminum oxide, zirconium oxide, and lithium oxide. With the microwave heater having the structure according to the seventeenth invention, it is possible to improve the microwave transmission performance, which can increase microwave energy radiated within the heating chamber, thereby increasing the efficiency of heating of the object to be heated through microwaves.

[0039] An eighteenth invention is configured that, especially in the sixteenth invention, the microwave transmission portion is mainly made of a plastic material. With the microwave heater having the structure according to the eighteenth invention, it is possible to improve the microwave transmission performance in comparison with cases of using a crystallized glass, which can increase the efficiency of heating the object to be heated.

[0040] A nineteenth invention is configured that, especially in the sixteenth invention, the microwave reflection portion is made of a metal material. With the microwave heater having the structure according to the nineteenth invention, it is possible to improve the microwave reflection performance, which can increase the efficiency of heating the object to be heated through microwaves.

[0041] Hereinafter, preferable embodiments of the microwave heater according to the present invention will be described, with reference to the accompanying drawings. Further, the microwave heaters according to the following embodiments will be described with respect to microwave ovens, but these microwave ovens are merely illustrative, and the microwave heater according to the present invention is not limited to such microwave ovens and is intended to include microwave heaters which utilize induction heating. Further, the present invention is not limited to the concrete structures according to the following embodiments and is intended to cover structures based on technical concepts similar thereto.

(First Embodiment)

[0042] Fig. 1 is a perspective view illustrating a microwave oven as a microwave heater according to a first embodiment of the present invention. Fig. 2 is a cross-sectional view of the microwave heater according to the first embodiment of the present invention, taken along a plane parallel with the front surface thereof, at a substantially-middle position in the depthwise direction, illustrating main structural portions therein. Fig. 3 is a top view of a waveguide as a waveguide portion, illustrating the positions of microwave radiation portions which are antennas for radiating circularly-polarized microwaves, in the microwave heater according to the first embodiment of the present invention.

[0043] As illustrated in Fig. 1, the microwave oven as the microwave heater 1 according to the first embodiment includes a door 7 having a window in its front surface, a heating chamber 2 which is enclosed by the door 7 being closed and is adapted to house, therein, an object to be heated through microwave heating, and a placement portion 3 for housing and placing, thereon, the object to be heated, within the heating chamber 2.

[0044] Just under the placement portion 3, there are provided a plurality of microwave radiating portions 6 as microwave radiating means for radiating microwaves within the heating chamber 2. Each of the microwave radiating portions 6 is adapted to radiate circularly-polarized waves within the heating chamber 2.

[0045] As illustrated in Fig. 2, the microwave heater 1 according to the first embodiment includes a microwave generating device 4 as a microwave generating portion which is constituted by a magnetron and the like for generating microwaves, and the waveguide 5 as the waveguide portion for propagating microwaves generated from the microwave generating device 4, to the respective microwave radiating portions 6.

[0046] As illustrated in Fig. 3, in the microwave heater 1 according to the first embodiment, there are formed, on the upper surface of the waveguide 5, the plurality of the microwave radiating portions 6 which are adapted to radiate substantially the same amount of circularly-polarized microwaves within the heating chamber 2. The microwave radiating portions 6 are placed such that the object to be heated on the placement portion 3 is uniformly and efficiently heated by microwaves.

[0047] If there is only a single microwave radiating portion, it is hard to adjust the microwave distribution within the heating chamber in such a way as to uniformize it, due to the directivity of microwaves radiated therefrom. For example, a microwave heater provided with only a single microwave radiating portion with higher directivity is enabled to intensively heat only the vicinity of the microwave radiating portion. This results in the problem of occurrences of heating unevenness in objects to be heated.

[0048] In the microwave heater 1 according to the first embodiment, the plurality of the microwave radiating portions 6 are provided in the waveguide 5 as the waveguide portion in its surface faced to the heating chamber 2, and the respective microwave radiating portions 6 are adapted to radiate substantially the same amount of circularly-polarized microwaves within the heating chamber 2. Therefore, even in cases where microwaves from the respective microwave radiating portions 6 have higher directivity, it is possible to realize uniform microwave heating for the object to be heated.

[0049] In the microwave heater 1 according to the first embodiment, the microwave radiating portions 6 are adapted to radiate circularly-polarized microwaves. Conventional ordinary microwave heaters have been structured to radiate linearly-polarized microwaves (having electric fields with constant polarization planes) from microwave radiating portions within heating chambers, which has induced standing waves due to interference of microwaves radiated within the heating chambers with microwaves having been reflected by the inner walls and the like of the heating chambers, thereby causing heating unevenness in objects to be heated. The microwave heater 1 according to the first embodiment can suppress the occurrence of standing waves due to the interference of radiated microwaves with microwaves having been reflected by the inner walls and the like of the heating chamber, which has been regarded as a problem in microwave heating through conventional microwave heaters. This can realize uniform microwave heating.

[0050] Hereinafter, circular polarization will be described. Circular polarization is a technique which has been widely utilized in the fields of mobile communications and satellite communications. Examples of familiar usages thereof include ETCs (Electronic- Toll Collection Systems) "Non- Stop Automated Fee Collection Systems".

[0051] A circularly-polarized wave is a microwave having an electric field with a polarization plane which is rotated, with time, with respect to the direction of propagation of radio waves, When such a circularly-polarized wave is created, the direction of its electric field continuously changes with time. Thus, when circularly-polarized microwaves are radiated within the heating chamber, the microwaves radiated within the heating chamber continuously change in terms of the direction of their electric fields, so that they have an electric field intensity with a magnitude which is substantially uniform regardless of the positions, thereby providing the property of suppressing the occurrence of standing waves, even in consideration of reflections at the inner walls and the like of the heating chamber.

[0052] The microwave heater 1 according to the first embodiment is provided with the plurality of the microwave radiating portions 6 and, further, is adapted to cause the respective microwave radiating portions 6 to radiate circularly-polarized microwaves within the heating chamber 2. The microwave heater 1 having this structure according to the first embodiment is enabled to perform microwave heating more uniformly on the object to be heated within the heating chamber 2, since microwaves are radiated more uniformly within the heating chamber 2, than in cases of microwave heating with linearly-polarized microwaves, which have been utilized in conventional ordinary microwave heaters.

[0053] Circularly- polarized waves are sorted into two types, which are right- handed polarized waves (CW : clockwise) and left- handed polarized waves (CCW : counter to clockwise), based on the direction of rotations thereof. The heating performance is not varied, depending on whether the circularly- polarized waves radiated within the heating chamber 2 are right- handed polarized waves (CW : clockwise) or left- handed polarized waves (CCW : counter to clockwise) .

[0054] In the waveguide adapted to propagate microwaves from the microwave generating device constituted by a magnetron or the like, there are linearly-polarized microwaves with electric fields and magnetic fields which are oscillating in constant directions. As described above, conventional ordinary microwave heaters have been adapted to radiate linearly-polarized microwaves through waveguides within heating chambers. Accordingly, in conventional ordinary microwave heaters adapted to radiate linearly-polarized waves within heating chamber, in order to alleviate non-uniformity of the microwave distribution within the heating chamber, there has been installed a mechanism for rotating a table for placing an object to be heated thereon, a mechanism for rotating an antenna for radiating microwaves through a waveguide within the heating chamber, or a phase shifter for causing a phase shift inside the waveguide.

[0055] However, even by providing such a mechanism for rotating a table or an antenna or by providing such a phase shifter, it has been hard to realize uniform microwave heating within the heating chambers in microwave heaters. Furthermore, since conventional microwave heaters have been required to be provided with such a rotating mechanism or a phase shifter, there has been induced the problem of complicacy of the structure due to an increased number of members and, further, there have been induced the problems of restrictions on the structure and degradation of the reliability of the device.

[0056] For coping with the problems of complicacy of the structure, restrictions on the structure and degradation of the reliability as described above, the microwave heater 1 according to the first embodiment is structured to overcome all of them. The microwave heater 1 according to the first embodiment is structured to have the plurality of the microwave radiating portions 6 provided on the surface of the waveguide 5 which is faced to the heating chamber 2 and to cause the respective microwave radiating portions 6 to radiate substantially the same amount of circularly-polarized microwaves within the heating chamber 2. Therefore, the microwave heater 1 according to the first embodiment forms a device which is capable of performing uniform and efficient microwave heating on objects to be heated, while having a simple and reliable structure and imposing less restrictions on its structure.

[Conditions which vary the amount of microwave radiations]

[0057] As described above, the microwave heater 1 according to the first embodiment is capable of realizing uniform microwave heating for objects to be heated within the heating chamber 2, without being provided with a mechanism for rotating a table or an antenna or being provided with a phase shifter. Accordingly, the microwave heater 1 according to the first embodiment is capable of certainly avoiding the problem of heating unevenness and the like in objects to be heated during heating operations, which are induced in the event of failures of the rotating mechanism and in the event of abnormal operations.

[0058] Further, in cases of propagating microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, using the waveguide 5 as the propagation means, the amounts of microwaves radiated within the heating chamber 2 from the respective microwave radiating portions 6 are varied by the following three conditions.

[0059] The first condition is the distance (the position) in the direction X of propagation (see Fig. 2) to the microwave radiating portions 6 from the microwave generating device 4 constituted by a magnetron and the like. The amount of microwaves is varied depending on the distance (the position) in the direction X of propagation, for the following reason. At positions at shorter propagation distances from the microwave generating device 4, and at positions where the direction X of propagation is displaced due to bending and the like in the waveguide 5, microwaves generated from the microwave generating device 4 are in un-stabilized propagation states. Thus, there is a cluttered electric field distribution within the waveguide. On the other hand, at positions at larger propagation distances from the microwave generating device 4, they are in stabilized states.

[0060] For example, in the case of using the waveguide 5 which is bent in an L shape as illustrated in Fig. 2 for propagation of microwaves, the microwave radiating portions 6 placed in the periphery of the bent portion are made to radiate larger amounts of microwaves than those from the microwave radiating portions 6 at sufficient distances from the periphery of the bent portion, wherein the amount of microwaves radiated therefrom is largely increased or decreased with varying position in the direction X of propagation.

[0061] The second condition is the distance in the direction X of propagation to the microwave radiating portions 6 from a termination end surface 15 which is a termination end of the waveguide 5 in Fig. 2. Microwaves propagating within the waveguide 5 are linearly-polarized waves. Therefore, due to the interference of them with waves having been reflected by the termination end surface 15 of the waveguide 5, there are induced standing waves within the waveguide 5. Generally, the electric field is zero at the termination end surface of the waveguide 5 and, thus, the electric field intensity varies with the distance from the termination end surface 15 in the direction X of propagation. Therefore, the amount of microwaves radiated within the heating chamber 2 is increased and decreased with the distance in the direction X of propagation to the microwave radiating portions 6 from the termination end surface 15 of the waveguide 5.

[0062] Namely, the electric field intensity is maximized, at the position at a distance equal to 1/4 the wavelength of standing waves, in the direction X of propagation, from the termination end surface 15 of the waveguide 5. Further, the electric field intensity is minimized, at the position at a distance equal to 1/2 the wavelength of standing waves, in the direction X of propagation, from the termination end surface 15 of the waveguide 5.

[0063] Accordingly, even when the microwave radiating portions 6 have the same shape, if they are at different distances from the termination end surface 15 of the waveguide 5 in the direction X of propagation, the respective microwave radiating portions 6 are caused to radiate increased or decreased amounts of microwaves.

[0064] The third condition is the position in the direction (the widthwise direction Z of the waveguide 5: see Fig. 3) which is orthogonal to the direction X of propagation and to the direction Y of the electric field (see Fig. 2), in the waveguide 5. This is due to the fact that the electric field intensity is varied in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field, in the waveguide 5 through which microwaves are propagating.

[0065] In general, microwave heaters such as microwave ovens are adapted to propagate microwaves in the TE10 mode. Therefore, there exists an electric-field-distribution symmetry axis which extends in the direction X of propagation, such that it passes through the center of the waveguide in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field.

[0066] Further, in cases where a plurality of microwave radiating portions are placed on the same straight line in the direction X of propagation, the relationship among the amounts of microwaves radiated within the heating chamber from the respective microwave radiating portions is changed, depending on the intervals L between the microwave radiating portions adjacent to each other in the direction X of propagation (see Fig. 6 and Fig. 12 which will be described later) .

[0067] For example, in cases where the intervals L between the microwave radiating portions adjacent to each other in the direction X of propagation are made to be equal to the wavelength of standing waves induced within the waveguide, the microwave radiating portions adjacent to each other are caused to radiate microwaves with the same electric field intensity.

[0068] However, in cases where the intervals L between the microwave radiating portions adjacent to each other in the direction X of propagation are made different from the wavelength of standing waves induced within the waveguide, the respective microwave radiating portions are caused to radiate microwaves with different electric field intensities corresponding to the length differences.

[0069] In consideration of the aforementioned three conditions, in the structure according to the first embodiment, the microwave radiating portions 6 are placed on the surface of the waveguide 5 which is faced to the heating chamber 2, in such a way as to uniformize the microwave distribution within the heating chamber. Accordingly, even when the microwave radiating portions 6 are placed at symmetric positions with respect to the center of the internal space in the heating chamber 2, if the microwave radiating portions 6 are placed without taking account of the aforementioned three conditions, the microwave distribution within the heating chamber 2 can not be uniformized, in many cases.

[0070] Therefore, in the microwave heater having the plurality of the microwave radiating portions 6 in the direction X of propagation, according to the first embodiment, the technique for properly placing the plurality of the microwave radiating portions 6 at desired positions for uniformizing the microwave distribution within the internal space in the heating chamber 2 is necessary.

[The Structures of the Microwave Radiating Portions]

[0071] There will be described the structures of the microwave radiating portions 6 for radiating circularly-polarized waves, in the microwave heater according to the first embodiment. In the microwave heater according to the first embodiment, the structures of the microwave radiating portions 6 can be any structures capable of radiating circularly-polarized waves and are not particularly limited. Examples of their concrete shapes will be described, with reference to Fig. 4. Fig. 4 illustrates concrete shapes of the microwave radiating portions 6 for use in the microwave heater according to the first embodiment. The microwave radiating portions 6 illustrated in Fig. 4 are constituted by at least two or more slits (elongated opening portions). The microwave radiating portions 6, which are formed on the surface of the waveguide 5 which is faced to the heating chamber 2, are formed at positions deviated from the center P of the waveguide 5 in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field.

[0072] Referring to Fig. 4, (a) to (f) illustrate microwave radiating portions 6 having shapes of six types. As illustrated in Fig. 4, each of the microwave radiating portions 6 is constituted by two or more slits (elongated opening portions). Only at least a single slit, out of them, is required to have a shape with a longer side inclined with respect to the direction X of propagation of microwaves.

[0073] (a) in Fig. 4 illustrates a microwave radiating portion 6 which is constituted by two slits intersected with each other at their center points to be integrated in an X shape and, thus, has a shape capable of certainly radiating circularly-polarized waves with a simple structure. The respective slits are formed to be inclined by an angle of 45 degrees with respect to the direction X of propagation. In the case of this shape, provided that the center points of the two slits at which they intersect with each other is deviated from at least the center P of the waveguide 5, it is possible to create circularly- polarized waves or elliptically- polarized waves.

[0074] (b) in Fig. 4 illustrates a microwave radiating portion 6 which is constituted by two slits inclined by an angle of 45 degrees with respect to the direction X of propagation and, further, is formed to have an integrated T shape such that one of the slits extends from a center position on the other slit.

[0075] (c) in Fig. 4 illustrates a microwave radiating portion 6 which is constituted by two slits inclined by an angle of 45 degrees with respect to the direction X of propagation and, further, is formed to have an integrated L shape such that one of the slits extends from an end position of the other slit.

[0076] (d) in Fig. 4 illustrates a microwave radiating portion 6 which is constituted by three slits inclined by an angle of 45 degrees with respect to the direction X of propagation and, further, is integrally formed such that slits extend from the vicinities of the opposite end positions of a single slit.

[0077] (e) in Fig. 4 illustrates a microwave radiating portion 6 which is constituted by two slits placed proximally to each other and, further, is formed such that the respective slits are inclined with respect to the direction X of propagation. Further, these slits are placed orthogonally to each other.

[0078] (f) in Fig. 4 illustrates a microwave radiating portion 6 which is constituted by four slits placed radially and, further, is formed such that the respective slits are inclined by an angle of 45 degrees with respect to the direction X of propagation.

[0079] The shapes of the microwave radiating portions 6 can be any shapes capable of creating circularly-polarized waves and, also, can be shapes formed by slits which are not intersected with each other as illustrated in (e) and (f) in Figs. 4, or shapes formed by integrated three slits as illustrated in (d) in Fig. 4.

[Conditions Required for the Shapes of the Microwave Radiating Portions]

[0080] There are three points as follows, as conditions required for a most preferable shape of the microwave radiating portion 6 for radiating circularly-polarized waves which is constituted by the two slits (the elongated opening portions) illustrated in (a) in Fig. 4, for example, in the microwave heater according to the first embodiment.

[0081] The first point is that each slit should have a longer side with a length equal to or more than about 1/4 the in-tube wavelength λg within the waveguide 5. The second point is that the two slits should be orthogonal to each other and, also, each slit should have a longer side inclined by an angle of 45 degrees with respect to the direction X of propagation. The third point is as follows. That is, the electric field distribution should not be formed symmetrically with respect to an axis which is coincident to a straight line which is parallel with the direction X of propagation in the waveguide 5 and, also, passes through a substantially-center portion of the microwave radiating portion 6.

[0082] For example, in cases of propagation of microwaves in the TE10 mode, there is an electric-field distribution with respect to a symmetry axis which is coincident to the center axis (the tube axis: P) extending in the direction X of propagation in the waveguide 5. Therefore, for the shape of the microwave radiating portion 6 for radiating circularly-polarized waves, it is necessary to impose, thereon, the condition that it should not be placed axisymmetrically with respect to the center axis (P) of the waveguide 5 in the direction X of propagation.

[0083] Also, as the shape of the microwave radiating portion 6, the slits (the elongated opening portions) can be intersected with each other such that they are inclined rather than being made orthogonal to each other. In the case where the microwave radiating portion 6 is made to have such a compressed- X- like shape, similarly, the microwave radiating portion 6 can radiate circularly- polarized waves, which enables bringing the center position at which the slits intersect with each other closer to an end portion of the waveguide 5 in the widthwise direction, without narrowing the slit opening portions for radiating circularly- polarized waves. As a result thereof, it is possible to further spread microwaves in the direction (the widthwise direction Z) orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5, which enables heating objects to be heated more uniformly, without using a driving mechanism.

[0084] Further, in cases where two or more slits are spaced apart from each other to form an L shape or a T shape, as illustrated in Figs. 4 (e) and (f), each of the two or more slits can be placed in such a way as to be spaced apart from the others. Further, although, in Figs. 4 (e) and (f), there are illustrated examples where the slits are placed orthogonally to each other, the slits can be also inclined by only an angle of about 30 degrees, rather than being orthogonal to each other.

[0085] Also, the shapes of the slits in the microwave radiating portion 6 are not limited to rectangular shapes. The opening portions in the slits can be also formed to have curved surfaces (R) or cut surfaces (C) at their corners. By shaping them as described above, it is possible to generate circularly- polarized waves and, also, it is possible to alleviate concentrations of electric fields, thereby enabling microwave heating with higher efficiency.

[0086] As described above, as basic opening shapes for radiating circularly-polarized waves in the microwave radiating portion 6 adapted to radiate circularly-polarized waves, it is possible to employ a combination of at least two elongated-hole openings with elongated slit shapes having a larger length in a single direction and a smaller length in the direction orthogonal thereto.

(Second Embodiment)

[0087] Hereinafter, there will be described a microwave heater according to a second embodiment of the present invention. The microwave heater according to the second embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0088] In the following description about the second embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0089] Fig. 5 is a perspective view illustrating a microwave oven as a microwave heater according to the second embodiment of the present invention. Fig. 6 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves, in the microwave heater according to the second embodiment of the present invention.

[0090] As illustrated in Fig. 5, the microwave oven as the microwave heater 1 according to the second embodiment includes a heating chamber 2 adapted to house an object to be heated therein, and a placement portion 3 for housing and placing, thereon, the object to be heated. Further, just under the placement portion 3, there are placed a plurality of microwave radiating portions 6 for radiating circularly-polarized microwaves within the heating chamber 2, such that they are arranged at least in the direction X of propagation, on the upper surface of the waveguide 5.

[0091] As illustrated in Fig. 5 and Fig. 6, in the microwave heater 1 according to the second embodiment, there are provided the plurality of the microwave radiating portions 6 adapted to radiate substantially the same amount of circularly-polarized waves within the heating chamber 2, as microwave radiating means, on the upper surface (the surface faced to the heating chamber 2) of the waveguide 5, such that they are arranged in the direction X of propagation. Due to this placement of the microwave radiating portions 6, it is possible to realize uniform and efficient microwave heating for objects to be heated within the heating chamber 2. In Fig. 6, there is illustrated an example where two microwave radiating portions 6 are juxtaposed in the direction X of propagation in the waveguide 5, with a predetermined interval L (a center-to-center distance) interposed therebetween, at positions deviated from a line vertically above the tube axis P of the waveguide 5.

