

DESCRIPTION

Title of Invention

HIGH-FREQUENCY HEATING APPARATUS

Technical Field

5 [0001]

The present invention substantially relates to high-frequency heating apparatuses, and particularly relates to a high-frequency heating apparatus that prevents uneven heating of a heating target.

Background Art

10 [0002]

There has been proposed a conventional high-frequency heating apparatus that "includes a heating chamber that accommodates a heating target, a high-frequency oscillator that generates a high-frequency wave for heating the heating target in the heating chamber, a waveguide that guides the high-frequency wave generated by the high-frequency oscillator, and an antenna that diffuses the high-frequency wave having propagated through the waveguide into the heating chamber, wherein the antenna includes a plate that emits the high-frequency wave, and an antenna shaft that has an end disposed in the waveguide and the other end connected to the plate such that the high-frequency wave in the waveguide propagates to the plate, and wherein the plate and the antenna shaft are connected to each other with two conductive paths branching from the upper part of the antenna shaft" (see, for example, Patent Literature 1).

Citation List

Patent Literature

25 [0003]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2009-170335 (Page 3, Figs. 3 and 4)

Summary of Invention

Technical Problem

30 [0004]

A high-frequency heating apparatus disclosed in Patent Literature 1 includes a substantially rectangular solid heating chamber, a high-frequency oscillator that generates a high-frequency wave, a waveguide through which the high-frequency wave propagates, and an antenna that causes the high-frequency wave in the waveguide to propagate into the heating chamber. A high-frequency transmission plate is disposed on the upper surface of the antenna. The high-frequency transmission plate serves as a plate for protecting the antenna as well as a plate on which a heating target is placed.

[0005]

The antenna includes a plate section that emits a high-frequency wave, and an antenna shaft that has an end disposed in the waveguide and the other end connected to the plate such that the high-frequency wave in the waveguide propagates to the plate. The plate and the antenna shaft are connected to each other with two conductive paths branching from the upper part of the antenna shaft. With this antenna configuration, it is possible to emit an intense electric field into a large area on the antenna plate, thereby achieving a certain level of effect in relatively evenly heating the heating target.

[0006]

However, since a high current tends to flow from the waveguide through the antenna shaft to the conductive path portions that are connected to the plate section which emits the high-frequency wave, the microwave radiation characteristics are more intense at the conductive path portions than at the plate section. As a result, the area directly above the conductive paths located at the center of the heating chamber might be excessively heated. Further, deterioration such as oxidation of metal might be accelerated due to resistance heat generated in the conductive path portions.

[0007]

The present invention has been made to overcome the above problems, and aims to provide a high-frequency heating apparatus capable of causing a high-

frequency wave generated by a high-frequency oscillator to more uniformly propagate into a heating chamber.

Solution to Problem

[0008]

5 A high-frequency heating apparatus according to the present invention includes a heating chamber that accommodates a heating target, a high-frequency oscillator that generates a high-frequency wave for heating the heating target, a waveguide that guides the high-frequency wave generated by the high-frequency oscillator, an antenna shaft that causes the high-frequency wave in the waveguide to propagate, a
10 plate-shaped antenna that is coupled to the antenna shaft, is arranged substantially parallel to a bottom of the heating chamber, and is configured to diffuse the high-frequency wave into the heating chamber, and rotary drive means that rotates the antenna through the antenna shaft. The antenna includes a first antenna in which an opening as a first radiation part is formed in a conductor section coupled to the
15 antenna shaft, first and second conductive paths branching from the first antenna, and a second antenna that has a plate section as a second radiation part which is connected to the first conductive path and the second conductive path.

Advantageous Effects of Invention

[0009]

20 According to the present invention, the first conductive path and the second conductive path are connected from the antenna shaft serving as a feeder through the first antenna having the first radiation part. Accordingly, it is possible to prevent concentration of the electric field on the first conductive path and the second conductive path, and thus to prevent deterioration of the conductive paths.

25 Further, an electric field having a high intensity is radiated from the first radiation part into a relatively small area, while an electric field having an intermediate intensity is radiated from the second radiation part into a relatively large area. Therefore, it is possible to cause the high-frequency wave generated by the high-frequency oscillator to more uniformly propagate into the heating chamber.

30 Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a schematic cross-sectional view illustrating main components of a heating cooker according to Embodiment.

[Fig. 2] Fig. 2 is a perspective view illustrating main components of the heating
5 cooker according to Embodiment.

[Fig. 3] Fig. 3 is a perspective view illustrating main components at the bottom of a heating chamber of the heating cooker according to Embodiment.

[Fig. 4] Fig. 4 is a top view illustrating an antenna of the heating cooker according to Embodiment.

[Fig. 5] Fig. 5 is a top view illustrating the antenna of the heating cooker according to Embodiment.

[Fig. 6] Fig. 6 is a schematic diagram illustrating high-frequency propagation on the antenna of the heating cooker according to Embodiment.

[Fig. 7] Fig. 7 is a transition diagram of a surface current on an antenna plate of
15 the heating cooker according to Embodiment.

[Fig. 8] Fig. 8 is a schematic diagram illustrating electric field distribution during rotation of the antenna according to Embodiment.

[Fig. 9] Fig. 9 is a top view illustrating another antenna according to Embodiment.

[Fig. 10] Fig. 10 is a top view illustrating an antenna of a conventional heating
20 cooker.

Description of Embodiments

[0011]

Embodiment

25 In Embodiment, a heating cooker for use at home or other locations will be described as an example of a high-frequency heating apparatus.

Fig. 1 is a schematic cross-sectional view illustrating main components of a heating cooker according to Embodiment. Fig. 2 is a perspective view illustrating main components of the heating cooker according to Embodiment. Fig. 3 is a
30 perspective view illustrating main components at the bottom of a heating chamber of

the heating cooker according to Embodiment. An antenna shown in Fig. 3 has a configuration characteristic to the heating cooker of Embodiment.

[0012]

As illustrated in Fig. 1, a heating chamber 2 is provided inside a main body 1 of the heating cooker. A door 4 and an operation panel 3 are provided on the front of the main body 1.

The heating chamber 2 is a substantially rectangular solid casing that is open at the front. A high-frequency transmission plate 6 is detachably disposed at the bottom of the heating chamber 2. The high-frequency transmission plate 6 serves as a plate on which a heating target 7 to be accommodated in the heating chamber 2 is placed. The high-frequency transmission plate 6 is made of, for example, ceramic that transmits a high-frequency wave. The operation panel 3 receives various input operations from the user, such as an instruction for starting a heating operation, the setting of the heating time, and the setting of the target heating temperature. The door 4 is openably attached to the main body 1, and is provided with a viewing window 5 that includes a perforated metal sheet held between glass panes. The cooked state of the heating target 7 accommodated in the heating chamber 2 may be observed through the viewing window 5.

[0013]

As illustrated in Fig. 2, a high-frequency oscillator 11 that generates a high-frequency wave for heating the heating target 7, and a waveguide 12 that guides the high-frequency wave generated by the high-frequency oscillator 11 into the heating chamber 2 are provided in the main body 1. The high-frequency oscillator 11 provided at the bottom of the heating chamber 2 of the main body 1 is a magnetron that generates a high-frequency wave.

[0014]

An antenna chamber 10 that accommodates an antenna 20 is formed between a bottom plate 9 of the heating chamber 2 and the high-frequency transmission plate 6. The antenna 20 diffuses the microwave generated by the high-frequency

oscillator 11 into the heating chamber 2. An antenna motor 23 for rotating the antenna 20 is attached to the antenna 20.

[0015]

A temperature detector 8 disposed in the heating chamber 2 may be, for example, an infrared sensor that measures the temperature of the heating target 7 on the basis of the infrared radiation from the heating target 7.