[0092] Further, in the microwave heater according to the second embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the direction X of propagation. The structure according to the second embodiment also covers structures having a plurality of microwave radiating portions 6 which are placed in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field, as well as in the direction X of propagation.

[The Waveguide]

[0093] In cases of propagating microwaves generated from a microwave generating device 4 as a microwave generating portion constituted by a magnetron and the like, using the waveguide 5 as a waveguide portion, the upper-limit size and the lower-limit size of the waveguide 5 in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field are restricted by the frequency of microwaves generated from the employed microwave generating device 4 and by the size of the waveguide 5 in the direction Y of the electric field (see Fig. 5).

[0094] This is because, in general, the TE 10 mode with H waves (TE waves ; Transverse Electric Waves) is used as a propagation mode, wherein the TE10 mode is a propagation mode having only magnetic-field components while having no electric-field component in the direction of the tube axis of the waveguide. Further, other propagation modes than the TE10 mode are hardly employed in waveguides in microwave heaters.

[0095] Next, with reference to Fig. 7, there will be described a rectangular waveguide 301 as a representative waveguide which is mounted in a microwave oven. A simplest ordinary waveguide is a rectangular- parallelepiped member having a constant rectangular- shaped cross section (width a x height b) which is extended in the direction X of propagation, as illustrated in Fig. 7. In the rectangular waveguide 301 formed from this rectangular- parallelepiped member, assuming that the wavelength of microwaves is λ, the width a of the waveguide 301. is selected within the range of ($\lambda > a > \lambda / 2$), and the height b of the waveguide 301 is selected within the range of ($b < \lambda / 2$) . By selecting the width a and the height b of the rectangular waveguide 301 as described above, the rectangular waveguide 301 is caused to propagate microwaves in the TE10 mode. This has been known.

[0096] Here, the TE10 mode refers to a propagation mode with H waves (TE waves ; Transverse Electric Waves) having only magnetic- field components while having no electric- field component in the direction X of propagation in the rectangular waveguide 301, within the rectangular waveguide 301. Further, other propagation modes than the TE10 mode are hardly employed in the waveguide 5 in the microwave heater 1 according to the first embodiment.

[0097] In microwave ovens, microwaves have wavelengths λ of about 120 mm. Generally, in microwave ovens, the width a of the waveguide is selected within the range of about 80 to 100 mm, and the height b thereof is selected within the range of about 15 to 40 mm, in many cases.

[0098] In the rectangular waveguide 301 illustrated in Fig. 7, the upper and lower surfaces are referred to as H planes 302 which mean planes in which magnetic fields are eddied in parallel, while the left and right surfaces are referred to as E planes 303 which mean planes parallel to the electric field. Further, assuming that the in-tube wavelength of microwaves being propagated within the waveguide 301 is λg, λg is expressed as the following equation (1).

[0099]

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

[0100] As indicated by the equation (1), the in-tube wavelength λg is varied depending on the size of the width a, but is unrelated to the size of the height b.

[0101] Further, in the TE10 mode, the electric field is zero at the opposite end surfaces (the E planes 303) of the rectangular waveguide 301 in the widthwise direction (Z), while the electric field is maximized at the center in the widthwise direction (Z) . Accordingly, the microwave generating device 4 constituted by a magnetron and the like is coupled to the waveguide 5 at the center thereof in the widthwise direction (Z), at which the electric field is maximized.

(Third Embodiment)

[0102] Hereinafter, a microwave heater according to a third embodiment of the present invention will be described. The microwave heater according to the third embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0103] In the following description about the third embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0104] Fig. 8 is a perspective view illustrating the microwave heater according to the third embodiment of the present invention. Fig. 9 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves, in the microwave heater according to the third embodiment.

[0105] As illustrated in Fig. 8, the microwave oven as the microwave heater 1 according to the third embodiment includes a heating chamber 2 adapted to house an object to be heated therein, and a placement portion 3 for housing and placing, thereon, the object to be heated. Further, just under the placement portion 3, there are placed a plurality of microwave radiating portions 6 adapted to radiate substantially the same amount of circularly-polarized microwaves within the heating chamber 2, such that they are arranged at least in the direction X of propagation, on the upper surface of the waveguide 5.

[0106] Further, in the microwave heater according to the third embodiment, the microwave radiating portions 6 for radiating circularly- polarized waves within the heating chamber 2 are constituted by two slits (elongated opening portions) intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5.

[0107] As illustrated in Fig. 9, in the microwave heater 1 according to the third embodiment, the plurality of the microwave radiating portions 6 with the X shape for radiating circularly-polarized waves are placed such that they are arranged in the direction X of propagation. Due to this placement of the plurality of the microwave radiating portions 6, it is possible to realize uniform and efficient microwave heating for objects to be heated within the heating chamber 2.

[0108] In Fig. 9, there is illustrated an example where at least two microwave radiating portions 6 with an X shape are provided at positions deviated from a line vertically above the tube axis P of the waveguide 5, with a predetermined interval L interposed therebetween, such that they are arranged in the direction X of propagation in the waveguide 5. Namely, in the example illustrated in Fig. 9, the line connecting the respective points at which the slits intersect with each other in the plurality of the X-shaped microwave radiating portions 6 to each other is coincident to the direction X of propagation in the waveguide 5.

[0109] Further, in the microwave heater according to the third embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the direction X of propagation. The present invention also covers cases where a plurality of microwave radiating portions 6 are placed in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field, as well as in the direction X of propagation,

[0110] In the structure of the microwave heater according to the third embodiment, similarly, as described in the aforementioned second embodiment, in cases of propagating microwaves generated from a microwave generating device 4 as a microwave generating portion constituted by a magnetron and the like, using the waveguide 5, the upper-limit size and the lower-limit size of the waveguide 5 in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field are restricted by the frequency of microwaves generated from the employed magnetron and by the size of the waveguide 5 in the direction Y of the electric field.

[0111] Further, as conditions required for the shapes of the microwave radiating portions 6 according to the third embodiment, as described with reference to (a) in Fig. 4 in the aforementioned first embodiment, the slits (the elongated opening portions) illustrated in Fig. 9 should have a length (2p) which is equal to or more than about 1/4 the in- tube wavelength λg of microwaves being propagated within the waveguide 5, the two slits should intersect with each other at their centers in the lengthwise directions, and each of the slits should be inclined by an angle of 45 degrees with respect to the direction X of propagation.

[0112] Further, the microwave radiating portions 6 constituted by the two slits intersected with each other are structured such that an axis which is parallel to the direction X of propagation and, further, passes through the intersection portions of the slits in the microwave radiating portions 6 is not at a position about which the electric- field distribution within the waveguide 5 is symmetric.

[0113] For example, in cases where the waveguide 5 propagates microwaves in the TE10 mode, the electric-field distribution within the waveguide 5 is symmetric about an axis which is coincident with the tube axis P which extends in the direction X of propagation and, further, passes through the center of the waveguide 5 in the direction Z orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5. Therefore, in the structure according to the third embodiment, the intersection portions of the slits in the microwave radiating portions 6 are placed at positions deviated from a line vertically above the symmetry axis in the waveguide 5, namely the tube axis P of the waveguide 5. By placing the slits in the microwave radiating portions 6 as described above, the microwave radiating portions 6 are enabled to certainly radiate circularly-polarized waves.

[0114] Further, in the plurality of the microwave radiating portions 6 for radiating circularly- polarized waves, as the intervals between the microwave radiating portions 6 adjacent to each other are decreased, the concentrations of electric fields between the microwave radiating portions 6 are increased, which increases microwave losses, thereby degrading the heating efficiency. It is preferable that the microwave radiating portions 6 adjacent to each other are placed with intervals of 5 mm or more interposed therebetween. Therefore, in the structure according to the third embodiment, the microwave radiating portions 6 adjacent to each other are placed in such a way as to provide largest possible intervals interposed therebetween, in the widthwise direction Z in the waveguide 5.

[0115] The microwave heater 1 having the aforementioned structure according to the third embodiment is capable of realizing uniform microwave heating for objects to be heated within the heating chamber 2, without being provided with a mechanism for rotating a table or an antenna or being provided with a phase shifter. Accordingly, the microwave heater 1 according to the third embodiment is capable of preventing the problem of heating unevenness and the like in objects to be heated during heating operations, which are induced in the event of failures of the rotating mechanism and in the event of abnormal operations.

[0116] Further, in the structure according to the third embodiment, in cases of propagating, through the waveguide 5, microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, the amounts of microwaves radiated within the heating chamber 2 from the microwave radiating portions 6 are increased or decreased, according to three conditions, as described in the aforementioned first embodiment.

[0117] The first condition is the distance in the direction X of propagation from the microwave generating device 4 to the microwave radiating portions 6. The second condition is the distance in the direction X of propagation from the termination end surface 15 of the waveguide 5 to the microwave radiating portions 6. The third condition is the position in the direction (the widthwise direction Z of the waveguide 5) orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5 (see Fig. 2).

[0118] If the microwave radiating portions 6 are not placed in such a way as to uniformize the microwave distribution within the heating chamber 2, in consideration of the aforementioned conditions, even when the microwave radiating portions 6 are placed symmetrically with respect to the center of the heating chamber 2, the microwave distribution within the heating chamber 2 may not be uniformized, in many cases.

[0119] Therefore, for the microwave heater 1 having the plurality of the microwave radiating portions 6 in the direction X of propagation, according to the third embodiment, the technique for varying the microwave distribution within the heating chamber 2 is necessary.

(Fourth Embodiment)

[0120] Hereinafter, a microwave heater according to a fourth embodiment of the present invention will be described. The microwave heater according to the fourth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0121] In the following description about the fourth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0122] Fig. 10 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves, in the microwave heater according to the fourth embodiment of the present invention.

[0123] As illustrated in Fig. 10, in the microwave heater 1 according to the fourth embodiment, a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are placed on the upper surface (the surface faced to the heating chamber 2) of the waveguide 5, such that they are arranged at least in the direction X of propagation.

[0124] In the microwave heater 1 according to the fourth embodiment, the microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are constituted by two slits (elongated opening portions) intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation the waveguide 5. In the structure according to the fourth embodiment, the lengths 2p of the slits in the microwave radiating portions 6 are varied depending on their positions in the direction X of propagation in the waveguide 5. In Fig. 10, there is illustrated an example where, among two microwave radiating portions 6, the microwave radiating portion 6 (the microwave radiating portion in the right side in Fig. 10) closer to the microwave generating portion 4 as the microwave generating portion constituted by a magnetron is formed to have an opening portion which is smaller than the opening portion of the microwave radiating portion 6 (the microwave radiating portion in the left side in Fig. 10) farther from the microwave generating portion 4, thereby suppressing the amount of microwaves radiated therefrom.

[0125] With the aforementioned structure, by changing the relationship among the placements of the plurality of the microwave radiating portions 6, and the lengths (the opening areas) 2p of the slits in the respective microwave radiating portions 6, it is possible to control the amounts of microwaves radiated therefrom. Accordingly, the microwave heater according to the fourth embodiment is structured to perform uniform and efficient microwave heating on objects to be heated within the heating chamber 2.

[0126] Further, in the microwave heater 1 according to the fourth embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the direction X of propagation. The structure according to the fourth embodiment also covers cases where a plurality of microwave radiating portions 6 are placed in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field, as well as in the direction X of propagation.

[0127] In the microwave heater 1 according to the fourth embodiment, the plurality of the microwave radiating portions 6 are not always placed symmetrically with respect to the center of the heating chamber 2, due to the relationship thereof with other designed components. Further, even when the plurality of the microwave radiating portions 6 are placed symmetrically with respect to the center of the heating chamber 2, a non-uniform microwave distribution may be formed within the heating chamber 2, in many cases, since various types of members such as heaters, a door glass are mounted inside the chamber of the microwave heater 1 such as a microwave oven.

[0128] Accordingly, the microwave heater 1 according to the fourth embodiment is adapted to ensure a uniform microwave distribution within the heating chamber 2, by varying the lengths 2p of the slits in the microwave radiating portions 6, in addition to the placements of the plurality of the microwave radiating portions 6.

[0129] In general, in a microwave radiating portion 6 having two slits intersected with each other, if the length 2p of the slits is decreased to make the opening area of the microwave radiating portions 6 smaller, the microwave radiating portion 6 is caused to radiate a decreased amount of microwaves within the heating chamber 2.

[0130] For example, when there is a stronger microwave distribution in a right-side area in the waveguide 5 illustrated in Fig. 10, the length 2p of the slits in the microwave radiating portion 6 in the right side can be made smaller for making the opening area in the microwave radiating portion 6 in the right side smaller, which can reduce the amount of microwaves radiated within the heating chamber 2 from the microwave radiating portion 6 in the right side, thereby causing the respective microwave radiating portions 6 to radiate substantially the same amount of microwaves. This can ensure uniformity of the microwave distribution within the heating chamber 2.

[0131] In the microwave heater according to the fourth embodiment of the present invention, as described above, the plurality of the microwave radiating portions 6 are each constituted by two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction X of propagation in the waveguide 5, and the lengths 2p of the longer sides of the slits are varied depending on their positions in the direction of propagation in the waveguide 5. The microwave heater having the aforementioned structure according to the fourth embodiment is enabled to control the amount of radiation of microwaves and, thus, is enabled to perform microwave heating uniformly and efficiently on the objects to be heated, by varying the respective lengths 2p of the slits in the microwave radiating portions 6, as well as the placements of the microwave radiating portions 6.

[0132] Further, in order to form a uniform microwave distribution within the heating chamber 2, the microwave radiating portions 6 should have different structures, according to specifications, structures and the like of respective microwave heaters. Therefore, by varying the shapes of the slits in the microwave radiating portions 6, which are to be provided in the waveguide 5 according to respective microwave heaters, it is possible to ensure uniformity of the microwave distribution within the heating chamber 2.

[0133] In the structure according to the fourth embodiment, similarly, as described in the aforementioned second embodiment, in cases of propagating microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, using the waveguide 5, the upper-limit size and the lower-limit size of the waveguide 5 in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field are restricted by the frequency of microwaves generated from the employed magnetron and by the size of the waveguide 5 in the direction Y of the electric field.

[0134] Further, as conditions required for the shapes of the microwave radiating portions 6 according to the fourth embodiment, as described with reference to (a) in Fig. 4 in the aforementioned first embodiment, the slits (the elongated opening portions) illustrated in Fig. 10 should have lengths 2p which are equal to or more than about 1/4 the in- tube wavelength λg of microwaves being propagated within the waveguide 5, the two slits should intersect with each other at their centers in the lengthwise directions, and each of the slits should be inclined by an angle of 45 degrees with respect to the direction X of propagation.

[0135] Further, in the microwave radiating portions 6 constituted by the two slits intersected with each other, an axis which is parallel to the direction X of propagation and, further, passes through the intersection portions of the slits in the microwave radiating portions 6 is not at a position about which the electric- field distribution within the waveguide 5 is symmetric.

[0136] For example, in cases where the waveguide 5 propagates microwaves in the TE10 mode, the electric-field distribution within the waveguide 5 is symmetric about an axis which is coincident with the tube axis P which extends in the direction X of propagation and, further, passes through the center of the waveguide 5 in the direction Z orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5. Therefore, in the structure according to the fourth embodiment, the intersection portions of the slits in the microwave radiating portions 6 are placed at positions deviated from a line vertically above the symmetry axis in the waveguide 5, namely the tube axis P of the waveguide 5. By placing the slits of the microwave radiating portions 6 as described above, the microwave radiating portions 6 are enabled to certainly radiate circularly-polarized waves.

[0137] Further, in the plurality of the microwave radiating portions 6 for radiating circularly- polarized waves, as the intervals between the microwave radiating portions 6 adjacent to each other are decreased, the concentrations of electric fields between the microwave radiating portions 6 are increased, which increases microwave losses, thereby degrading the heating efficiency. It is preferable that the microwave radiating portions 6 adjacent to each other are placed with intervals of 5 mm or more interposed therebetween. Therefore, in the structure according to the fourth embodiment, the microwave radiating portions 6 adjacent to each other are placed in such a way as to provide largest possible intervals interposed therebetween, in the widthwise direction Z in the waveguide 5.

[0138] Further, in the structure according to the fourth embodiment, in cases of propagating, through the waveguide 5, microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, the amounts of microwaves radiated within the heating chamber 2 from the microwave radiating portions 6 are increased or decreased, according to three conditions, as described in the aforementioned first embodiment.

[0139] The first condition is the distance in the direction X of propagation from the microwave generating device 4 to the microwave radiating portions 6. The second condition is the distance in the direction X of propagation from the termination end surface 15 of the waveguide 5 to the microwave radiating portions 6. The third condition is the position in the direction (the widthwise direction Z of the waveguide 5) orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5 (see Fig. 2).

[0140] If the microwave radiating portions 6 are not placed in such a way as to uniformize the microwave distribution within the heating chamber 2, in consideration of the aforementioned conditions, even when the microwave radiating portions are placed symmetrically with respect to the center of the heating chamber 2, the microwave distribution within the heating chamber 2 may not be uniformized, in many cases.

[0141] Therefore, in the microwave heater 1 having the plurality of the microwave radiating portions 6 in the direction X of propagation, according to the fourth embodiment, the technique for varying the microwave distribution within the heating chamber 2 is necessary.

(Fifth Embodiment)

[0142] Hereinafter, a microwave heater according to a fifth embodiment of the present invention will be described. The microwave heater according to the fifth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0143] In the following description about the fifth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0144] Fig. 11 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves, in the microwave heater according to the fifth embodiment of the present invention.

[0145] As illustrated in Fig. 11, in the microwave heater 1 according to the fifth embodiment, a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are placed on the upper surface (the surface faced to the heating chamber 2) of the waveguide 4 such that they are arranged at least in the direction X of propagation.

[0146] In the microwave heater 1 according to the fifth embodiment, the microwave radiating portions 6 for radiating circularly-polarized waves (left-handed polarized waves or right-handed polarized waves) within the heating chamber 2 are constituted by two slits (elongated opening portions) intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5. In the structure according to the fifth embodiment, the widths 2q of the slits in the microwave radiating portions 6 are varied depending on their positions in the direction X of propagation in the waveguide 5.

[0147] In Fig. 11, there is illustrated an example where, among two microwave radiating portions 6, the microwave radiating portion 6 (the microwave radiating portion in the right side in Fig. 11) closer to the microwave generating portion 4 constituted by a magnetron is formed to have an opening portion which is smaller than the opening portion of the microwave radiating portion 6 (the microwave radiating portion in the left side in Fig. 11) farther from the microwave generating portion 4, thereby suppressing the amount of microwaves radiated therefrom.

[0148] The microwave heater according having the aforementioned structure according to the fifth embodiment is enabled to control the amount of radiation of microwaves, by varying the relationship among the placements of the plurality of the microwave radiating portions 6, and the widths (the opening areas) of the slits in the respective microwave radiating portions 6. Accordingly, the microwave heater according to the fifth embodiment is structured to perform uniform and efficient microwave heating on objects to be heated within the heating chamber 2.

[0149] Further, in the microwave heater according to the fifth embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the direction X of propagation. The structure according to the fifth embodiment also covers structures having a plurality of microwave radiating portions 6 which are placed in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field, as well as in the direction X of propagation.

[0150] In the microwave heater 1 according to the fifth embodiment, the plurality of the microwave radiating portions 6 are not always placed symmetrically with respect to the center of the heating chamber 2, due to the relationship thereof with other designed components. Further, even when the plurality of the microwave radiating portions 6 are placed symmetrically with respect to the center of the heating chamber 2, the microwave distribution within the heating chamber 2 may be made non-uniform, since various types of members such as heaters, a door glass are mounted inside the chamber of the microwave heater 1 such as a microwave oven.

[0151] Accordingly, the microwave heater 1 according to the fifth embodiment is adapted to ensure a uniform microwave distribution within the heating chamber 2, by varying the widths 2q of the slits in the microwave radiating portions 6, in addition to the placements of the plurality of the microwave radiating portions 6.

[0152] In general, in a microwave radiating portion 6 having two slits intersected with each other, if the width 2q of the slits is decreased to make the opening area of the microwave radiating portions 6 smaller, the microwave radiating portion 6 is caused to radiate a decreased amount of microwaves within the heating chamber 2.

[0153] For example, when there is a stronger microwave distribution in a right-side area (an area closer to the microwave generating device 4) in the waveguide 5 illustrated in Fig. 11, the width 2q of the slits in the microwave radiating portion 6 in a left-side area (an area farther from the microwave generating device 4) can be made larger for making the opening area in the microwave radiating portion 6 in the left-side area larger. As a result thereof, the microwave radiating portion 6 in the left-side area is caused to radiate an increased amount of microwaves within the heating chamber 2, which can ensure uniformity of the microwave distribution within the heating chamber 2.

[0154] In the structure according to the fifth embodiment, similarly, as described with respect to the aforementioned second embodiment, in cases of propagating microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, using the waveguide 5, the upper-limit size and the lower-limit size of the waveguide 5 in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field are restricted by the frequency of microwaves generated from the employed magnetron and by the size of the waveguide 5 in the direction Y of the electric field.