[0016]

The heating cooker includes a controller (not illustrated) including a control circuit that controls driving of the high-frequency oscillator 11, the antenna motor 23, and the like, on the basis of an input from the operation panel 3. This controller serves to control the output of the high-frequency oscillator 11 on the basis of the temperature detected by the temperature detector 8, and also serves to rotate and stop the antenna motor 23 at predetermined timings. Since the antenna 20 is rotated and stopped by the antenna motor 23, it is possible to vary the radiation state of a microwave onto the heating target 7, and thus to evenly and quickly heat the heating target 7.

[0017]

The following describes propagation of the high-frequency wave emitted from the high-frequency oscillator 11 through the antenna 20 to the heating target 7.

The magnetron serving as the high-frequency oscillator 11 generates a high-frequency wave of 2.45 GHz in the case of a home microwave oven, for example. A home microwave oven generates a high-frequency wave with power output of about 1,000 W through 200 W, for example.

The high-frequency wave generated by the high-frequency oscillator 11 propagates through the space in the hollow waveguide 12 formed of a conductor.

A shaft hole 12a and a shaft hole 9a are formed in the waveguide 12 and the bottom plate 9 of the heating chamber 2, respectively, at positions corresponding to each other. Thus, the high-frequency wave having propagated through the space in the waveguide 12 propagates through the shaft hole 12a and the shaft hole 9a into the heating chamber 2.

[0018]

However, it is not possible to efficiently direct the high-frequency wave into the heating chamber 2 by simply providing the shaft hole 12a and the shaft hole 9a. To address this issue, a conductive metal antenna shaft 22 coaxially coupled to a shaft of the antenna motor 23 is inserted through the shaft hole 12a and the shaft hole 9a, and the plate-shaped antenna 20 connected to an end of the antenna shaft 22 is disposed in the antenna chamber of the heating chamber 2. With this configuration, in the antenna shaft 22 of the antenna 20, the high-frequency wave propagating through the waveguide 12 is converted into a surface current. The converted current flows through the surface of the antenna 20. Along with a temporal change of the current due to a high frequency wave, a magnetic field is excited. Then, an electric field is generated by the magnetic field. The temporal changes of the magnetic field and electric field increase or decrease in accordance with the phase of the high-frequency wave, and thus an electromagnetic wave is radiated.

[0019]

That is, since a current flows through the surface of the antenna 20, the behavior of the high-frequency wave propagating from a plate section of the antenna 20 into the heating chamber 2 varies in accordance with the flow of the surface current due to the temporal change (phase change) of the high-frequency wave. Accordingly, the area of the plate from which the high-frequency wave is generated can be increased by increasing the area in which the current flows on the antenna surface and the temporal change of the current occurs. In this way, the transmission efficiency is improved by causing the high-frequency wave to propagate into the heating chamber 2 through the antenna shaft 22 and the antenna 20.

[0020]

The following describes an antenna of a conventional example. Fig. 10 is a top view illustrating the antenna of the conventional example. In the conventional example, there are two current paths branching from a shaft connection portion 66, which is a joint portion connected to an antenna shaft (not illustrated) serving as the current source to an antenna 60. The divided currents flow through a conductive

path 64 and a conductive path 65, respectively. The conductive path 64 extends from the shaft connection portion 66 in the lateral direction in the drawing and bends one time to reach an antenna plate 63. The conductive path 65 extends from the shaft connection portion 66 in the lateral direction in the drawing and bends two times to reach the antenna plate 63. The individual currents then meet on the disk-shaped antenna plate 63 illustrated in Fig. 10. In the conventional example, the high-frequency current flowing from the lower side in the drawing through the conductive path 64, and the high-frequency current flowing from the right side in the drawing through the conductive path 65 are combined in terms of vector, so that a variety of currents flow on the antenna plate 63, thereby achieving the effect of varying the distribution of a generated electromagnetic wave.

[0021]

However, it is found from the studies of the present invention that, in the case of the antenna of the conventional example, since the currents flow through the conductive paths 64 and 65 extending to the antenna plate 63, an electromagnetic wave having effects of a level that cannot be disregarded is generated.