[0155] Further, as conditions required for the shapes of the microwave radiating portions 6 according to the fifth embodiment, as described with reference to (a) in Fig. 4 in the aforementioned first embodiment, the slits (the elongated opening portions) illustrated in Fig. 11 should have lengths (2p) which are equal to or more than about 1/4 the in- tube wavelength λg of microwaves being propagated within the waveguide 5, the two slits should intersect with each other at their centers in the lengthwise directions, and each of the slits should be inclined by an angle of 45 degrees with respect to the direction X of propagation.

[0156] Further, in the microwave radiating portions 6 constituted by the two slits intersected with each other, an axis which is parallel to the direction X of propagation and, further, passes through the intersection portions of the slits in the microwave radiating portions 6 is not at a position about which the electric- field distribution within the waveguide 5 is symmetric.

[0157] For example, in cases where the waveguide 5 propagates microwaves in the TE10 mode, the electric-field distribution within the waveguide 5 is symmetric about an axis which is coincident with the tube axis P which extends in the direction X of propagation and, further, passes through the center of the waveguide 5 in the widthwise direction Z.

Therefore, in the structure according to the fifth embodiment, the intersection portions of the slits in the microwave radiating portions 6 are placed at positions deviated from a line vertically above the symmetry axis in the waveguide 5, namely the tube axis P of the waveguide 5. By placing the slits of the microwave radiating portions 6 as described above, the microwave radiating portions 6 are enabled to certainly radiate circularly-polarized waves.

[0158] Further, in the plurality of the microwave radiating portions 6 for radiating circularly- polarized waves, as the intervals between the microwave radiating portions 6 adjacent to each other are decreased, the concentrations of electric fields between the microwave radiating portions 6 are increased, which increases microwave losses, thereby degrading the heating efficiency. It is preferable that the microwave radiating portions 6 adjacent to each other are placed with intervals of 5 mm or more interposed therebetween. Therefore, in the structure according to the fifth embodiment, the microwave radiating portions 6 adjacent to each other are placed in such a way as to provide largest possible intervals interposed therebetween, in the widthwise direction Z in the waveguide 5.

[0159] Further, in the structure according to the fifth embodiment, in cases of propagating, through the waveguide 5, microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, the amounts of microwaves radiated within the heating chamber 2 from the microwave radiating portions 6 are increased or decreased, according to three conditions, as described in the aforementioned first embodiment.

[0160] The first condition is the distance in the direction X of propagation from the microwave generating device 4 to the microwave radiating portions 6. The second condition is the distance in the direction X of propagation from the termination end surface 15 of the waveguide 5 to the microwave radiating portions 6. The third condition is the position in the direction (the widthwise direction Z of the waveguide 5) orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5 (see Fig. 2).

[0161] If the microwave radiating portions 6 are not placed in such a way as to uniformize the microwave distribution within the heating chamber 2, in consideration of the aforementioned conditions, even when the microwave radiating portions are placed symmetrically with respect to the center of the heating chamber 2, the microwave distribution within the heating chamber 2 may not be uniformized, in many cases.

[0162] Therefore, in the microwave heater 1 having the plurality of the microwave radiating portions 6 in the direction of propagation, according to the fifth embodiment, the technique for varying the microwave distribution within the heating chamber 2 is necessary.

[0163] In the microwave heater according to the fifth embodiment of the present invention, as described above, the plurality of the microwave radiating portions 6 are each constituted by two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction X of propagation in the waveguide 5, and the widths 2q of the slits are varied depending on their positions in the direction of propagation X in the waveguide 5. The microwave heater having the aforementioned structure according to the fifth embodiment is enabled to change the microwave distribution within the heating chamber 2 and, thus, is enabled to ensure uniformity of the microwave distribution within the heating chamber 2, by varying the widths 2q of the slits in the microwave radiating portions 6, as well as the placements of the microwave radiating portions 6.

(Sixth Embodiment)

[0164] Hereinafter, a microwave heater according to a sixth embodiment of the present invention will be described. The microwave heater according to the sixth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0165] In the following description about the sixth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0166] Fig. 12 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves, in the microwave heater according to the sixth embodiment of the present invention.

[0167] As illustrated in Fig. 12, in the microwave heater 1 according to the sixth embodiment, a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are placed on the upper surface (the surface faced to the heating chamber 2) of the waveguide 5 such that they are arranged at least in the direction X of propagation.

[0168] In the microwave heater 1 according to the sixth embodiment, the microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are constituted by two slits (elongated opening portions) intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5. In the microwave heater 1 according to the sixth embodiment, the microwave radiating portions 6 are shaped such that their intersection portions 12 (see Fig. 12) have been subjected to round chamfering (R) or chamfering (C) at their corners.

[0169] With the microwave heater 1 having the aforementioned structure according to the sixth embodiment, it is possible to reduce microwave losses in the microwave radiating portions 6, which enables performing microwave heating on objects to be heated, with higher efficiency.

[0170] Microwaves have the property of being concentrated at corners, and portions with sharp tip ends. Therefore, if the microwave radiating portions 6 constituted by the two slits intersected with each other are made to have sharp shapes at their intersection portions, this induces concentrations of electric fields of microwaves, thereby inducing the problem of reduction of the heating efficiency.

[0171] To cope therewith, in the microwave heater 1 according to the sixth embodiment, the microwave radiating portions 6 constituted by the two slits intersected with each other have been subjected to round chamfering (R) or chamfering (C) at the corner portions in their intersection portions 12, which alleviates concentrations of electric fields, thereby increasing the heating efficiency.

(Seventh Embodiment)

[0172] Hereinafter, a microwave heater according to a seventh embodiment of the present invention will be described. The microwave heater according to the seventh embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0173] In the following description about the seventh embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0174] Fig. 13 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves, in the microwave heater according to the seventh embodiment of the present invention.

[0175] As illustrated in Fig. 13, in the microwave heater 1 according to the seventh embodiment, a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are placed on the upper surface (the surface faced to the heating chamber 2) of the waveguide 5 such that they are arranged at least in the direction X of propagation.

[0176] In the microwave heater 1 according to the seventh embodiment, the microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are constituted by two slits (elongated opening portions) intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5. In the microwave heater 1 according to the seventh embodiment, the microwave radiating portions 6 are shaped such that the distal end portions 13 of the respective slits have been subjected to round chamfering (R) or chamfering (C).

[0177] With the microwave heater 1 having the aforementioned structure according to the seventh embodiment, it is possible to reduce microwave losses in the microwave radiating portions 6, which enables performing microwave heating on objects to be heated, with higher efficiency.

[0178] Microwaves have the property of being concentrated at corners, and portions with sharp tip ends. Therefore, if the microwave radiating portions constituted by the two slits intersected with each other are made to have sharp shapes at the distal end portions 13 of the slits, this induces concentrations of electric fields of microwaves, thereby inducing the problem of reduction of the heating efficiency.

[0179] To cope therewith, in the microwave heater 1 according to the seventh embodiment, the microwave radiating portions 6 constituted by the two slits intersected with each other have been subjected to round chamfering (R) or chamfering (C) at the distal end portions 13 of the slits, which alleviates concentrations of electric fields, thereby increasing the heating efficiency.

[0180] Further, Fig. 14 is a view illustrating a concrete structure of a microwave radiating portion 6 according to the aforementioned sixth and seventh embodiments, illustrating an example of a microwave radiating portion 6 constituted by two slits (elongated opening portions) intersected with each other in an X shape.

[0181] As illustrated in Fig. 14, there is illustrated an example where the intersection portion 12 of the slits in the microwave radiating portion 6 has been subjected to round chamfering (R) or chamfering (C), while the distal end portions 13 of the slits have been subjected to round chamfering (R) or chamfering (C). In the present invention, by applying any of round chamfering (R) and chamfering (C) to the intersection portion 12 and the distal end portions 13 of the slits, it is possible to alleviate concentrations of electric fields, thereby increasing the heating efficiency.

(Eighth Embodiment)

[0182] Hereinafter, a microwave heater according to an eighth embodiment of the present invention will be described. The microwave heater according to the eighth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0183] In the following description about the eighth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0184] Fig. 15 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves, in the microwave heater according to the eighth embodiment of the present invention.

[0185] As illustrated in Fig. 15, the microwave heater 1 according to the eighth embodiment includes a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2, at least in the direction X of propagation.

[0186] The microwave radiating portions 6 are constituted by two slits intersected with each other, wherein each slit is shaped to have a longer side inclined with respect to the direction X of propagation in the waveguide 5. In the structure illustrated in Fig. 15, out of the two microwave radiating portions 6 arranged in the direction X of transmission in the right side, the microwave radiating portion 6 (the microwave radiating portion at the center in Fig. 15) at a larger propagation distance from the position at which the microwave generating device 4 as the microwave generating portion is installed is structured to have a higher rate of radiation of microwaves to the heating chamber 2 through the waveguide 5, than that of the microwave radiating portion 6 (the microwave radiating portion at the right end in Fig. 15) at a smaller propagation distance from the position at which the microwave generating device 4 is installed. Further, in the structure according to the eighth embodiment, out of the plurality of the microwave radiating portions 6 arranged in the direction X of propagation, the microwave radiating portions 6 at larger propagation distances from the position at which the microwave generating device 4 is installed can be structured to have higher rates of radiation of microwaves to the heating chamber 2 through the waveguide 5, than those of the microwave radiating portions 6 at smaller propagation distances from the position at which the microwave generating device 4 is installed.

[0187] With the aforementioned structure, the respective microwave radiating portions 6 are caused to radiate substantially the same amount of microwaves, which enables uniform microwave heating on the object to be heated within the heating chamber 2, thereby enabling efficient microwave heating on the object to be heated. In this case, the term "the rate of radiation" refers to the ratio of the amount of microwaves radiated from each microwave radiating portion 6 to the amount of microwaves being propagated through the waveguide 5.

[0188] Further, in the microwave heater 1 according to the eighth embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the direction X of propagation. The structure according to the eighth embodiment also covers cases where a plurality of microwave radiating portions 6 are placed in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field, as well as in the direction X of propagation.

[0189] In the microwave heater 1 according to the eighth embodiment, the plurality of the microwave radiating portions 6 are not always placed symmetrically with respect to the center of the heating chamber 2, due to the relationship thereof with other designed components. Further, even when the plurality of the microwave radiating portions 6 are placed symmetrically with respect to the center of the heating chamber 2, the microwave distribution within the heating chamber 2 may be made non-uniform, since various types of members such as heaters, a door glass are mounted inside the chamber of the microwave heater 1 such as a microwave oven.

[0190] Further, in general, in cases where there are a plurality of microwave radiating portions 6 in the direction X of propagation, even when the respective microwave radiating portions 6 have the same rate of radiation of microwaves to the heating chamber 2 through the waveguide 5, the microwave radiating portions 6 at smaller propagation distances from the position at which the microwave generating device 4 is installed are caused to radiate larger amounts of microwaves.

[0191] As a result thereof, even when the plurality of the microwave radiating portions 6 are placed symmetrically with respect to the center of the heating chamber 2, a non-uniform microwave distribution is formed within the heating chamber 2, which induces heating unevenness in the object to be heated within the heating chamber 2 during cooking through microwave heating.

[0192] This is because the microwave radiating portions 6 are caused to radiate microwaves within the heating chamber 2, in ascending order of their propagation distances from the position at which the microwave generating device 4 is installed and, in the direction X of propagation in the waveguide 5, the amount of microwaves being propagated therethrough is gradually decreased.

[0193] Accordingly, the microwave heater according to the eighth embodiment is enabled to certainly ensure uniformity of the microwave distribution within the heating chamber 2, by making the respective microwave radiating portions 6 have different rates of radiation of microwaves to the heating chamber 2 through the waveguide 5, as well as through the placements of the plurality of the microwave radiating portions 6.

[0194] As described above, in the microwave heater according to the eighth embodiment, the microwave radiating portions 6 are constituted by two slits (elongated opening portions) intersected with each other, wherein each slit is shaped to have a longer side inclined with respect to the direction X of propagation in the waveguide 5. As an example where the microwave radiating portions 6 having this structure are made to have different radiation rates, there is an example where the lengths (2p) of the slits or the widths (2q) of the slits are varied to increase or decrease their opening areas for radiating microwaves.

[0195] For example, as illustrated in Fig. 16, on the upper surface (the surface faced to the heating chamber 2) of the rectangular waveguide 5, there are provided microwave radiating portions 6 arranged in series in two rows in the direction X of propagation and, further, there are provided microwave radiating portions 6 arranged in series, in three rows, in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field, namely there are provided, in total, six microwave radiating portions 6. Microwaves are propagated through the rectangular waveguide 5 provided with the six microwave radiating portions 6 as described above.

[0196] The following equation (1) is an equation for determining the coupling factor Cu of a cruciform directional coupler. Based on the equation (1) for determining the coupling factor Cu of a cruciform directional coupler, there will be described a method for determining the shapes of microwave radiating portions 6.

[0197] Further, in the microwave heater according to the eighth embodiment of the present invention, the coupling factor Cu of the cruciform directional coupler means the rate of radiation of microwaves from each microwave radiating portion 6 to the heating chamber 2 through the waveguide 5.

[0198]

$$\begin{aligned} Cu = & \\ & -20\log_{10}\left[2\pi M / a^2 b \times 1/\left(1 - f^2 / fr^2\right) \times \sin\left(2\pi X_0 / a\right) \times \sin\left(4\pi X_0 / \lambda_g\right)\right] \\ & +27.3\sqrt{1-\left(4p/\lambda\right)^2} \times \left(t/2p\right) \qquad [dB] \end{aligned}$$

(1)

[0199] Here, the respective parameters in the aforementioned equation (1) are defined as follows (see Fig. 7 and Fig. 9) .

a: the longer-side (A) size of the rectangular waveguide 5 [mm]
b: the shorter-side (B) size of the rectangular waveguide 5 [mm]
p: 1/2 the length (2p) of the slits (the long radius) [mm]
q: 1/2 the width (2q) of the slits (the short radius) [mm]
t: the plate thickness of the waveguide coupling plane [mm]
λg: the in-tube wavelength [mm]
λ: the wavelength in a free space [mm]
Xo: the center-to-center distance between the microwave radiating portion 6 and the tube axis of the waveguide 5 [mm]
f: the oscillation frequency of the microwave generating portion 4 [Hz]
fr=c/ (4p- 1.092q) fr: the resonance frequency of the slits (in cases of p»q) [Hz]
c: the velocity of light (nearly equal to 3×10^{11}) [mm]
$M=\pi p^3 / 3 [\log_e (4p/q) - 1]$ M : the polarizability in the direction of the longer axis of the slits

[0200] Regarding the aforementioned equation (1), as conditions required for realizing uniform and efficient microwave heating on the object to be heated, it is considered that the following conditions should be satisfied. That is, the respective microwave radiating portions 6 should be caused to radiate the same amount of microwaves within the heating chamber 2, and traveling waves generated from the microwave generating device 4 should be all radiated within the heating chamber 2, namely there should be induced no reflected wave at the termination end surface 15 of the waveguide 5.

[0201] Accordingly, under the aforementioned conditions, in cases where the number of the microwave radiating portions 6 is six, each of the microwave radiating portions 6 is required to radiate microwaves in an amount of about 16.7 % of the amount of microwaves generated from the microwave generating device 4.

[0202] Further, in the microwave heater according to the eighth embodiment of the present invention, there will be described, as an example, a case where the aforementioned respective parameters are determined as follows, and only the lengths of the slits in the respective microwave radiating portions 6 are varied, in order to adjust the rates of radiations from the respective microwave radiating portions 6.

[0203] The respective parameters in the equation (1) are determined as follows, for example, and the length of the slits is determined.

a: the longer-side (A) size of the rectangular waveguide = 100.0 mm

b: the shorter-side (B) size of the rectangular waveguide = 30.0 mm
q: 1/2 the width of the slits (the short radius) = 5.0 mm
t: the plate thickness of the waveguide coupling plane = 1.0 mm
λg: the in-tube wavelength = 154.7 mm
λ: the wavelength in a free space = 122.4 mm
Xo: the center-to-center distance between the microwave radiating portion 6 and the tube axis of the waveguide 5 = 25.0 mm
f: the oscillation frequency of the microwave generating portion 4 = 2450×10^6 Hz

[0204] The microwave radiating portions 6 at the same propagation distance from the position at which the microwave generating device 4 is installed are required to have the same rate of radiation of microwaves within the heating chamber 2. In this case, each of the microwave radiating portions 6 is caused to radiate, within the heating chamber 2, microwaves in an amount of about 16.7 % of the amount of microwaves generated from the microwave generating device 4. Here, as supplementation, the equation (1) regarding a cruciform directional coupler is an equation for cases where there are two microwave radiating portions. Therefore, the slit lengths can be determined, such that, in ascending order of propagation distance from the position at which the microwave generating device 4 is installed, each two microwave radiating portions 6 have a radiation rate of 4.8 dB (namely, the first two microwave radiating portions are caused to radiate microwaves in an amount of 33.4 %=16.7%$\times$2), 3.0 dB (the next two microwave radiating portions are caused to radiate microwaves in an amount of 50 % of the remainder), and 0 dB (the last two microwave radiating portions are caused to radiate all of the remainder, namely 100 % thereof). Therefore, according to the equation (1), the respective microwave radiating portions 6 should have slit lengths 2p of 53.6 mm, 55.0 mm, and 57.0 mm, in ascending order to their propagation distances from the position at which the microwave generating device 4 is installed.

[0205] Further, although the microwave heater according to the eighth embodiment of the present invention has been described with respect to a case where the number of microwave radiating portions 6 is six, the present invention is not limited to the case of six microwave radiating portions and can be also applied to cases where there are a plurality of microwave radiating portions 6 in the direction X of propagation.

[0206] Further, although the microwave heater according to the eighth embodiment has been described with respect to a case where the respective microwave radiating portions 6 are varied in terms of only the slit lengths 2p, for adjusting the radiation rates of the respective microwave radiating portions 6, the present invention is not limited to this structure. The present invention also covers structures adapted to vary other parameters, such as the longer- side (A) size of the aforementioned rectangular waveguide 301 (see Fig. 7), the shorter- side (B) size of the rectangular waveguide, the length of 1/2 the slit width, for adjusting the radiation rates of the respective microwave radiating portions 6.

[0207] Further, in cases where the respective microwave radiating portions 6 radiate non- uniform amounts of microwaves within the heating chamber 2, such as in cases where there are a plurality of microwave radiating portions 6 in the direction X of propagation, and the microwave radiating portions 6 are desired to radiate gradually- increased amounts of microwaves in descending order of their propagation distances from the position at which the microwave generating device 4 is installed, it is possible to adjust these parameters for adjusting them.

[0208] Further, in cases where portions of traveling waves generated from the microwave generating device 4 are not radiated within the heating chamber 2 and, thus, there are induced reflected waves at the termination end surface 15 of the waveguide 5, the parameters are varied for adjusting them, in consideration of such reflected waves, in such a way as to uniformize the amounts of radiations of microwaves within the heating chamber 2 from the respective microwave radiating portions 6.

(Ninth Embodiment)

[0209] Hereinafter, a microwave heater according to a ninth embodiment of the present invention will be described. The microwave heater according to the ninth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0210] In the following description about the ninth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0211] Fig. 17 is a perspective view illustrating a microwave oven as the microwave heater according to the ninth embodiment of the present invention. Fig. 18 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves (left-handed polarized waves or right-handed polarized waves), in the microwave heater according to the ninth embodiment of the present invention.

[0212] As illustrated in Fig. 17, the microwave oven as the microwave heater 1 according to the ninth embodiment includes a door 7 having a window in its front surface, a heating chamber 2 adapted to house an object to be heated therein, and a placement portion 3 made of a non-metal material for housing and placing, thereon, the object to be heated.

[0213] Further, just under the placement portion 3, there are provided microwave radiating means for radiating microwaves within the heating chamber 2. As the microwave radiating means according to the ninth embodiment, there are provided a plurality of microwave radiating portions 6 for radiating circularly- polarized waves (left- handed polarized waves or right- handed polarized waves) within the heating chamber 2, such that they are arranged in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field.

[0214] As illustrated in Fig. 18, in the microwave heater 1 according to the ninth embodiment, there are provided the plurality of the microwave radiating portions 6 for radiating circularly-polarized waves (left-handed polarized waves or right-handed polarized waves) within the heating chamber 2, in the direction (the widthwise direction Z) orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5, which enables performing uniform and efficient microwave heating on the object to be heated within the heating chamber 2.

[0215] Further, in the microwave heater according to the ninth embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the direction Z orthogonal to the direction X of propagation and to the direction Y of the electric field. The structure according to the ninth embodiment also covers structures having a plurality of microwave radiating portions 6 which are placed in the direction X of propagation, as well as in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field.

(Tenth Embodiment)

[0216] Hereinafter, a microwave heater according to a tenth embodiment of the present invention will be described. The microwave heater according to the tenth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0217] In the following description about the tenth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0218] Fig. 19 is a perspective view illustrating a microwave heater according to the tenth embodiment of the present invention. Fig. 20 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves (left-handed polarized waves or right-handed polarized waves), in the microwave heater according to the tenth embodiment of the present invention.

[0219] As illustrated in Fig. 19, the microwave oven as the microwave heater 1 according to the tenth embodiment includes a door 7 having a window in its front surface, a heating chamber 2 adapted to house an object to be heated therein, and a placement portion 3 made of a non-metal material for housing and placing, thereon, the object to be heated. Further, just under the placement portion 3, there are provided microwave radiating portions 6 for radiating microwaves as circularly-polarized waves (left-handed polarized waves or right-handed polarized waves) within the heating chamber 2. There are provided a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2, such that they are arranged at least in the direction Z orthogonal to the direction X of propagation and to the direction Y of the electric field.

[0220] Further, in the microwave heater according to the tenth embodiment, the microwave radiating portions 6 for radiating circularly- polarized waves within the heating chamber 3 are constituted by two slits (elongated opening portions) intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5.

[0221] As illustrated in Fig. 20, in the microwave heater 1 according to the tenth embodiment, there are provided the plurality of the microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2, such that they are arranged at least in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field. By placing the plurality of the microwave radiating portions 6 as described above, it is possible to realize uniform and efficient microwave heating on the object to be heated within the heating chamber 2.

[0222] Referring to Fig. 20, at least two microwave radiating portions 6 with an X shape are placed at symmetric positions in the opposite sides with respect to a line vertically above the tube axis P of the waveguide 5, with a predetermined interval interposed therebetween. Namely, the two microwave radiating portions 6 are provided such that they are arranged in the widthwise direction Z of the waveguide 5. In the example illustrated in Fig. 20, the line connecting the points of the intersections of the slits in the two microwave radiating portions 6 with the X shape is coincident with the widthwise direction Z of the waveguide 5.

[0223] Further, in the microwave heater according to the tenth embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field. The present invention also covers cases where there are placed a plurality of microwave radiating portions 6 in the direction X of propagation, as well as in the widthwise direction Z.

[0224] In the structure of the microwave heater according to the tenth embodiment, similarly, as described with respect to the aforementioned second embodiment, in cases of propagating microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, using the waveguide 5, the upper-limit size and the lower-limit size of the waveguide 5 in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field are restricted by the frequency of microwaves generated from the employed magnetron and by the size of the waveguide 5 in the direction Y of the electric field.

[0225] Further, as conditions required for the shapes of the microwave radiating portions 6 according to the tenth embodiment, as described with reference to (a) in Fig. 4 in the aforementioned first embodiment, the slits (the elongated opening portions) illustrated in Fig. 20 should have lengths (2p) which are equal to or more than about 1/4 the in- tube wavelength λg of microwaves being propagated within the waveguide 5, the two slits should intersect with each other at their centers in the lengthwise directions, and each of the slits should be inclined by an angle of 45 degrees with respect to the direction X of propagation.

[0226] Further, in the microwave radiating portions 6 constituted by the two slits intersected with each other, an axis which is parallel to the direction X of propagation and, further, passes through the intersection portions of the slits in the microwave radiating portions 6 is not at a position (on the tube axis) about which the electric- field distribution within the waveguide 5 is symmetric.

[0227] For example, in cases of propagation of microwaves in the TE10 mode, there exists an electric-field distribution symmetry axis (the tube axis P) which extends in the direction X of propagation such that it passes through the center of the waveguide 5 in the direction (the widthwise direction Z) orthogonal to the direction Y of the electric field and to the direction X of propagation within the waveguide 5. Therefore, the intersection portions of the slits should be provided at positions deviated from the position of the center of the waveguide 5 in the widthwise direction Z.

[0228] For example, in cases where the waveguide 5 propagates microwaves in the TE10 mode, the electric-field distribution within the waveguide 5 is symmetric about an axis which is coincident with the tube axis P which extends in the direction X of propagation and, further, passes through the center of the waveguide 5 in the direction Z orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5. Therefore, in the structure according to the tenth embodiment, the intersection portions of the slits in the microwave radiating portions 6 are placed at positions deviated from a line vertically above the symmetry axis in the waveguide 5, namely the tube axis P of the waveguide 5. By placing the microwave radiating portions 6 as described above, the microwave radiating portions 6 are enabled to certainly radiate circularly-polarized waves (left-handed polarized waves or right-handed polarized waves).

[0229] Further, in the plurality of the microwave radiating portions 6 for radiating circularly- polarized waves, as the intervals between the microwave radiating portions 6 adjacent to each other are decreased, the concentrations of electric fields between the microwave radiating portions 6 are increased, which increases microwave losses, thereby degrading the heating efficiency. It is preferable that the microwave radiating portions 6 adjacent to each other are placed with intervals of 5 mm or more interposed therebetween. Therefore, in the structure according to the tenth embodiment, the microwave radiating portions 6 adjacent to each other are placed in such a way as to provide largest possible intervals interposed therebetween, in the widthwise direction Z in the waveguide 5.

[0230] The microwave heater 1 having the aforementioned structure according to the tenth embodiment is enabled to realize uniform microwave heating for objects to be heated within the heating chamber 2, without being provided with a mechanism for rotating a table or an antenna or being provided with a phase shifter. Accordingly, the microwave heater 1 according to the tenth embodiment is capable of certainly avoiding the problem of heating unevenness and the like in objects to be heated during heating operations, which are induced in the event of failures of the rotating mechanism and in the event of abnormal operations.

(Eleventh Embodiment)

[0231] Hereinafter, a microwave heater according to an eleventh embodiment of the present invention will be described. The microwave heater according to the eleventh embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0232] In the following description about the eleventh embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0233] Fig. 21 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves (left-handed polarized waves or right-handed polarized waves), in the microwave heater according to the eleventh embodiment of the present invention.

[0234] As illustrated in Fig. 21, in the microwave heater 1 according to the eleventh embodiment, a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are placed on the upper surface (the surface faced to the heating chamber 2) of the waveguide 5 such that they are arranged at least in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field.

[0235] In the microwave heater 1 according to the eleventh embodiment, the microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are constituted by two slits intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5. In the structure according to the eleventh embodiment, the lengths 2p of the slits in the microwave radiating portions 6 are varied depending on their positions in the direction (the widthwise direction Z) orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5.

[0236] The microwave heater 1 having the aforementioned structure according to the eleventh embodiment is enabled to control the amount of radiation of microwaves, by varying the relationship among the placements of the plurality of the microwave radiating portions 6, and the lengths (the opening areas) of the slits 2p in the respective microwave radiating portions 6. Accordingly, the microwave heater according to the eleventh embodiment is enabled to perform uniform and efficient microwave heating on objects to be heated within the heating chamber 2.

[0237] Further, in the microwave heater 1 according to the eleventh embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the widthwise direction Z of the waveguide 5. The structure according to the eleventh embodiment also covers structures having a plurality of microwave radiating portions 6 which are placed in the direction X of propagation, as well as in the widthwise direction Z.

[0238] In the microwave heater 1 according to the eleventh embodiment, the plurality of the microwave radiating portions 6 are not always placed symmetrically with respect to the center of the heating chamber 2, due to the relationship thereof with other designed components. Further, even when the plurality of the microwave radiating portions 6 are placed symmetrically with respect to the center of the heating chamber 2, the microwave distribution within the heating chamber 2 may be made non-uniform, since various types of members such as heaters, a door glass are mounted inside the chamber of the microwave heater 1 such as a microwave oven.

[0239] Accordingly, the microwave heater according to the eleventh embodiment is adapted to ensure a uniform microwave distribution within the heating chamber 2, by varying the lengths 2p of the slits in the microwave radiating portions 6, in addition to the placements of the plurality of the microwave radiating portions 6.

[0240] In general, in a microwave radiating portion 6 having two slits intersected with each other, if the length 2p of the slits is decreased to make the opening area of the microwave radiating portions 6 smaller, the microwave radiating portion 6 is caused to radiate a decreased amount of microwaves within the heating chamber 2.

[0241] For example, when there is a stronger microwave distribution in a rear-surface-side area (an area in a right side when viewed in the direction of propagation : in an upper side in Fig. 21) in the waveguide 5 illustrated in Fig. 21, the length 2p of the slits in the microwave radiating portion 6 constituted by the two slits intersected with each other in the rear-surface-side area in Fig. 21 can be made smaller for making the opening area in the microwave radiating portion 6 smaller. As a result thereof, the microwave radiating portion 6 in the rear-surface-side area is caused to radiate a decreased amount of microwaves within the heating chamber 2, which can ensure uniformity of the microwave distribution within the heating chamber 2.

[0242] In the microwave heater according to the eleventh embodiment of the present invention, as described above, the plurality of the microwave radiating portions 6 are each constituted by two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction X of propagation in the waveguide 5, and the lengths 2p of the longer sides of the slits are varied depending on their positions in the direction Z orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5. The microwave heater having the aforementioned structure according to the eleventh embodiment is enabled to perform microwave heating uniformly and efficiently on the objects to be heated.

[0243] In the structure according to the eleventh embodiment, similarly, as described in the aforementioned second embodiment, in cases of propagating microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, using the waveguide 5, the upper-limit size and the lower-limit size of the waveguide 5 in the direction (the widthwise direction Z) orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5 are restricted by the frequency of microwaves generated from the employed magnetron and by the size of the waveguide 5 in the direction Y of the electric field.

[0244] Further, as conditions required for the shapes of the microwave radiating portions 6 according to the eleventh embodiment, as described with reference to (a) in Fig. 4 in the aforementioned first embodiment, the slits (the elongated opening portions) illustrated in Fig. 21 should have lengths (2p) which are equal to or more than about 1/4 the in- tube wavelength λg of microwaves being propagated within the waveguide 5, the two slits should intersect with each other at their centers in the lengthwise directions, and each of the slits should be inclined by an angle of 45 degrees with respect to the direction X of propagation.

[0245] Further, the microwave radiating portions 6 constituted by the two slits intersected with each other are structured such that an axis which is parallel to the direction X of propagation and, further, passes through the intersection portions of the slits in the microwave radiating portions 6 is not at a position about which the electric- field distribution within the waveguide 5 is symmetric.

[0246] For example, in cases where the waveguide 5 propagates microwaves in the TE10 mode, the electric-field distribution within the waveguide 5 is symmetric about an axis which is coincident with the tube axis P which extends in the direction X of propagation and, further, passes through the center of the waveguide 5 in the direction Z orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5. Therefore, in the structure according to the eleventh embodiment, the intersection portions of the slits in the microwave radiating portions 6 are placed at positions deviated from a line vertically above the symmetry axis in the waveguide 5, namely the tube axis P of the waveguide 5. By placing the slits in the microwave radiating portions 6 as described above, the microwave radiating portions 6 are enabled to certainly radiate circularly-polarized waves (left-handed polarized waves or right-handed polarized waves).

[0247] Further, in the plurality of the microwave radiating portions 6 for radiating circularly- polarized waves, as the intervals between the microwave radiating portions 6 adjacent to each other are decreased, the concentrations of electric fields between the microwave radiating portions 6 are increased, which increases microwave losses, thereby degrading the heating efficiency. It is preferable that the microwave radiating portions 6 adjacent to each other are placed with intervals of 5 mm or more interposed therebetween. Therefore, in the structure according to the eleventh embodiment, the microwave radiating portions 6 adjacent to each other are placed in such a way as to provide largest possible intervals interposed therebetween, in the widthwise direction Z in the waveguide 5.

(Twelfth Embodiment)

[0248] Hereinafter, a microwave heater according to a twelfth embodiment of the present invention will be described. The microwave heater according to the twelfth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0249] In the following description about the twelfth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0250] Fig. 22 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves (left-handed polarized waves or right-handed polarized waves), in the microwave heater according to the twelfth embodiment of the present invention.

[0251] As illustrated in Fig. 22, in the microwave heater 1 according to the twelfth embodiment, a plurality of microwave radiating portions 6 for radiating circularly-polarized waves (left-handed polarized waves or right-handed polarized waves) within the heating chamber 2 are placed, such that they are arranged at least in the direction Z orthogonal to the direction X of propagation and to the direction Y of the electric field.

[0252] In the microwave heater 1 according to the twelfth embodiment, the microwave radiating portions 6 for radiating circularly-polarized waves (left-handed polarized waves or right-handed polarized waves) within the heating chamber 2 are constituted by two slits intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5. In the structure according to the twelfth embodiment, the widths 2q of the slits in the microwave radiating portions 6 are varied depending on their positions in the direction Z orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5.

[0253] Out of the two microwave radiating portions 6 illustrated in Fig. 22, the microwave radiating portion 6 in a rear-surface-side area (an area in a right side when viewed in the direction of propagation : in an upper side in Fig. 22) is formed to have an opening portion larger than the opening area of the microwave radiating portion 6 in a front-surface-side area (in an area in a left side viewed in the direction of propagation : in a lower side in Fig. 22). Therefore, in Fig. 22, there is illustrated an example where the microwave radiating portion 6 in the rear-surface side area (the area in the right side when viewed in the direction of transmission) is caused to radiate, from its opening portion, an increased amount of microwaves.

[0254] The microwave heater having the aforementioned structure according to the twelfth embodiment is enabled to control the amount of microwaves radiated therefrom, through the relationship between the placements of the microwave radiating portions 6, and by varying the widths (the opening areas) of the slits in the respective microwave radiating portions 6. Accordingly, the microwave heater according to the twelfth embodiment is enabled to perform microwave heating on the object to be heated within the heating chamber 2, uniformly and efficiently.

[0255] Further, in the microwave heater according to the twelfth embodiment, it is necessary only that a plurality of microwave radiating portions 6 be placed such that they are arranged at least in the direction Z. The structure according to the twelfth embodiment also covers structures having a plurality of microwave radiating portions 6 placed in the direction X of propagation, as well as in the widthwise direction Z.

[0256] In the microwave heater 1 according to the twelfth embodiment, the plurality of the microwave radiating portions 6 are not always placed symmetrically with respect to the center of the heating chamber 2, due to the relationship thereof with other designed components. Further, even when the plurality of the microwave radiating portions 6 are placed symmetrically with respect to the center of the heating chamber 2, the microwave distribution within the heating chamber 2 may be made non-uniform, since various types of members such as heaters, a door glass are mounted inside the chamber of the microwave heater 1 such as a microwave oven.

[0257] Accordingly, the microwave heater according to the twelfth embodiment is enabled to ensure a uniform microwave distribution within the heating chamber 2, by varying the widths 2q of the slits in the microwave radiating portions 6, as well as through the placements of the plurality of the microwave radiating portions 6.

[0258] In general, in a microwave radiating portion 6 having two slits intersected with each other, if the width 2q of the slits is decreased to make the opening area of the microwave radiating portions 6 smaller, the microwave radiating portion 6 is caused to radiate a decreased amount of microwaves within the heating chamber 2.

[0259] For example, when there is a stronger microwave distribution in the front-surface-side area (in the lower side in Fig. 22) in the waveguide 5 illustrated in Fig. 22, the slit width 2q in the microwave radiating portion 6 constituted by the two slits intersected with each other in the rear-surface-side area (the upper side in Fig. 22) is made larger, in order to make the microwave radiating portion 6 in the rear-surface-side area have a larger opening area. As a result thereof, the microwave radiating portion 6 in the rear-surface-side area is caused to radiate an increased amount of microwaves within the heating chamber 2, which can ensure uniformity of the microwave distribution within the heating chamber 2.

[0260] In the structure according to the twelfth embodiment, similarly, as described in the aforementioned second embodiment, in cases of propagating microwaves generated from the microwave generating device 4 constituted by a magnetron and the like, using the waveguide 5, the upper-limit size and the lower-limit size of the waveguide 5 in the widthwise direction Z are restricted by the frequency of microwaves generated from the employed magnetron and by the size of the waveguide 5 in the direction Y of the electric field.

[0261] Further, as conditions required for the shapes of the microwave radiating portions 6 according to the twelfth embodiment, as described with reference to (a) in Fig. 4 in the aforementioned first embodiment, the slits (the elongated opening portions) illustrated in Fig. 22 should have lengths (2p) which are equal to or more than about 1/4 the in- tube wavelength λg of microwaves being propagated within the waveguide 5, the two slits should intersect with each other at their centers in the lengthwise directions, and each of the slits should be inclined by an angle of 45 degrees with respect to the direction X of propagation.

[0262] Further, the microwave radiating portions 6 constituted by the two slits intersected with each other are structured such that an axis which is parallel to the direction X of propagation and, further, passes through the intersection portions of the slits in the microwave radiating portions 6 is not at a position about which the electric- field distribution within the waveguide 5 is symmetric.

[0263] For example, in cases where the waveguide 5 propagates microwaves in the TE10 mode, the electric-field distribution within the waveguide 5 is symmetric about an axis which is coincident with the tube axis P which extends in the direction X of propagation and, further, passes through the center of the waveguide 5 in the widthwise direction Z. Therefore, in the structure according to the fifth embodiment, the intersection portions of the slits in the microwave radiating portions 6 are placed at positions deviated from a line vertically above the symmetry axis in the waveguide 5, namely the tube axis P of the waveguide 5. By placing the slits in the microwave radiating portions 6 as described above, the microwave radiating portions 6 are enabled to certainly radiate circularly-polarized waves.

[0264] Further, in the plurality of the microwave radiating portions 6 for radiating circularly- polarized waves, as the intervals between the microwave radiating portions 6 adjacent to each other are decreased, the concentrations of electric fields between the microwave radiating portions 6 are increased, which increases microwave losses, thereby degrading the heating efficiency. It is preferable that the microwave radiating portions 6 adjacent to each other are placed with intervals of 5 mm or more interposed therebetween. Therefore, in the structure according to the twelfth embodiment, the microwave radiating portions 6 adjacent to each other are placed in such a way as to provide largest possible intervals interposed therebetween, in the widthwise direction Z in the waveguide 5.

[0265] In the microwave heater according to the twelfth embodiment of the present invention, the plurality of the microwave radiating portions 6 are each constituted by two slits intersected with each other, wherein each slit is shaped to have a longer side inclined with respect to the direction X of propagation in the waveguide 5, and the slit widths 2q are varied depending on their positions in the direction Z orthogonal to the direction Y of the electric field and to the direction X of propagation in the waveguide 5. The microwave heater having the aforementioned structure according to the twelfth embodiment is enabled to perform microwave heating uniformly and efficiently on the objects to be heated.

(Thirteenth Embodiment)

[0266] Hereinafter, a microwave heater according to a thirteenth embodiment of the present invention will be described. The microwave heater according to the thirteenth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0267] In the following description about the thirteenth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0268] Fig. 23 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves (left-handed polarized waves or right-handed polarized waves), in the microwave heater according to the thirteenth embodiment of the present invention.

[0269] As illustrated in Fig. 23, in the microwave heater 1 according to the thirteenth embodiment, a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are placed on the upper surface (the surface faced to the heating chamber 2) of the waveguide 5 such that they are arranged at least in the direction Z orthogonal to the direction X of propagation and to the direction Y of the electric field.

[0270] In the microwave heater 1 according to the thirteenth embodiment, the microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are constituted by two slits intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5. In the microwave heater 1 according to the thirteenth embodiment, the microwave radiating portions 6 are shaped such that the intersection portions 12 have been subjected to round chamfering (R) or chamfering (C) at their corners. The aforementioned Fig. 14 illustrates an example of the round chamfering (R) or chamfering (C) applied to the corners of the intersection portions 12 of the slits in the microwave radiating portions 6. Although, in Fig. 14, there is illustrated an example where both round chamfering (R) and chamfering (C) have been applied thereto, it is necessary only that at least one of both the processes be applied to the intersection portions 12 in the slits in the microwave radiating portions 6.

[0271] With the microwave heater 1 having the aforementioned structure according to the thirteenth embodiment, it is possible to reduce microwave losses in the microwave radiating portions 6, which enables performing microwave heating on objects to be heated, with higher efficiency.

[0272] Microwaves have the property of being concentrated at corners, and portions with sharp tip ends. Therefore, if the microwave radiating portions 6 constituted by the two slits intersected with each other are made to have sharp shapes at their intersection portions, this induces concentrations of electric fields of microwaves, thereby inducing the problem of reduction of the heating efficiency.

[0273] Accordingly, in the microwave heater 1 according to the thirteenth embodiment, the microwave radiating portions 6 constituted by the two slits intersected with each other have been subjected to round chamfering (R) or chamfering (C) at the corners of the intersection portions 12, which alleviates concentrations of electric fields, thereby increasing the heating efficiency.

(Fourteenth Embodiment)

[0274] Hereinafter, a microwave heater according to a fourteenth embodiment of the present invention will be described. The microwave heater according to the fourteenth embodiment is different from the microwave heater according to the aforementioned first embodiment, in terms of the placement and the concrete structure of microwave radiating portions, but the other structures are the same as those of the microwave heater according to the first embodiment.

[0275] In the following description about the fourteenth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0276] Fig. 24 is a top view of a waveguide 5, illustrating microwave radiation portions 6 for radiating circularly-polarized microwaves (left-handed polarized waves or right-handed polarized waves), in the microwave heater according to the fourteenth embodiment of the present invention.