The conductive paths 64 and 65 are narrow passages having a smaller surface area than the antenna plate 63. Since the surface area is small, the current tends to be relatively high. Therefore, the energy, which is emitted as an electromagnetic wave, per unit area (power density) is increased.

That is, the area directly above the antenna shaft serving as a feeder and the conductive paths 64 and 65 in the vicinity of the shaft is relatively easily heated, which result in uneven heating.

[0022]

The antenna 20 of Embodiment is configured in view of the conventional example described above. Fig. 4 is a top view of the antenna of the heating cooker according to Embodiment, and illustrates the structure of the antenna 20.

[0023]

First, the structure of the antenna 20 will be described.

As illustrated in Fig. 4, the antenna 20 is formed of a substantially plate-shaped conductor, and is connected to the antenna shaft 22. The antenna 20 is accommodated in the antenna chamber 10 in a manner such that the plate surface is parallel to the bottom surface of the heating chamber 2.

5 The antenna 20 includes two slot antennas 31 and 32 (collectively referred to as a first antenna), a disk-shaped antenna plate 41 (second antenna), a conductive path 42 (first conductive path) connecting the antenna plate 41 and the slot antenna 31, and a conductive path 43 (second conductive path) connecting the antenna plate 41 and the slot antenna 32. A shaft connection portion 21 is provided at the center of
10 the antenna 20 such that the antenna shaft 22 is vertically coupled thereto. The antenna 20 substantially horizontally rotates about the shaft connection portion 21 so as to evenly emit the high-frequency wave onto the heating target 7, and thus to achieve even heating.

[0024]

15 The slot antenna 31 and the slot antenna 32 have strip-shaped or arc-shaped slit apertures 31b and 32b (openings) in conductor sections 31a and 32a, respectively. In the slot antennas 31 and 32, the slit apertures 31b and 32b serve as radiation parts for radiating high-frequency waves. Especially, in the case where the length of the slit apertures 31b and 32b is approximately $1/2$ the wavelength in use,
20 resonance occurs, so that a strong high-frequency wave can be radiated. The outline of each of the slot antennas 31 and 32 has the shape of a sector, and the conductive paths 42 and 43 are respectively connected to sides 31c and 32c each corresponding to the radius of the sector. Further, in Embodiment, the two slot antennas 31 and 32 are symmetrically arranged with respect to the shaft connection
25 portion 21 located at the center of the antenna 20.

[0025]

The antenna plate 41 is a radiation part capable of radiating a high-frequency wave as described below. In Embodiment, the antenna plate 41 has the shape of a disk, and is disposed in a substantially sector-shaped region between the slot
30 antenna 31 and the slot antenna 32 on the same plane. The diameter of the

antenna plate 41 is slightly less than the length of the side 31c of the slot antenna 31. The antenna plate 41 is connected to the first antenna with the conductive path 42 and the conductive path 43 branching from the first antenna. In Embodiment, the antenna plate 41 is connected to one slot antenna 31 with the conductive path 42, and is connected to the other slot antenna 32 with the conductive path 43.

[0026]

The conductive path 42 and the conductive path 43 are connected to the antenna plate 41 on the same plane at positions shifted by approximately 90 degrees with respect to the center of the antenna plate 41. Further, a distance L2 from a connection point 43a between the conductive path 43 and the antenna plate 41 to the shaft connection portion 21 is greater than a distance L1 from a connection point 42a between the conductive path 42 and the antenna plate 41 to the shaft connection portion 21. Due to this configuration, in Embodiment, when a connection point between the side 31c of the slot antenna 31 and the conductive path 42 is referred to as a connection point 42b and a connection point between the side 32c of the slot antenna 32 and the conductive path 43 is referred to as a connection point 43b, the distance from the connection point 42b to the shaft connection portion 21 is less than the distance from the connection point 43b to the shaft connection portion 21.