[0277] As illustrated in Fig. 24, in the microwave heater 1 according to the fourteenth embodiment, a plurality of microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are placed on the upper surface (the surface faced to the heating chamber 2) of the waveguide 5 such that they are arranged at least in the direction (the widthwise direction Z) orthogonal to the direction X of propagation and to the direction Y of the electric field.

[0278] In the microwave heater 1 according to the fourteenth embodiment, the microwave radiating portions 6 for radiating circularly-polarized waves within the heating chamber 2 are constituted by two slits intersected with each other in an X shape, wherein each slit has a longer side inclined (by an angle of 45 degrees) with respect to the direction X of propagation in the waveguide 5. In the fourteenth embodiment, the microwave radiating portions 6 have been subjected to round chamfering (R) or chamfering (C) at their slit distal end portions 13. The aforementioned Fig. 14 illustrates an example of the round chamfering (R) or chamfering (C) applied to the slit distal end portions 13 in the microwave radiating portions 6. Although, in Fig. 14, there is illustrated an example where both round chamfering (R) and chamfering (C) have been applied thereto, it is necessary only that at least one of both the processes be applied to the slit distal end portions 13 in the microwave radiating portions 6.

[0279] With the microwave heater 1 having the aforementioned structure according to the fourteenth embodiment, it is possible to reduce microwave losses in the microwave radiating portions 6, which enables performing microwave heating on objects to be heated, with higher efficiency.

[0280] Microwaves have the property of being concentrated at corners, and portions with sharp tip ends. Therefore, if the microwave radiating portions 6 constituted by the two slits intersected with each other are made to have angular shapes at their slit distal end portions 13, this induces concentrations of electric fields of microwaves, thereby inducing the problem of reduction of the heating efficiency.

[0281] Accordingly, in the microwave heater 1 according to the fourteenth embodiment, the microwave radiating portions constituted by the two slits intersected with each other have been subjected to round chamfering (R) or chamfering (C) at the slit distal end portions 13, which alleviates concentrations of electric fields, thereby increasing the heating efficiency.

(Fifteenth Embodiment and Sixteenth Embodiment)

[0282] The microwave heaters according to the aforementioned first to fourteenth embodiments have been described as being structured to have a plurality of microwave radiating portions 6 for radiating circularly-polarized waves which are placed at desired positions in the surface of the waveguide 5 which is faced to the heating chamber 2 in order to perform microwave heating uniformly and efficiently on objects to be heated within the heating chamber 2. Hereinafter, microwave heaters according to the fifteenth and sixteenth embodiments will be described, with respect to structures provided with an opening-sealing means which will be described later, as the placement portion in the microwave heaters according to the aforementioned first to fourteenth embodiments, which enables microwave heating with increased efficiency.

[0283] Among conventional representative microwave heaters, there have been microwave heaters which are adapted to propagate microwaves generated therein to a rotational antenna and, further, to radiate the microwaves within a heating chamber while stirring the microwaves through the rotational antenna.

[0284] Fig. 30 illustrates a conventional microwave heater described in Unexamined Japanese Patent Publication No. 2007-225186 (Patent Literature 3). The conventional microwave heater illustrated in Fig. 30 includes a heating chamber 21 for housing an object to be heated therein, a magnetron 22 for generating microwaves, a waveguide 23 for propagating microwaves, a rotational antenna 24 for radiating microwaves within the heating chamber 21, and an opening sealing plate 25 provided between the heating chamber 21 and the rotational antenna 24.

[0285] Microwaves generated from the magnetron 22 are propagated through the waveguide 23, and the microwaves having been propagated therethrough are coupled through the rotational antenna 24 and are radiated within the heating chamber 21 through the rotational antenna 24. At this time, in order to prevent heating unevenness in the object to be heated, the rotational antenna 24 is rotated by a rotational driving source such as a motor, thereby uniformizing the microwave distribution within the heating chamber 21.

[0286] Within the heating chamber 21, the opening sealing plate 25 provided between the heating chamber 21 and the rotational antenna 24 is provided in order to ensure stable placement of the object to be heated and, also, in order to prevent the rotational antenna 24 and the waveguide 23 from being contaminated and corroded by gasses (water vapor, oils) generated from the object to be heated. Microwaves from the rotational antenna 24 are radiated within the heating chamber 21 by passing through the opening sealing plate 25. The opening sealing plate 25 is formed from a plate member made of a ceramic, a glass and the like.

[0287] In the conventional microwave heater having this structure, in order to uniformly distribute microwaves within the heating chamber 21, microwaves are radiated within the heating chamber 21 while being stirred by the rotational antenna 24. Therefore, it is necessary that the opening sealing plate 25 provided between the heating chamber 21 and the rotational antenna 24 have a microwave transmission portion with a larger area. The opening sealing plate 25 which allows microwaves to be penetrated has been adapted to largely absorb microwave energy.

[0288] This has resulted in larger energy losses in microwaves radiated from the rotational antenna 24, which has reduced the energy of microwave radiated within the heating chamber, thereby degrading the heating efficiency.

[0289] Further, in the structure of the conventional microwave heater, in order to realize a uniform microwave distribution within the heating chamber 21, there has been a need for a mechanism for rotating the rotational antenna 24, besides the rotational antenna 24. This has necessitated a space for driving the rotational antenna 24 and, further, has necessitated securing an installation space for a motor and the like as the mechanism for rotating the rotational antenna 24. As described above, conventional microwave heaters as illustrated in Fig. 30 have involved many factors which obstruct size reduction.

[0290] Further, in order to stably rotate the rotational antenna 24, it has been necessary to provide the rotational antenna 24 at an upper portion or a lower portion in the heating chamber, which has restricted the structure.

[0291] In the structures according to the fifteenth and sixteenth embodiments of the present invention which will be described later, there are provided a plurality of microwave radiating portions for radiating circularly-polarized waves within the heating chamber at desired positions, which eliminates the necessity of providing a rotational antenna and a mechanism for rotating the rotational antenna, further, realizes uniform, microwave heating on objects to be heated and, further, largely suppresses microwave absorption losses, since the placement portion 3 is constituted by an opening sealing portion as an opening sealing means. This can provide a microwave heater capable of realizing excellent heating efficiency.

[0292] In the microwave heaters according to the fifteenth and sixteenth embodiments of the present invention, the microwave transmission area in the opening sealing portion as the placement portion 3 is restricted to a smaller area, which can suppress microwave energy absorption losses in the opening sealing portion. As a result thereof, the microwave heaters according to the fifteenth and sixteenth embodiments are capable of increasing the efficiency of heating objects to be heated through microwaves, thereby largely improving the energy saving performance.

(Fifteenth Embodiment)

[0293] Hereinafter, a microwave heater according to the fifteenth embodiment of the present invention will be described. The microwave heater according to the fifteenth embodiment is different from the microwave heaters according to the aforementioned first to fourteenth embodiments, in that an opening sealing portion as a placement portion within a heating chamber has a specific structure, but the structures of the microwave heaters according to the first to fourteenth embodiments are applied to the other structures.

[0294] In the following description about the fifteenth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0295] Fig. 25 is a perspective view illustrating the entire structure of a microwave oven as a microwave heater according to the fifteenth embodiment of the present invention. Fig. 26 is a front cross-sectional view of the microwave heater according to the fifteenth embodiment. Fig. 27 is a plan cross-sectional view illustrating the bottom-surface portion and the like in the heating chamber in the microwave heater according to the fifteenth embodiment.

[0296] Referring to Fig. 25, the microwave oven 1 as the microwave heater includes the heating chamber 2, wherein the heating chamber 2 is adapted to be surrounded by a door (a front-surface wall) 7 which enables taking in and out an object to be heated, such as food, thereinto and therefrom, and respective wall surfaces (a bottom surface, an upper surface, a left side surface, a right side surface, and a back surface).

[0297] As a placement portion 3 which forms the bottom surface of the heating chamber 2, there is provided an opening sealing portion 10 as an opening sealing means which is penetrated by microwaves from microwave radiating portions 6 (see Fig. 26) and for radiating them within the heating chamber 2. The opening sealing portion 10 is constituted by a microwave transmission portion 8 which is penetrated by microwaves, and a microwave reflection portion 9 for reflecting microwaves.

[0298] As illustrated in Fig. 26 and Fig. 27, under the opening sealing portion 10 placed in the bottom surface of the heating chamber 2, there are provided a waveguide 5 for propagating microwaves from a microwave generating device 4 as a microwave generating portion constituted by a magnetron, and the microwave radiating portions 6 provided in the surface of the waveguide 5 which is faced to the opening sealing portion 10. The microwave radiating portions 6, which are constituted by opening portions with predetermined shapes which have been described in the aforementioned first to fourteenth embodiments, are provided for radiating, within the heating chamber 12, microwaves having been propagated through the waveguide 5 from the microwave generating device 4.

[0299] The plurality of the microwave radiating portions 6 are placed oppositely to the microwave transmission portion 8 in the opening sealing portion 10. The microwave transmission portion 8, which is made of a material which is penetrated by microwaves without absorbing them, is placed just above the opening portions in the plurality of the microwave radiating portions 6 and is adapted to cover the opening portions.

[0300] Next, there will be described the microwave oven as the microwave heater 1 having the aforementioned structure according to the fifteenth embodiment, in terms of operations and effects thereof.

[0301] In heating operations with the microwave heater 1, at first, an object to be heated, such as an object to be cooked, is placed on the opening sealing portion 10 which forms the bottom surface of the heating chamber 2 and, then, the door 7 is closed. In a state where the heating chamber 2 is enclosed for confining microwaves therein, if a predetermined manipulation for staring a heating operation is performed, this activates the microwave generating device 4 through a control portion (not illustrated), thereby generating microwaves therefrom.

[0302] Microwaves generated therefrom are propagated through the waveguide 5, and circularly-polarized microwaves are radiated from the microwave radiating portions 6 provided in the waveguide 5. Microwaves radiated from the microwave radiating portions 6 are transmitted through the microwave transmission potion 8 in the opening sealing portion 10 and are supplied (radiated) to the inside of the heating chamber 2. The object to be heated is subjected to microwave heating through microwaves supplied to the inside of the heating chamber 2, so that desired cooking is performed thereon.

[0303] Circular polarization is a technique which has been widely utilized in the fields of mobile communications and satellite communications, as described in the aforementioned first embodiment. Examples of familiar usages thereof include ETCs (Electronic-Toll Collection Systems) "Non-Stop Automated Fee Collection System".

[0304] A circularly-polarized wave is a microwave having an electric field with a polarization plane which is rotated, with time, with respect to the direction of propagation of radio waves. When such a circularly-polarized wave is created, its electric field continuously changes with time in direction. Therefore, when circularly-polarized microwaves are radiated within the heating chamber, the microwaves radiated within the heating chamber exhibit the property of continuously changing in angle of radiation, while having a magnitude of electric-field intensity which is substantially unchanged with time.

[0305] However, in cases where there is only a single microwave radiating portion for radiating microwaves within the heating chamber, a non- uniform microwave distribution is created within the heating chamber due to influences of the directivity of the radiated microwaves, and it is difficult to perform control in such a way as to uniformize the microwave distribution. In cases where there is only a single microwave radiating portion as described above, the vicinity of the microwave radiating portion is intensively heated, which induces the problem of the occurrence of heating unevenness in the object to be heated.

[0306] The aforementioned problem of the occurrence of heating unevenness can be overcome, by providing a plurality of microwave radiating portions 6 for radiating circularly-polarized microwaves, as described in the aforementioned first to fourteenth embodiments. Namely, by providing a plurality of microwave radiating portions 6, it is possible to disperse the radiation of microwaves within the heating chamber 2, which can alleviate concentrations of microwaves in comparison with cases of a single microwave radiating opening portion, thereby enabling uniformly heating the object to be heated.

[0307] Further, in conventional microwave heaters of types of radiating microwaves through rotational antennas 24 as illustrated in Fig. 30, standing waves are induced due to interference of microwaves radiated within the heating chamber 21 with microwaves having been reflected by the inner walls of the heating chamber 21. This induces heating unevenness in the object to be heated, in principle.

[0308] In the microwave heater according to the present invention, the plurality of the microwave radiating portions 6 are structured to radiate circularly-polarized waves, which prevents the occurrence of standing waves due to interferences between microwaves, in principle. Therefore, the microwave heater according to the present invention is enabled to avoid the occurrence of microwaves energy intensity differences due to standing waves within the heating chamber and, therefore, is enabled to uniformly heat the object to be heated.

[0309] In the microwave heater according to the fifteenth embodiment, the opening sealing portion 10 is provided as the bottom surface of the heating chamber 2, and the microwave transmission portion 8 in the opening sealing portion 10 is made of a material which is penetrated by microwaves. However, in the microwave transmission portion 8, some parts of microwaves are absorbed by the material of itself, and it is difficult to enable the microwave transmission portion 8 to transmit 100 % of microwaves.

[0310] Accordingly, if the opening sealing portion 10 which forms the bottom surface of the heating chamber 2 is entirely made of the material of the microwave transmission portion 8, this increases the amount of microwaves absorbed by the material of itself, which reduces the energy available for heating the object to be heated, thereby degrading the heating efficiency.

[0311] In the microwave heater according to the fifteenth embodiment of the present invention, in order to reduce microwave energy losses as mush as possible, the microwave transmission portion 8 as the microwave transmission area in the opening sealing portion 10 is made to be as small as possible. In the microwave heater according to the fifteenth embodiment, the opening sealing portion 10 is constituted by the microwave transmission portion 8 and the microwave reflection portion 9, and the microwave transmission portion 8 is provided only at a position faced to the microwave radiating portions 6.

[0312] In the microwave heater having the aforementioned structure according to the fifteenth embodiment, the area which is penetrated by microwaves can be formed to be smaller, in the opening sealing portion 10, which can suppress absorption of microwaves in the opening sealing portion 10. As a result thereof, with the microwave heater according to the fifteenth embodiment, it is possible to reduce the amount of energy losses in microwaves radiated within the heating chamber 2, which can increase the efficiency of microwave heating for the object to be heated.

[0313] Further, if the shape of the microwave transmission portion 8 as the microwave transmission area is smaller than the shapes of the microwave radiating portions 6, this induces the problem that microwaves radiated from the microwave radiating portions 6 are returned to the waveguide 5 by being reflected by the microwave reflection portion 9 in the opening sealing portion 10. If microwaves are returned to the waveguide 5 as described above, they are returned as reflected waves to the microwave generating device 4, thereby increasing the energy losses. Therefore, it is preferable that the microwave transmission portion 8 is structured to cover the opening portions of the microwave radiating portions 6 and has a shape larger than at least the opening portions of the microwave radiating portions 6.

[0314] In the microwave heater having the aforementioned structure according to the fifteenth embodiment, the opening sealing portion 10 is made to have a smaller area which is penetrated by microwaves, while the other area is made to be a reflective area. This largely reduces microwave energy losses caused by absorption of microwaves in the microwave transmission portion 8 in the opening sealing portion 10. As a result thereof, with the structure of the microwave heater according to the fifteenth embodiment, it is possible to increase the efficiency of heating of objects to be heated through microwaves, thereby realizing excellent energy saving performance.

[0315] Further, the microwave heater according to the fifteenth embodiment is of a type for radiating circularly- polarized microwaves within the heating chamber, which eliminates the necessity of providing a rotational antenna and a motor for driving the rotational antenna. As a result thereof, the microwave heater according to the fifteenth embodiment can eliminate the necessity of providing a driving space for the rotational antenna and an installation space for a rotational antenna and a mechanism for driving it, which can realize size reduction of the microwave heater. Further, the microwave heater having the reduced size has the excellent advantage of necessitating a reduced installation space in a kitchen and the like.

[0316] Further, as the material of the microwave transmission portion 8, it is preferable to employ a material having a high mechanical strength and high durability while inducing less losses due to microwave absorption. For example, it is preferable to employ crystallized glasses containing silicon oxide, aluminum oxide, zirconium oxide, and lithium oxide.

[0317] Further, in cases where the microwave heater is provided with no oven function and no grill function or is desired to have cooking temperatures equal to or less than 250 degrees C within the heating chamber, it is also possible to employ materials mainly containing plastics, which induce smaller losses due to microwave absorption than those by the aforementioned crystallized glasses. In this case, it is preferable to employ engineering plastics having higher heat resistance, in particular.

[0318] As described above, in the microwave heater according to the fifteenth embodiment, the opening sealing portion 10 is constituted by the microwave transmission portion 8 and the microwave reflection portion 9. Since the opening sealing portion 10 is provided with the microwave reflection portion 9 having the function of reflecting microwaves, microwaves reflected by the object to be heated within the heating chamber without being absorbed thereby are reflected by the microwave reflection portion 9 and, then, can be directed to the object to be heated, again.

[0319] As described above, in the microwave heater according to the fifteenth embodiment, due to the provision of the microwave reflection portion 9 therein, it is possible to further increase the efficiency of heating the object to be heated through microwaves, thereby further improving the energy saving performance.

[0320] Further, by forming the microwave reflection portion 9 from a metal material, it is possible to cause it to exhibit an enhanced microwave reflection property, which can further increase the efficiency of heating of objects to be heated through microwaves.

[0321] The microwave reflection portion 9 can be also formed from a metal which is provided, on its surface, with a coating layer such as a fluorine coating layer, for example, which prevents microwave absorption therein, such as dielectric losses and magnetic losses.

[0322] Further, although the microwave heater according to the fifteenth embodiment illustrated in Fig. 27 has been described with respect to an example where it is provided with six microwave radiating portions 6, the number of the microwave radiating portions 6 is not limited and can be properly determined depending on the size of the heating chamber in the microwave heater, the microwave electric power, the types of cookings to be executed, in the structure according to the fifteenth embodiment.

[0323] Further, although, in Fig. 27, the microwave radiating portions 6 are illustrated as having a circular shape in the microwave heater according to the fifteenth embodiment, it is also possible to employ various types of shapes as described in the aforementioned Fig. 4, as the shapes of the microwave radiating portions 6. The shapes of the microwave radiating portions 6 can be properly determined depending on the size and the shape of the microwave heater, additional members provided in the heating chamber, and the like. In order to realize a uniform heating distribution, the shapes of the microwave radiating portions 6 can be determined by selection from a circular shape, an elliptical shape, a rectangular shape, an X shape, a Y shape and other shapes.

(Sixteenth Embodiment)

[0324] Hereinafter, a microwave heater according to the sixteenth embodiment of the present invention will be described. The microwave heater according to the sixteenth embodiment is different from the microwave heater according to the aforementioned fifteenth embodiment, in terms of the structure of an opening sealing portion as a placement portion in a heating chamber.

[0325] In the following description about the sixteenth embodiment, components having the same functions and structures as those of the components in the microwave heater according to the first embodiment will be designated by the same reference characters, and the description about the first embodiment is substituted for detailed description thereof.

[0326] Fig. 28 is a front cross-sectional view of the microwave heater according to the sixteenth embodiment of the present invention. Fig. 29 is a plan cross-sectional view illustrating a bottom-surface portion and the like in the heating chamber in the microwave heater according to the sixteenth embodiment.

[0327] In the microwave heater according to the sixteenth embodiment, a microwave transmission portion 8 is placed and divided such that it conforms to the shapes of microwave radiating portions 6, in the opening sealing portion 10 as the placement portion 3.

[0328] As illustrated in Fig. 28 and Fig. 29, the microwave transmission portion 8 in the opening sealing portion 10 as the placement portion 3 is divided into the same number of parts as the number of the plurality of the microwave radiating portions 6 and, thus, is shaped to conform to the shapes of the microwave radiating portions 6. In the microwave heater according to the sixteenth embodiment, the respective parts of the microwave transmission portion 8 are placed oppositely to the different microwave radiating portions 6, and the microwave transmission portion 8 is adapted to be penetrated by microwave, circularly-polarized microwaves radiated therefrom.

[0329] Microwaves from a microwave generating device 4 as a microwave generating portion are propagated through a waveguide 5 and are radiated as circularly-polarized waves from the microwave radiating portions 6. Circularly-polarized microwaves radiated therefrom are transmitted through the microwave transmission portion 8 having the shape conforming to the microwave radiating portions 6 and, then, are radiated within the heating chamber 2.

[0330] Since the microwave transmission portion 8 is made to have a shape conforming to the microwave radiating portions 6, it is possible to allow the microwave transmission portion 8 in the opening sealing portion 10 to have a minimum necessary transmission area. As a result thereof, with the microwave hater according to the sixteenth embodiment, it is possible to significantly suppress absorption of microwaves by the microwave transmission portion 8, which can increase the efficiency of supply of microwave energy to the heating chamber 2, thereby further increasing the efficiency of heating of objects to be heated.

[0331] Further, the shape of the microwave transmission portion 8 is preferably a shape conforming to the shapes of the opening portions of the microwave radiating portions 6, but is not particularly limited. As the microwave transmission portion 8, it is possible to employ one having the same shape as those of the microwave radiating portions 6. In this case, the microwave transmission portion 8 can be placed such that its shape is overlaid on the opening portions of the microwave radiating portions 6.