[0027]

The antenna plate 41 is disposed in a sector-shaped region between the substantially sector-shaped slot antenna 31 and slot antenna 32. The conductive path 42 connecting the antenna plate 41 and the slot antenna 31 and the conductive path 43 connecting the antenna plate 41 and the slot antenna 32 are connected to the sides 31c and 32c of the slot antennas 31 and 32, respectively. With this positional relationship, the conductive paths 42 and 43 can be formed to extend linearly without any bend, so that the path length of the conductive paths 42 and 43 can be reduced.

[0028]

Next, the functions of the antenna 20 will be described. Fig. 5 is a top view of the antenna according to Embodiment, and illustrates the functions of the antenna 20. Fig. 6 is a schematic diagram illustrating high-frequency propagation on the antenna

of the heating cooker according to Embodiment. Fig. 7 is a transition diagram of a surface current on an antenna plate of the heating cooker according to Embodiment.

The functions of the antenna 20 will be described with reference to Figs. 5, 6, and 7.

5 [0029]

As illustrated in Fig. 6, high-frequency waves are emitted from the slot antennas 31 and 32 as linearly-polarized waves 100 on a plane that passes the slit apertures 31b and 32b. The slit apertures 31b and 32b that radiate these high-frequency waves are referred to as first radiation parts 30. Then, regions above the slot antennas 31 and 32 are referred to as intense electric field regions F (see Fig. 5) that have intense electric fields. In Embodiment, since the slot antennas 31 and 32 capable of radiating high-frequency waves are provided at two locations, it is possible to improve the radiation efficiency of the antenna 20, and to improve the efficiency of heating the heating target 7.

15 [0030]

Next, electric field radiation from the antenna plate 41 will be described.

Supposing that the conductive paths 42 and 43 are the current sources for the antenna plate 41, since the geometrical positions of the current sources are shifted by 90 degrees, the vector of the surface current greatly varies on the antenna plate 41. Thus, high-frequency waves can be radiated in various directions.

20

Further, high-frequency waves to be introduced onto the antenna plate 41 are arranged so as to have different distances (L_1 , L_2) from the antenna shaft 22 as an introduction position. Thus, currents having a phase shift of 90 degrees can be introduced. Then, the introduced currents are combined, so that a circularly-polarized wave 101 can be generated that is capable of annularly radiating a high electric field. This antenna plate 41 is referred to as a second radiation part 40.

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[0031]

In the following, the principle of generation of a circularly-polarized wave will be described with reference to Fig. 7. Fig. 7 illustrates the currents flowing on the antenna plate 41. In Fig. 7, the currents flowing on the antenna plate 41 are

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indicated by the solid lines, and the currents flowing into and flowing out the respective conductive paths are indicated by the broken lines. The magnitude of the currents is indicated by the length of the broken lines.

[0032]

5 The currents excited by the high-frequency wave oscillate such that the flow direction is reversed at 90 degrees phase intervals. For example, at the phase of 0 degrees, a large amount of incident current flows downward from the conductive path 43 extending from the lower side in the drawing. However, as the phase increases to 22.5 degrees and then to 45 degrees, the amount of current decreases. Then, the
10 flow direction of the current starts to be reversed. At the phase of 90 degrees, the current has the same amount as that of the phase of 0 degrees, and flows in the direction opposite to that of the phase of 0 degrees.

[0033]

15 The current flowing from the lower side and the current flowing from the right side in the drawing are combined. As indicated by the solid lines, the flow direction of the resultant current is gradually changed on the antenna plate 41 as the phase changes. As a result, the direction of the current flowing on the antenna plate 41 is rotated by 360 degrees while the phase is shifted by 180 degrees.

20 That is, the electromagnetic wave generated in the vertical direction in the drawing due to the movement of the current moves annularly on the high-electric-field portion in accordance with the phase.

[0034]

25 As illustrated in Fig. 6, with the circularly-polarized wave 101 emitted from the antenna plate 41, it is possible to emit a high-frequency wave having an intermediate level of energy which is slightly lower than the energy emitted from the slot antenna 31. This high-frequency wave tends to be relatively strong especially at the edge of the antenna plate 41 where the current flows easily. The outer peripheral edge of the disk section of the antenna plate 41 is referred to as an intermediate electric field region G having an intermediate electric field intensity (see Fig. 5).

It is to be noted that, upon shifting the phase of the current flowing onto the antenna plate 41 by 90 degrees, the position and length of the conductive paths 42 and 43 may be changed in accordance with analysis and verification using electromagnetic field simulation software or the like, for example.

5 [0035]

Fig. 8 is a schematic diagram illustrating electric field distribution during rotation of the antenna according to Embodiment. The electric field distribution during rotation of the antenna 20 will be described with reference to Fig. 5 and Fig. 8.

10 First, as illustrated in Fig. 5, the loci of the centers of the intense electric field regions F of the slot antennas 31 and 32 of the rotating antenna 20 are indicated by a locus C. Further, the loci of the portions in the vicinity of the outer edge and the inner edge of the intermediate electric field G of the antenna plate 41 of the rotating antenna 20 are referred to as a locus D and a locus E, respectively.

[0036]

15 As illustrated in Fig. 8, when the antenna 20 rotates, the electric field intensity of the region of the locus C is increased by the intense electric field regions F, so that the electric field intensity of the portions directly above the slot antennas 31 and 32 tend to be increased concentrically. Accordingly, the heating target 7 placed directly above the slot antennas 31 and 32 in the close proximity of the antenna 20 is heated
20 in the same manner. Further, when the antenna 20 rotates, the electric field intensity of the region between the locus D and the locus E is increased by the intermediate electric field region G, so that the electric field intensity of the portion directly above the antenna plate 41 tends to be increased concentrically.

[0037]

25 In this way, when the antenna 20 rotates, a relatively small annular electric field region F1 is formed by the intense electric field regions F, and a relatively large annular electric field region G1 is formed by the intermediate electric field region G. Since the areas and positions of the intense electric field regions F and the intermediate electric field region G differ from each other, although the annular electric
30 field region F1 formed by the intense electric field regions F overlap the annular

electric field region G1 formed by the intermediate electric field region G, the electric field region F1 and the electric field region G1 do not coincide with each other. The electric field is emitted to a rotating area directly above the antenna 20 from the circular locus D and locus E in addition to the locus C, so that an electric field is emitted from a large area of the rotating region of the antenna 20. Since the electric field is emitted from a large area, it is possible to effectively and uniformly increase the temperature of the heating target 7. For example, in the case where only the slot antennas 31 and 32 are provided, there are no heating element in locations out of the locus C, and hence heating is relatively weak. On the other hand, in Embodiment, since the antenna plate 41 is provided as a second radiation part, it is possible to achieve more even heating, compared with the case in which only the slot antennas 31 and 32 are provided.

[0038]

As described above, according to Embodiment, the antenna 20 includes the slot antennas 31 and 32 in which the slit apertures 31b and 32b as the first radiation parts 30 are formed in the respective conductor sections 31a and 32a coupled to the antenna shaft 22, the conductive paths 42 and 43 branching from the respective slot antennas 31 and 32, and a second antenna that has the antenna plate 41 as a second radiation part which is connected to the conductive paths 42 and 43.

In Embodiment, since the conductive paths 42 and 43 are connected from the antenna shaft 22 serving as a feeder through the first antenna (slot antennas 31 and 32), the conductive paths 42 and 43 are shorter than the conductive paths 64 and 65 of the antenna of the conventional example. Therefore, there is almost no electric radiation from these portions, so that the problem of local intense heating can be prevented. Accordingly, it is possible to prevent concentration of the electric field on the conductive path 42 and the conductive path 43, and thus to prevent deterioration of the conductive paths 42 and 43.