[0332] Further, regardless of the shapes of the microwave radiating portions 6 for radiating circularly- polarized microwaves, it is possible to employ one having a circular shape, as the microwave transmission portion 8. In this case, it is desirable that the microwave transmission portion 8 covers at least the opening portions of the microwave radiating portions 6 and, further, has a circular shape with a diameter which is equal to or slightly larger than the lengths of the longer sides of the slits, for example, in the microwave radiating portions 6.

[0333] The microwave heater according to the present invention includes the plurality of the microwave radiating portions for radiating circularly-polarized waves within the heating chamber and, therefore, is capable of realizing uniform and efficient microwave heating for objects to be heated. As a result thereof, the microwave heater according to the present invention is capable of performing microwave heating on objects to be heated uniformly and efficiently, without being provided with a mechanism for rotating an antenna, a mechanism for rotating a table and a phase shifter. This enables reduction of the cost for the device, reduction of the size of the electricity feeing portion and improvement of the reliability.

Industrial Applicability

[0334] The microwave heater according to the present invention is capable of uniformly directing microwaves to objects to be heated and, therefore, can be effectively applied to apparatuses for performing heating processes, disinfections and the like and, also, can be applied to heating apparatuses which utilize induction heating and to microwave heaters in various types of appliances, such as garbage disposers, semiconductor fabrication apparatuses.

Reference Signs List

[0335]

1 Microwave heater
2 Heating chamber
3 Placement portion
4 Microwave generating portion
5 Waveguide
6 Microwave radiating portion

7 Door
8 Microwave transmission portion
9 Microwave reflection portion
10 Opening sealing portion

Claims

1. A microwave heater comprising:

   a heating chamber adapted to house an object to be heated;
   a placement portion which forms a bottom surface of the heating chamber and is adapted to accommodate and place, thereon, the object to be heated within the heating chamber;
   a microwave generating portion adapted to generate a microwave;
   a waveguide adapted to propagate the microwave from the microwave generating portion; and
   a plurality of microwave radiating portions which are provided in a surface of the waveguide which is faced to the heating chamber and are adapted to radiate a circularly-polarized wave within the heating chamber.

2. The microwave heater according to Claim 1, wherein the plurality of the microwave radiating portions are placed just under the placement portion.

3. The microwave heater according to Claim 2, wherein the respective plurality of the microwave radiating portions are adapted to radiate substantially the same amount of microwaves.

4. The microwave heater according to Claim 3, wherein the plurality of the microwave radiating portions are placed, in such a way as to be arranged at least in a direction of propagation in the waveguide.

5. The microwave heater according to Claim 3, wherein the plurality of the microwave radiating portions are placed, in such a way as to be arranged at least in a direction orthogonal to a direction of an electric field and to a direction of propagation in the waveguide.

6. The microwave heater according to Claim 4 or 5, wherein the plurality of the microwave radiating portions comprise two slits intersected with each other, and each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide.

7. The microwave heater according to Claim 4 or 5, wherein the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the longer sides of the slits have lengths which are varied depending on their positions in the direction of propagation in the waveguide.

8. The microwave heater according to Claim 4 or 5, wherein the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the longer sides of the slits have lengths which are varied depending on their positions in a direction orthogonal to the direction of the electric field and to the direction of propagation in the waveguide.

9. The microwave heater according to Claim 4 or 5, wherein the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the slits have widths which are varied depending on their positions in the direction of propagation in the waveguide.

10. The microwave heater according to Claim 4 or 5, wherein the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the slits have widths which are varied depending on their positions in a direction orthogonal to the direction of the electric field and to the direction of propagation in the waveguide.

11. The microwave heater according to Claim 4 or 5, wherein the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the slits have been subjected to round chamfering (R) or chamfering (C) at their intersection portions.

12. The microwave heater according to Claim 4 or 5, wherein the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and the slits have been subjected to round chamfering (R) or chamfering (C) at their distal end portions.

13. The microwave heater according to Claim 4 or 5, wherein the plurality of the microwave radiating portions comprise two slits intersected with each other, each slit is shaped to have a longer side inclined with respect to the direction of propagation in the waveguide, and
in terms of the positions of the intersection portions of the slits, a microwave radiating portion at a larger propagation distance from the position at which the microwave generating portion is installed is shaped to have a higher rate of radiation of a microwave to the heating chamber through the waveguide, than that of a microwave radiating portion at a smaller propagation distance from the position at which the microwave generating portion is installed.

14. The microwave heater according to Claim 3, wherein the placement portion adapted to accommodate and place, thereon, the object to be heated within the heating chamber includes a microwave transmission portion which is penetrated by microwaves, the microwave transmission portion is placed oppositely to the microwave radiating portions, and the microwave transmission portion is provided at least just above the microwave radiating portions.

15. The microwave heater according to Claim 14, wherein the microwave transmission portion has a shape conforming to the microwave radiating portions.

16. The microwave heater according to Claim 15, wherein the placement portion includes the microwave transmission portion, and a microwave reflection portion for reflecting microwaves.

17. The microwave heater according to Claim 16, wherein the microwave transmission portion is made of a crystallized glass containing at least one material, out of silicon oxide, aluminum oxide, zirconium oxide, and lithium oxide.

18. The microwave heater according to Claim 16, wherein the microwave transmission portion is mainly made of a plastic material.