[0039]

Further, electric fields having a high intensity are radiated from the slot antennas 31 and 32 connected to the antenna shaft 22 into relatively small areas

above the slit apertures 31b and 32b, while an electric field having an intermediate intensity is radiated from the antenna plate 41 into a relatively large area. In this way, since the radiation parts of different electric field intensities are provided, it is possible to vary the intensity of electric field radiation on the antenna 20. For example, it is possible to vary the intensity of electric field radiation on the antenna 20 when the areas of electric field radiation of the first radiation parts 30 and the second radiation part 40 are different. Further, it is possible to make the intensity of electric field radiation on the antenna 20 more even, by adjusting the area and arrangement of the first radiation parts 30 and the second radiation part 40.

[0040]

Further, since the two slot antennas 31 and 32 are provided, the center of gravity during rotation is stabilized. This reduces wobbling of the flat section of the antenna 20, and stabilizes the operation. Further, the slot antennas 31 and 32 are symmetrically arranged with respect to the shaft connection portion 21 located at the center of the antenna 20. With this configuration, the distance between the slot antenna 31 and the slot antenna 32 can be increased. Therefore, it is possible to reduce the interaction between the high-frequency waves radiated from the slot antennas 31 and 32, and to achieve effective radiation of high-intensity waves from the slot antennas 31 and 32. That is, with the two slot antennas 31 and 32, it is possible to stabilize the center of gravity and to achieve effective emission of high-frequency waves.

[0041]

Further, in Embodiment, the locus of the first radiation parts 30 and the locus of the second radiation part 40 of the rotating antenna 20 are different from each other. That is, as illustrated in Fig. 8, the annular electric field region F1 formed by the intense electric field regions F of the first radiation parts 30 overlap the annular electric field region G1 formed by the intermediate electric field region G of the second radiation part 40. However, these electric field regions do not coincide with each other. Therefore, it is possible to radiate an electric field into a large area on the antenna 20, and therefore to prevent uneven heating.

[0042]

Further, in Embodiment, the second radiation part 40 radiates a circularly-polarized wave whose electric field vector changes periodically. Therefore, microwaves may be incident on the heating target 7 from various directions. This increases the effect of preventing uneven heating.

[0043]

In the above Embodiment, the slit aperture 31b and the slit aperture 32b are arranged on the same radius. However, the slit aperture 31b and the slit aperture 32b may be arranged in positions shifted in the radial direction. In this case, since the slit aperture 31b and the slit aperture 32b need to have the same slit length, the angles of the sectors are different from each other. However, this increases the effect of preventing uneven heating.

Further, in order to maintain the weight balance, the radial length of the slit aperture having a sector shape of a greater angle may be less than the radial length of the other slit aperture.

[0044]

Further, in the above Embodiment, two slot antennas 31 and 32 are provided. However, only one slot antenna (first antenna) may be provided. Fig. 9 is a top view illustrating another antenna according to Embodiment. In comparing an antenna 20 of Fig. 9 and the antenna 20 of Fig. 4, the antenna 20 of Fig. 9 is different in not having a slit aperture 31b. For example, if heating is excessive when two slot antennas are provided, one slot antenna 32 may be provided as illustrated in Fig. 9 such that a high-frequency wave is radiated only from a slit aperture 32b. Thus, more even heating may be provided. Alternatively, three or more slot antennas may be provided. Further, a plurality of openings may be provided in one slot antenna (first antenna) so as to form a plurality of radiation parts. Further, a plurality of second radiation parts may be provided.

[0045]

It is to be noted that high-frequency heating of the present invention may be employed in combination with a radiant heater (not illustrated) as a heating device

which may be provided on the top surface of the heating chamber, a hot-air heater which may be provided on the rear surface, or a steam generator. Further, heating control including interruption of power supply may be performed in accordance with the finished state of the heating target with use of a temperature detector which may be provided in the heating chamber.