19. The microwave heater according to Claim 16, wherein the microwave reflection portion is made of a metal material.

Fig.1

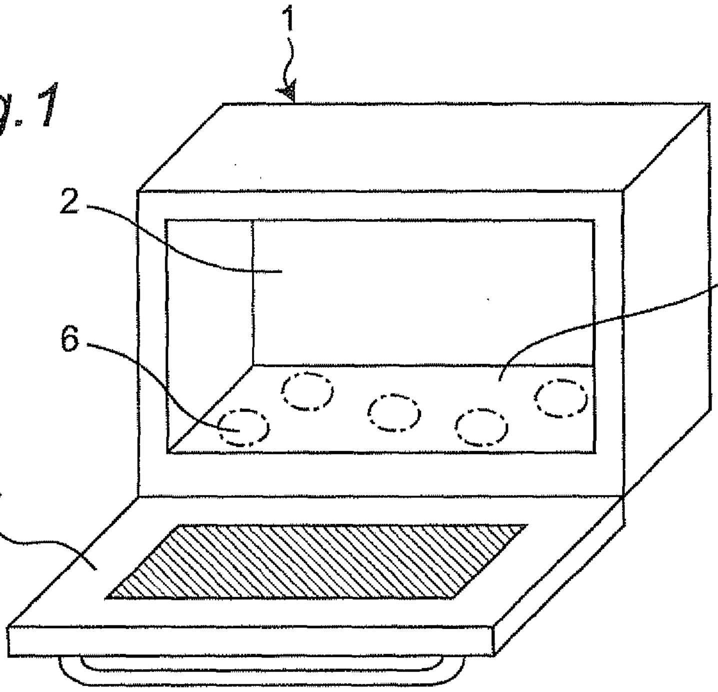


Fig.2

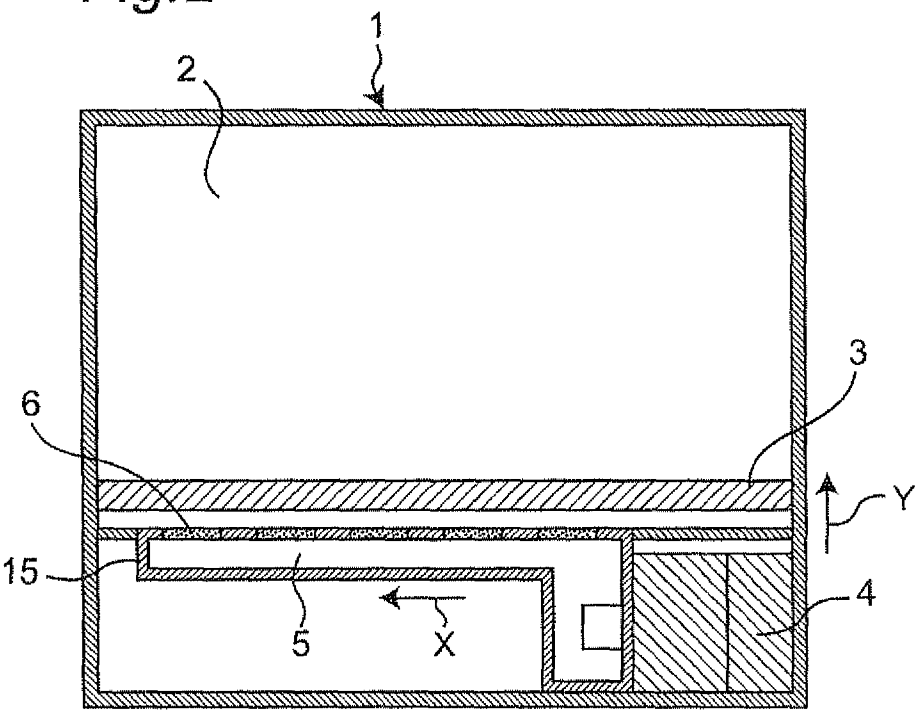


Fig.3

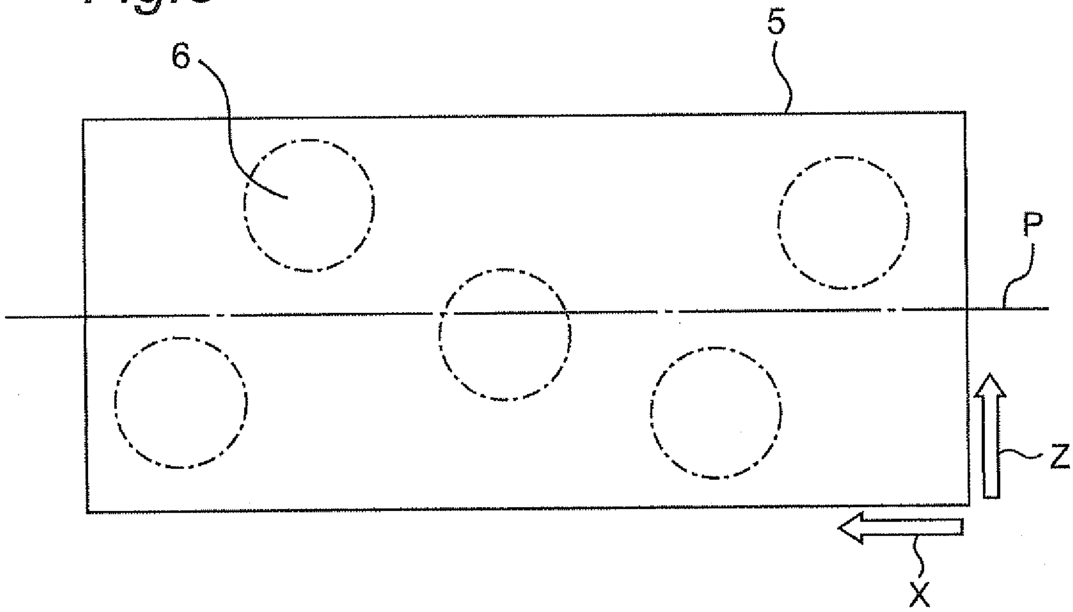


Fig.4

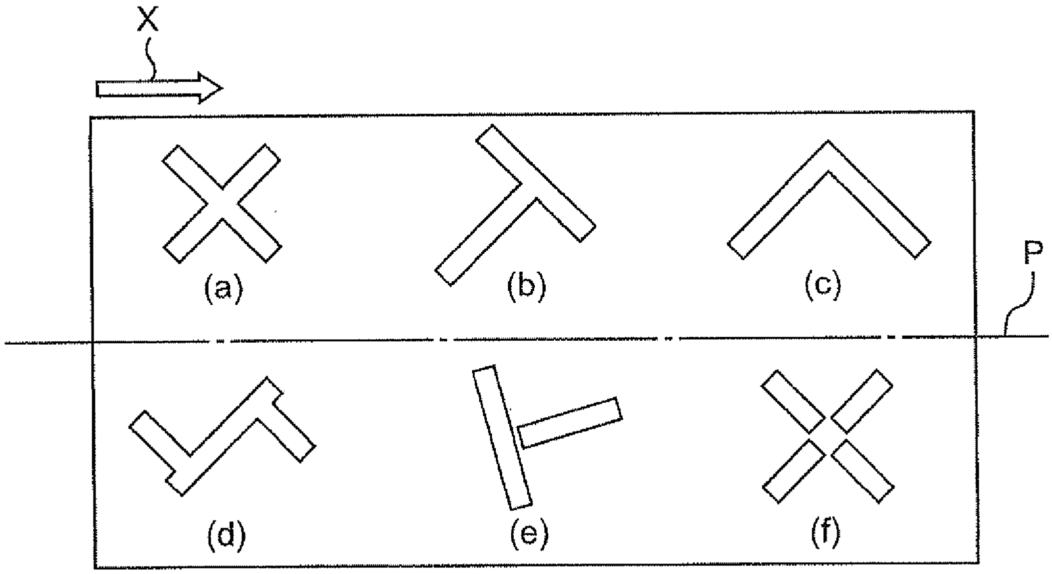


Fig.5

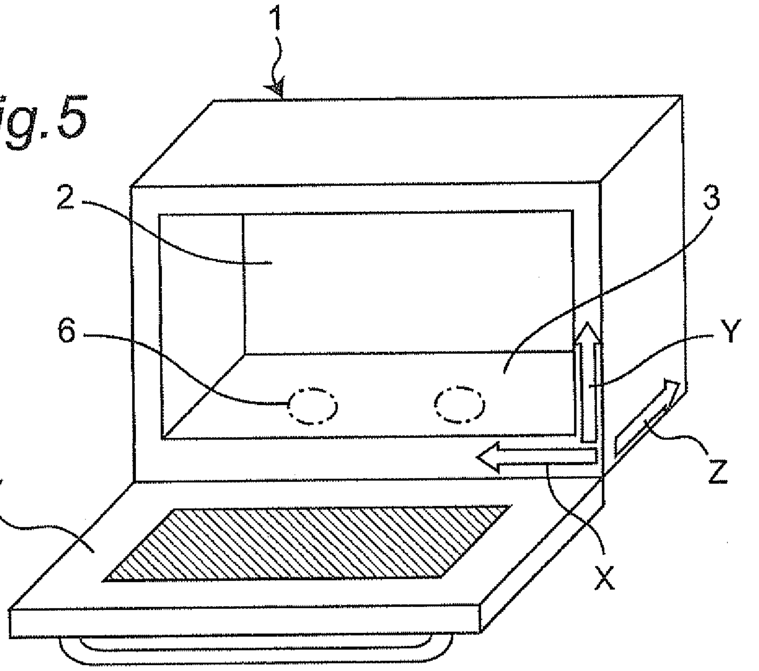


Fig.6

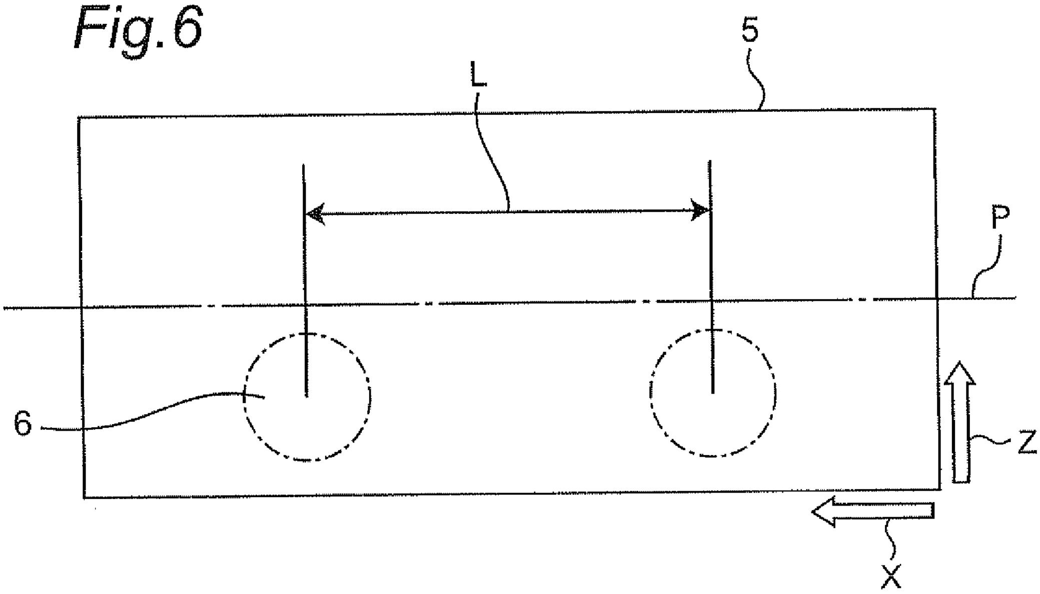


Fig.7

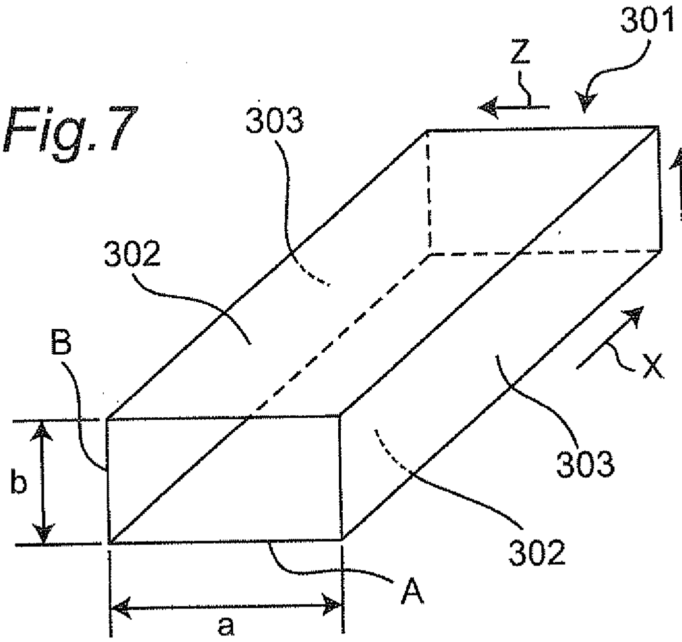


Fig.8

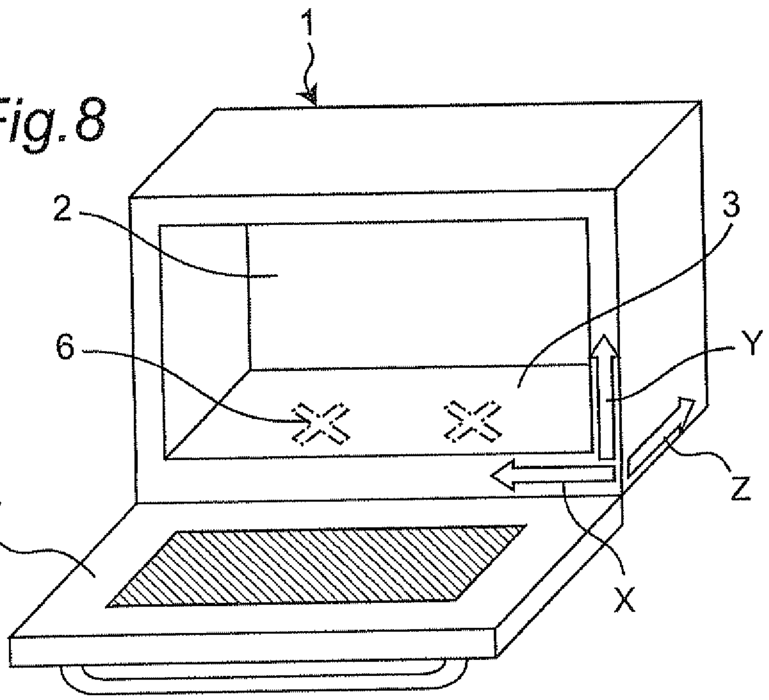


Fig.9

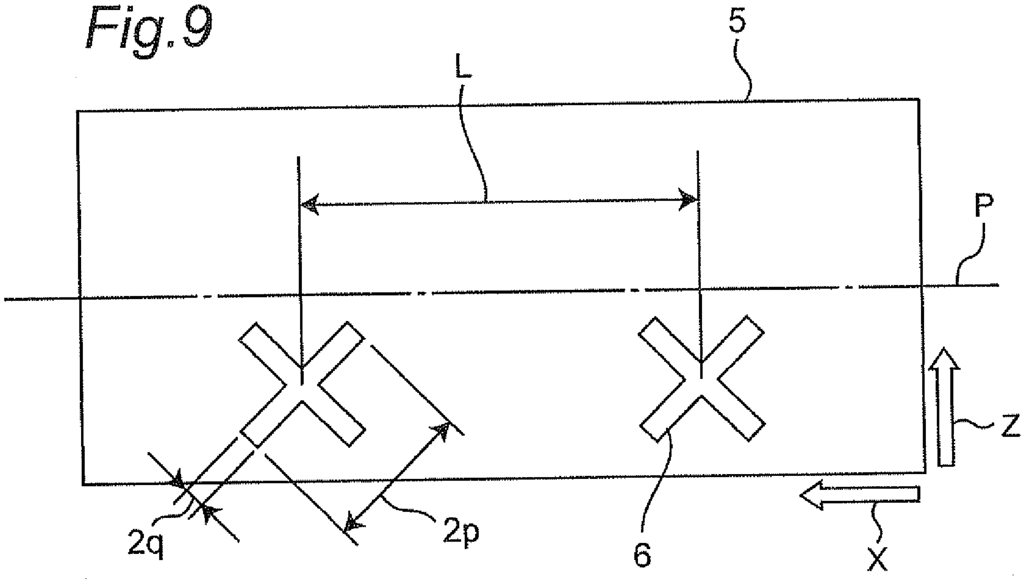


Fig.10

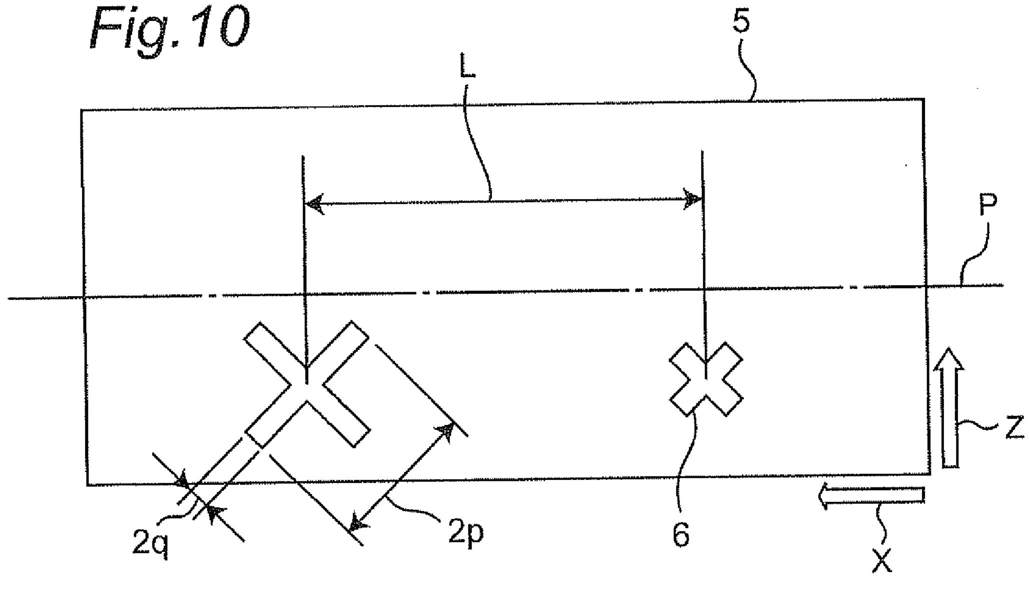


Fig.11

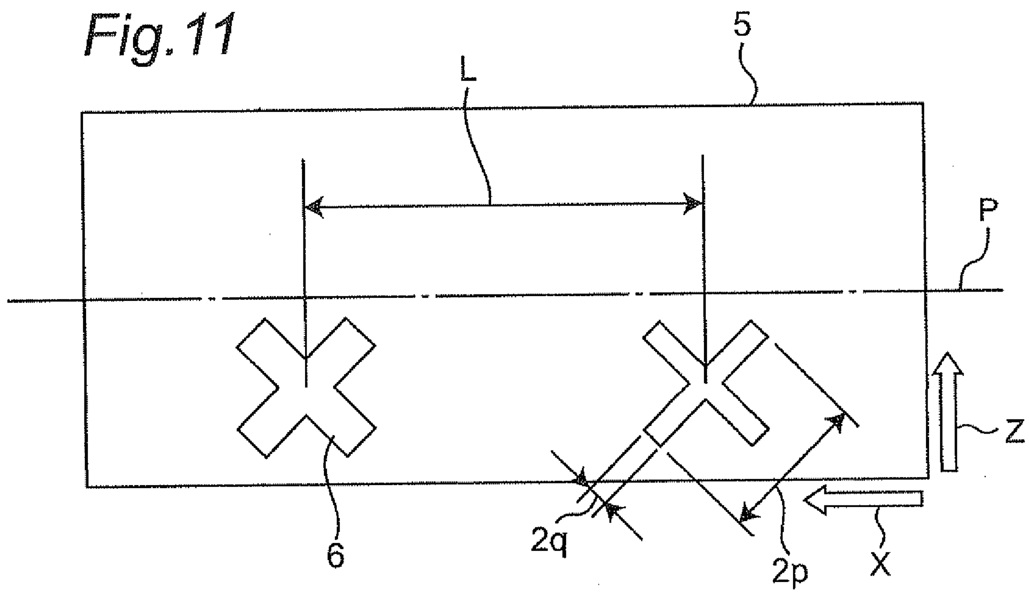


Fig.12

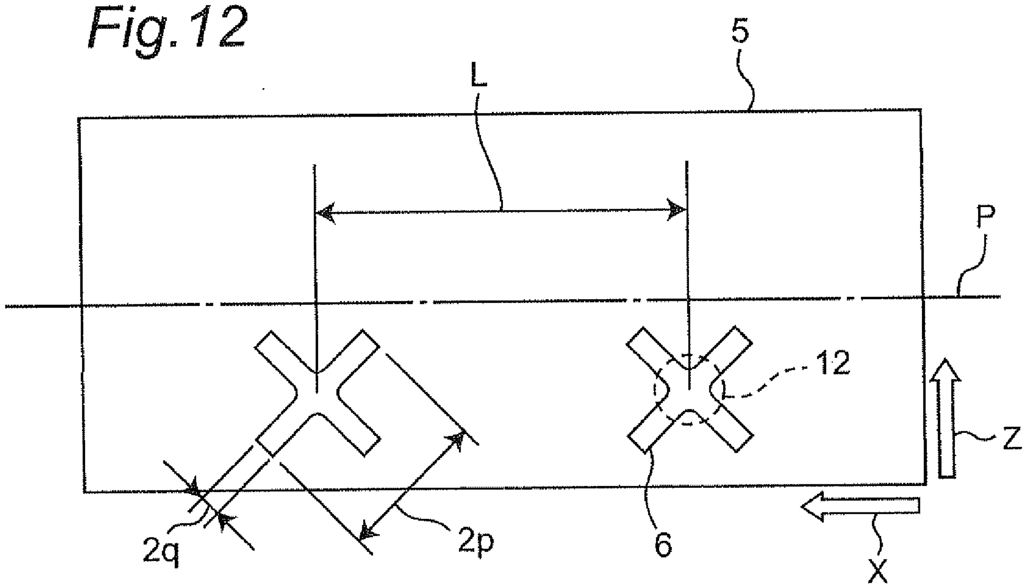


Fig.13

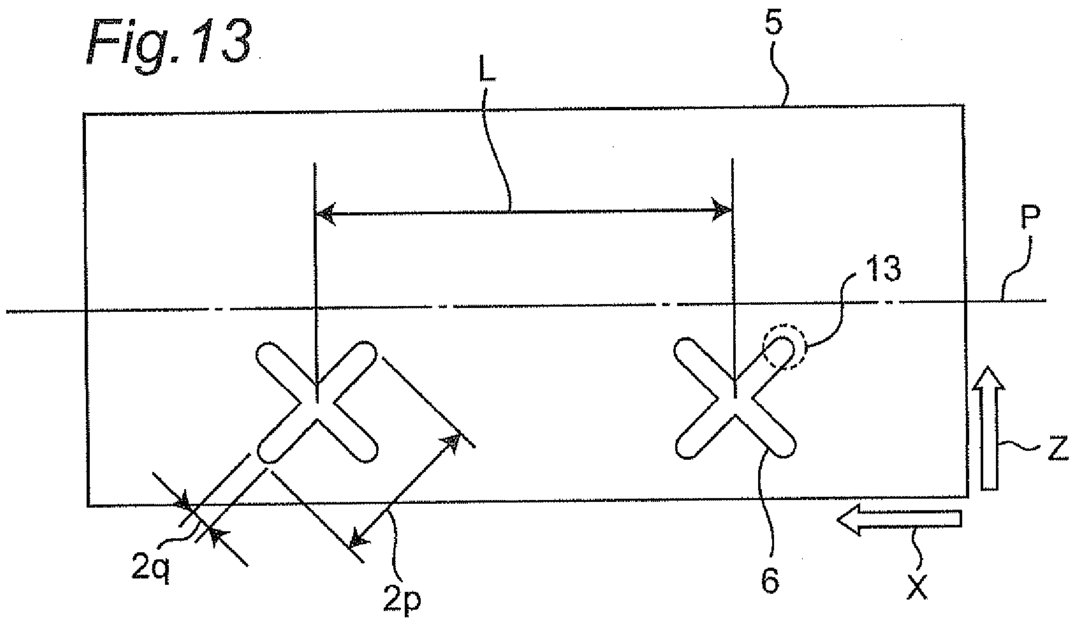


Fig.14

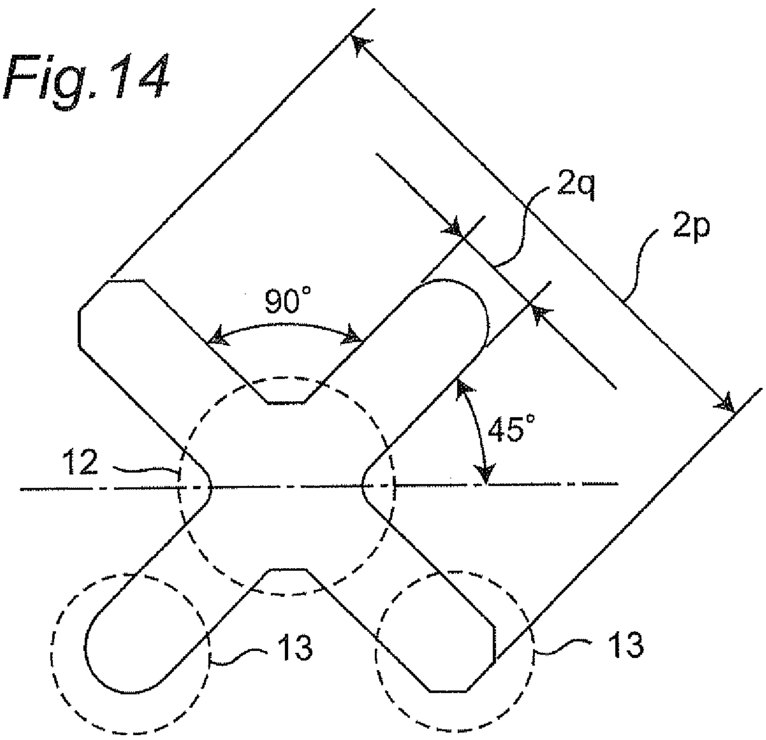


Fig.15

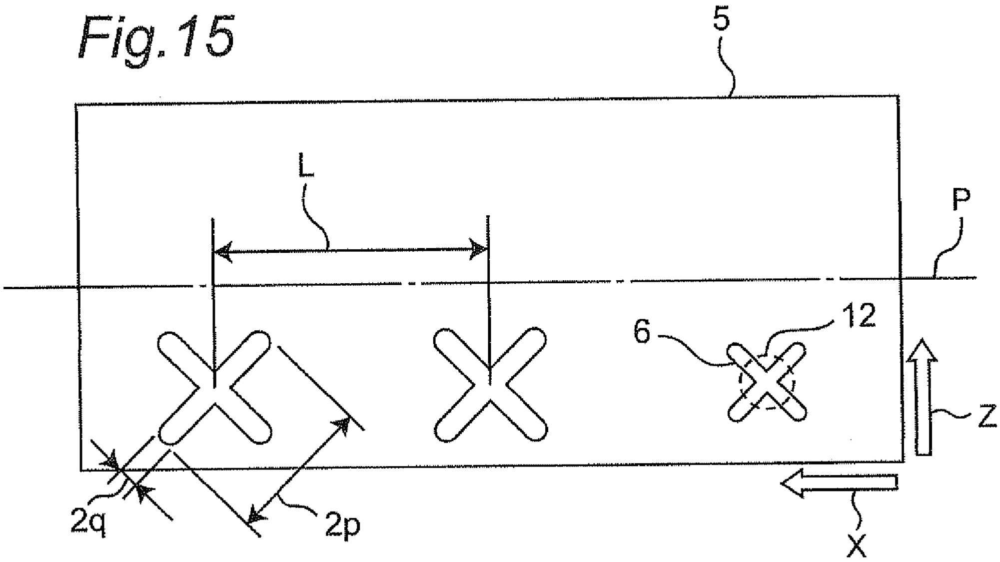


Fig.16

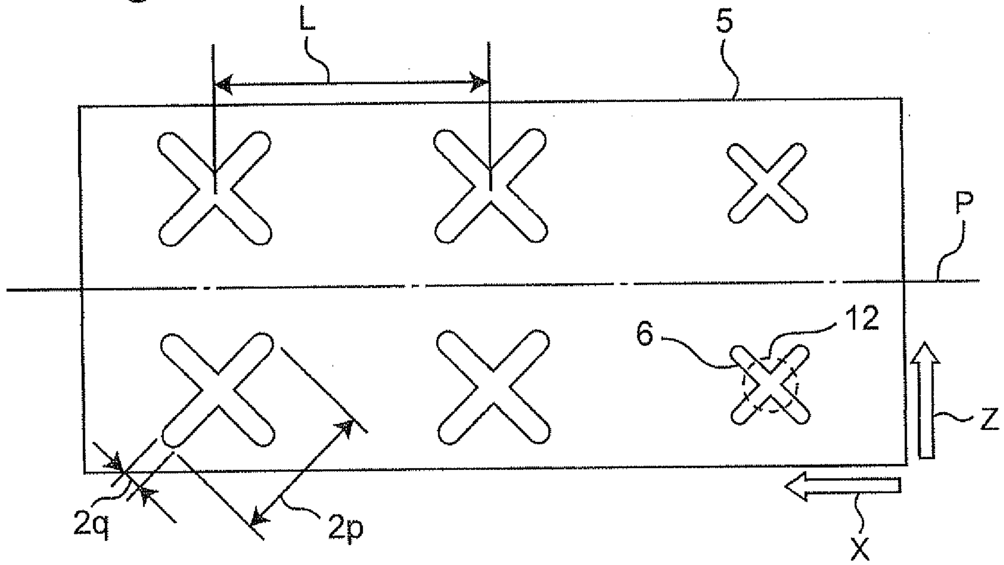


Fig.17

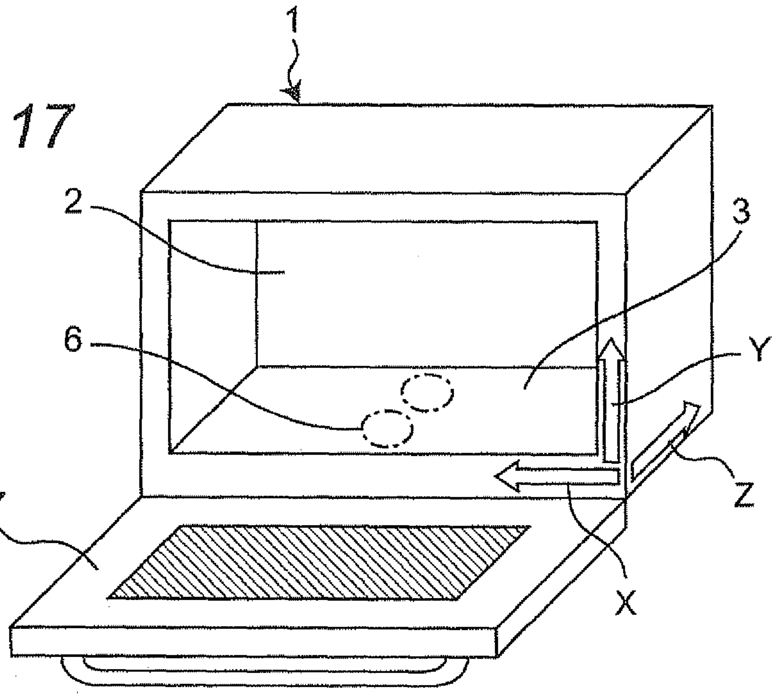


Fig.18

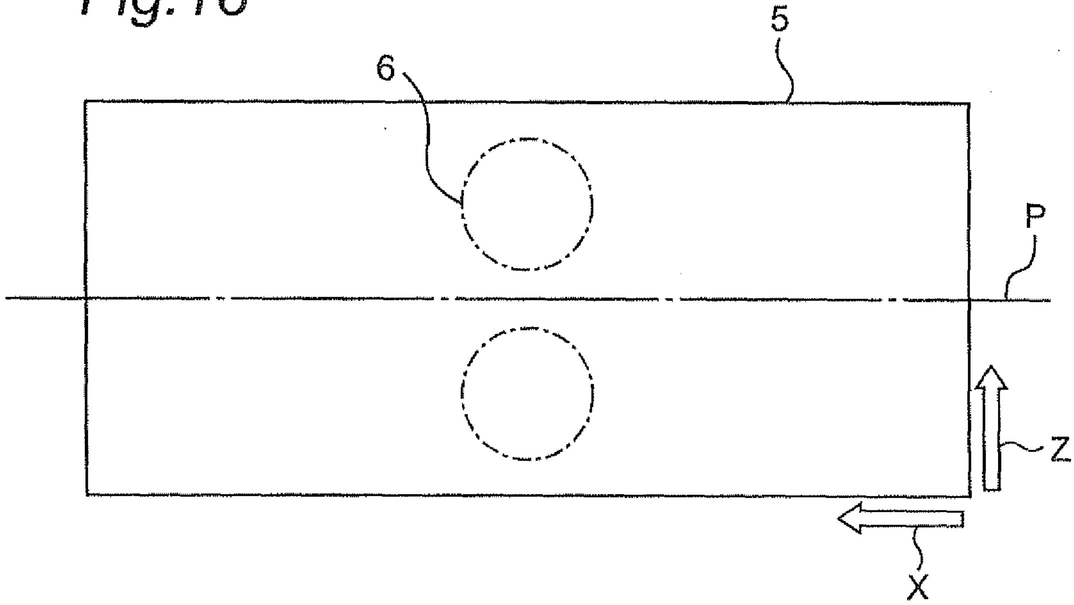


Fig.19

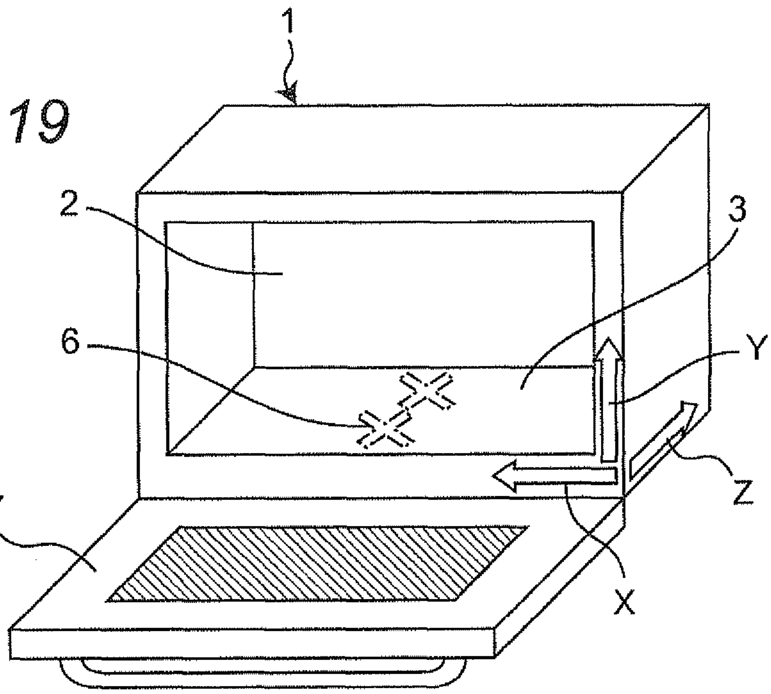


Fig.20

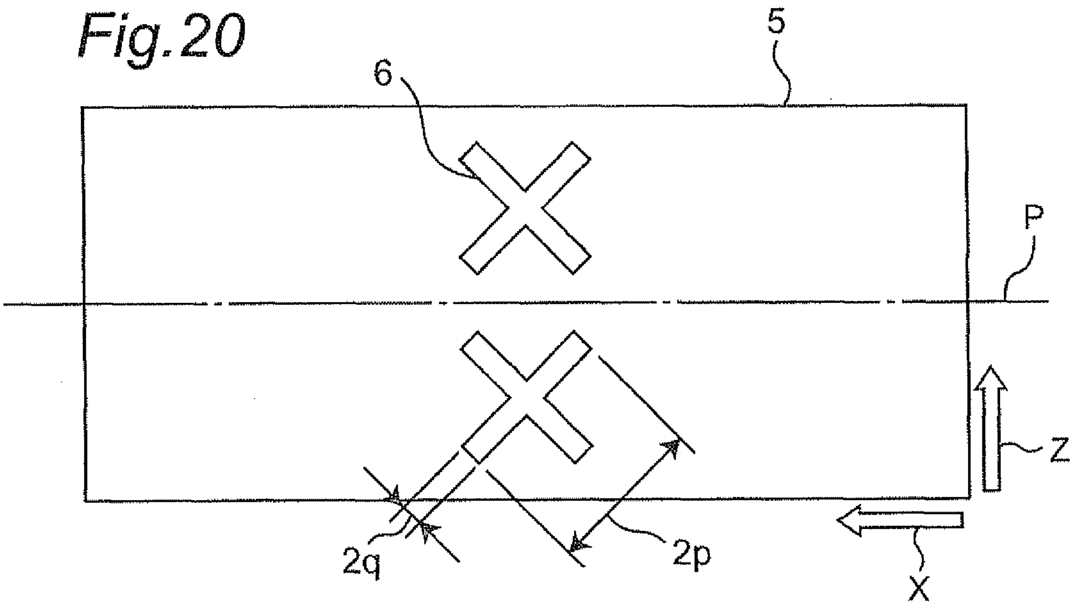


Fig.21

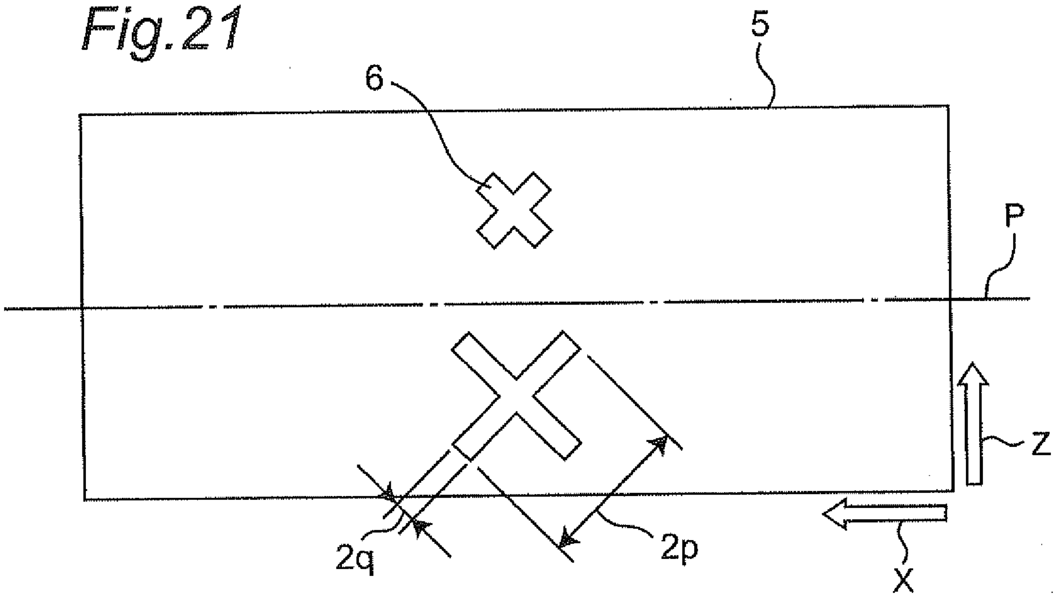


Fig.22

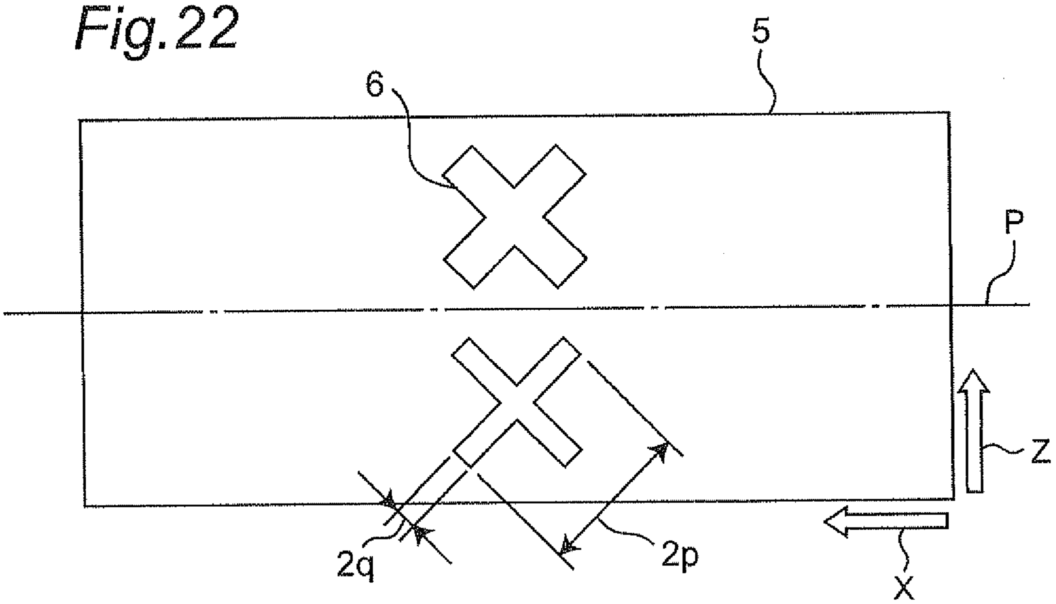


Fig.23

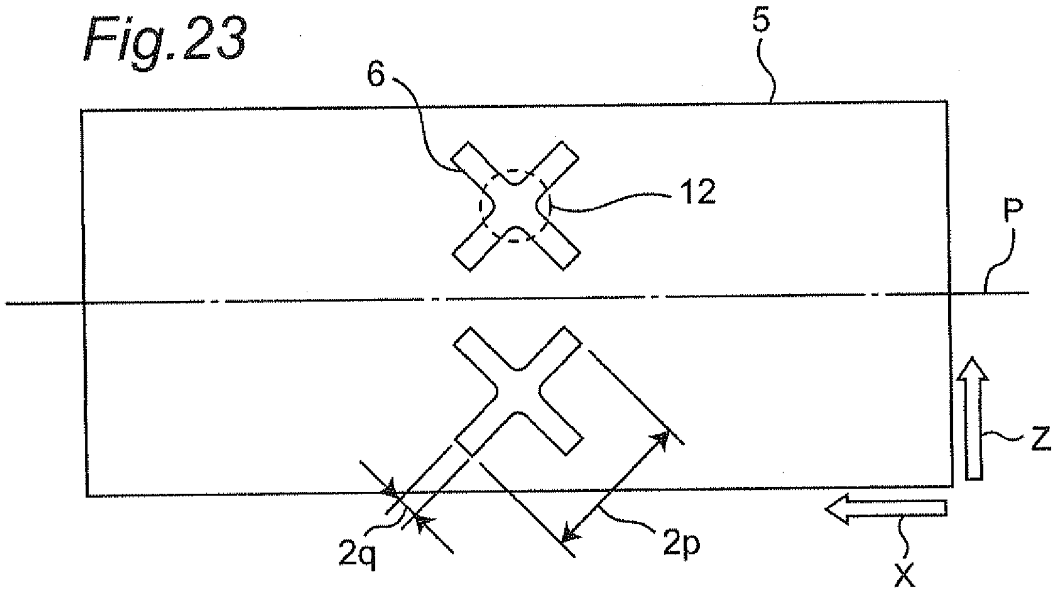


Fig.24

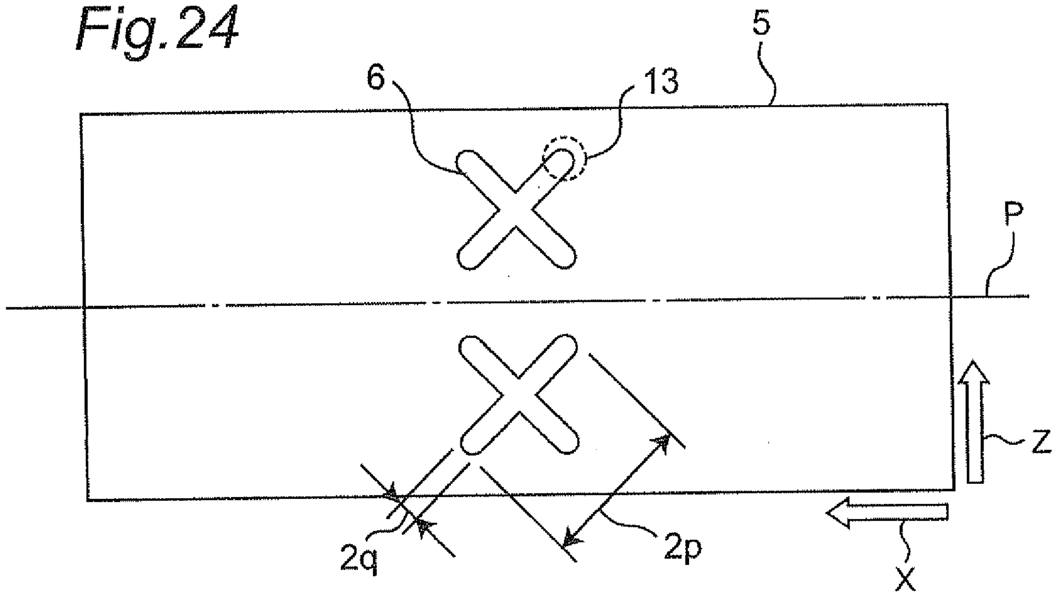


Fig.25

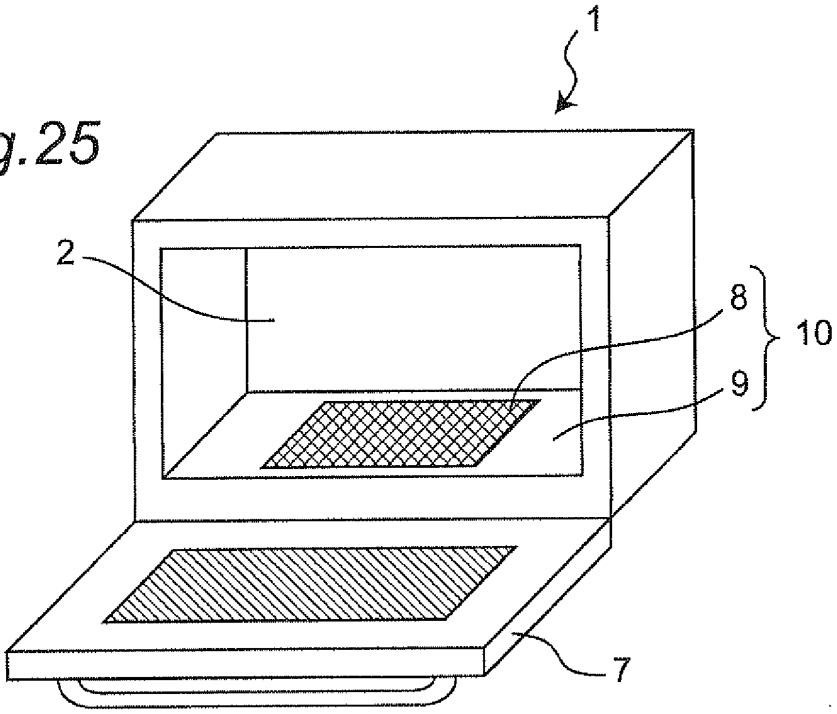


Fig.26

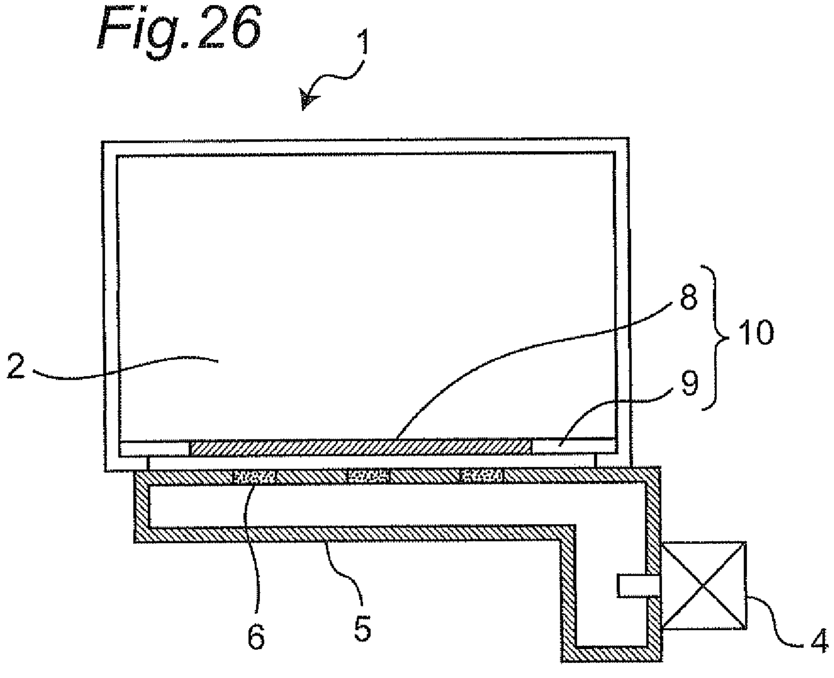


Fig.27

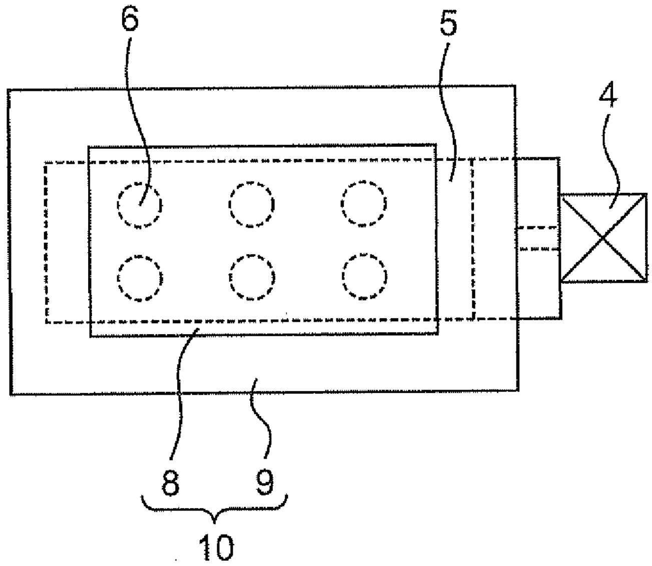


Fig.28

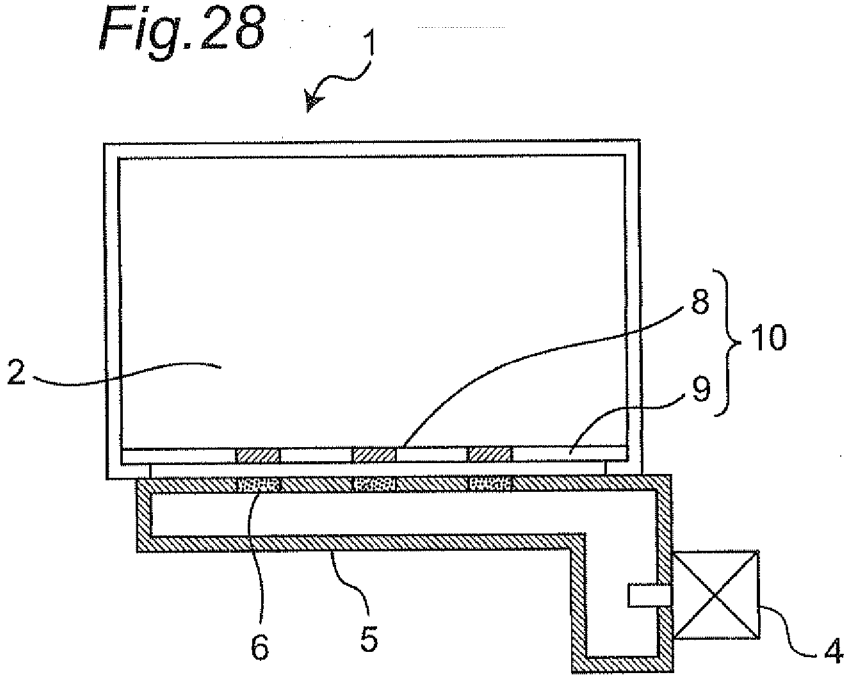


Fig.29

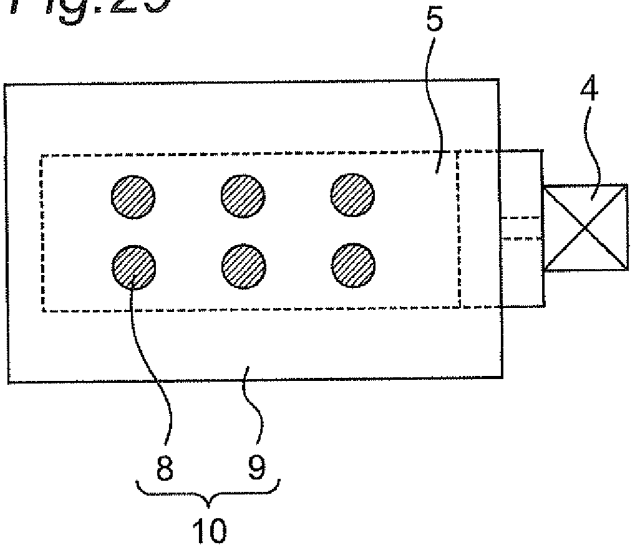
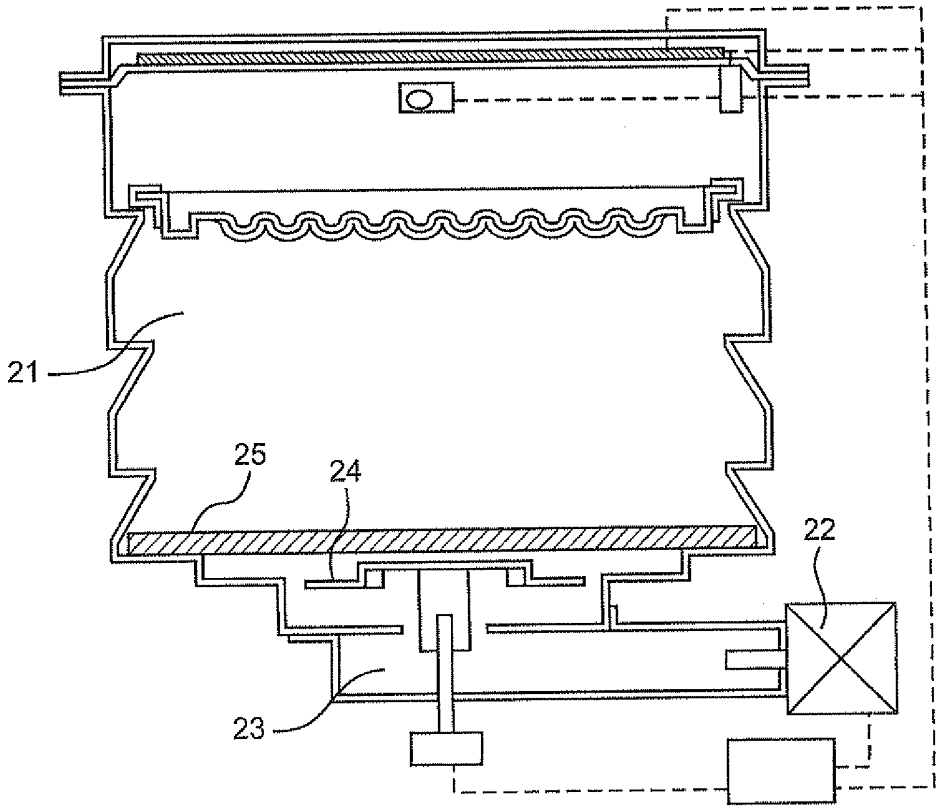


Fig.30



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2011/006487