Reference Signs List

[0046]

1 main body; 2 heating chamber; 3 operation panel; 4 door; 5 viewing window; 6 high-frequency transmission plate; 7 heating target; 8 temperature detector; 9 bottom plate; 9a shaft hole; 10 antenna chamber; 11 high-frequency oscillator; 12 waveguide; 12a shaft hole; 20 antenna; 21 shaft connection portion; 22 antenna shaft; 23 antenna motor; 30 first radiation part; 31 slot antenna; 31a conductor section; 31b slit aperture; 31c side; 32 slot antenna; 32a conductor section; 32b slit aperture; 32c side; 40 second radiation part; 41 antenna plate; 42 conductive path; 42a connection point; 42b connection point; 43 conductive path; 43a connection point; 43b connection point; 100 linearly-polarized wave; and 101 circularly-polarized wave.

[Claim 1]

A high-frequency heating apparatus comprising:

- a heating chamber that accommodates a heating target;
- a high-frequency oscillator that generates a high-frequency wave for heating the heating target;
- a waveguide that guides the high-frequency wave generated by the high-frequency oscillator;
- an antenna shaft that causes the high-frequency wave in the waveguide to propagate;
- a plate-shaped antenna that is coupled to the antenna shaft, is arranged substantially parallel to a bottom of the heating chamber, and is configured to diffuse the high-frequency wave into the heating chamber; and
- rotary drive means that rotates the antenna through the antenna shaft;

wherein the antenna includes

- a first antenna in which an opening as a first radiation part is formed in a conductor section coupled to the antenna shaft,
 - first and second conductive paths branching from the first antenna, and
 - a second antenna being a plate antenna that has a plate section as a second radiation part which is connected to the first conductive path and the second conductive path, receives power via the antenna shaft, the conductor section of the first antenna, and the first and second conductive paths, and radiates a circularly-polarized wave.

[Claim 2]

The high-frequency heating apparatus of claims 1, wherein:

- at least two of the first antennas are coupled to the antenna shaft, and
- the first conductive path is connected to either one of the first antennas, and the second conductive path is connected to the other one of the first antennas.

[Claim 3]

A high-frequency heating apparatus comprising:

- a heating chamber that accommodates a heating target;

a high-frequency oscillator that generates a high-frequency wave for heating the heating target;

a waveguide that guides the high-frequency wave generated by the high-frequency oscillator;

an antenna shaft that causes the high-frequency wave in the waveguide to propagate;

a plate-shaped antenna that is coupled to the antenna shaft, is arranged substantially parallel to a bottom of the heating chamber, and is configured to diffuse the high-frequency wave into the heating chamber; and

rotary drive means that rotates the antenna through the antenna shaft;

wherein the antenna includes

a first antenna in which an opening as a first radiation part is formed in a conductor section coupled to the antenna shaft,

first and second conductive paths branching from the first antenna, and

a second antenna that has a plate section as a second radiation part which is connected to the first conductive path and the second conductive path, wherein

a pair of the first antennas that are symmetric with respect to a joint portion connected to the antenna shaft are provided, and

the first conductive path is connected to one of the first antennas, and the second conductive path is connected to the other one of the first antennas.

[Claim 4]

The high-frequency heating apparatus of any one of claims 1 through 3, wherein a rotation locus defined by the first radiation part upon rotating the antenna shaft is different from a rotation locus defined by the second radiation part.

[Claim 5]

The high-frequency heating apparatus of any one of claims 1 through 4, wherein either one of or both the first radiation part and the second radiation part include plural of the first radiation parts and plural of the second radiation parts, respectively.

[Claim 6]

The high-frequency heating apparatus of any one of claims 1 through 5, wherein a distance from a joint portion connected to the antenna shaft to a connection point between the plate section and the first conduction path is different from a distance from the joint portion connected to the antenna shaft to a connection point between the plate section and the second conduction path.

[Claim 7]

The high-frequency heating apparatus of any one of claims 1 through 6, wherein the first conductive path and the second conductive path are connected at positions that are geometrically shifted by 90 degrees with respect to a center of the plate section.

[Claim 8]

The high-frequency heating apparatus of any one of claims 1 through 7, wherein a phase of a high-frequency wave that is incident on the second radiation part from the first conductive path and a phase of a high-frequency wave that is incident on the second radiation part from the second conductive path are shifted by approximately 90 degrees.