A. CLASSIFICATION OF SUBJECT MATTER
H05B6/72(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, 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	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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.
Y	JP 2004-335304 A (Matsushita Electric Industrial Co., Ltd.), 25 November 2004 (25.11.2004), paragraphs [0016] to [0022]; fig. 1, 2 & US 2008/0087662 A1 & US 2006/0289526 A1 & EP 1619933 A & WO 2004/098241 A	1-19
Y	JP 2000-30853 A (LG Electronics Inc.), 28 January 2000 (28.01.2000), paragraphs [0016] to [0045]; fig. 4 to 20 & US 6097018 A & EP 949847 A & KR 10-0304810 B1 & KR 10-2000-0008418 A & KR 10-2000-0008419 A & CN 1231397 A	1-19

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

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Date of the actual completion of the international search	Date of mailing of the international search report
27 December, 2011 (27.12.11)	10 January, 2012 (10.01.12)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/006487

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2005-268624 A (Sumitomo Osaka Cement Co., Ltd.), 29 September 2005 (29.09.2005), paragraphs [0021] to [0028]; fig. 4 (Family: none)	6-13
Y	JP 61-294790 A (Toshiba Corp.), 25 December 1986 (25.12.1986), page 2, upper left column, line 19 to page 4, upper right column, line 7; fig. 1 to 6 (Family: none)	6-13
Y	JP 2004-257725 A (Matsushita Electric Industrial Co., Ltd.), 16 September 2004 (16.09.2004), paragraphs [0032] to [0052]; fig. 1 to 10 & US 2005/0211705 A1 & CA 2496186 A	16-19

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP S62064093 B **[0006] [0008]**
- US 4301347 A **[0007] [0008]**
- JP 2007225186 A **[0008] [0284]**