(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 481 150 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.05.2019 Bulletin 2019/19

(21) Application number: **17819947.7**

(22) Date of filing: **20.06.2017**

(51) Int Cl.:
H05B 6/74 *(2006.01)* ***H05B 6/70*** *(2006.01)*

(86) International application number:
PCT/JP2017/022618

(87) International publication number:
WO 2018/003588 (04.01.2018 Gazette 2018/01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **30.06.2016 JP 2016129562**
30.06.2016 JP 2016129564

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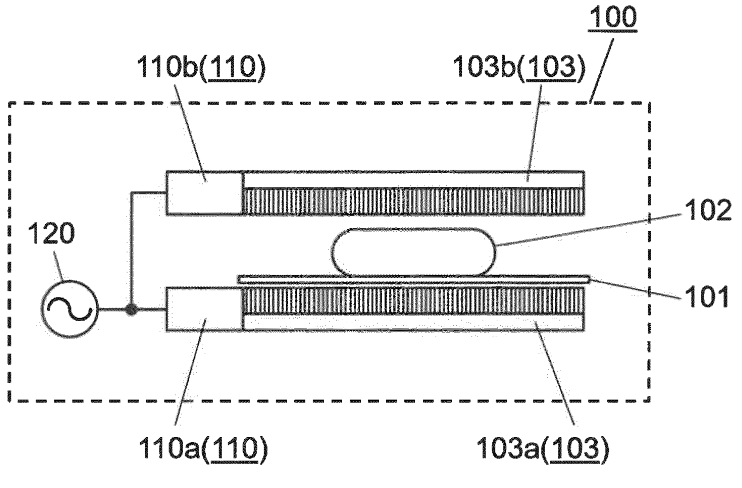
(54) **HIGH-FREQUENCY HEATING DEVICE**

(57) High-frequency heating device (100) includes first surface wave excitation body (103a), second surface wave excitation body (103b), first high-frequency power supply unit (110a), second high-frequency power supply unit (110b), and high-frequency power generation unit (120). First and second surface wave excitation bodies (103a) and (103b) are disposed at locations opposite to each other such that heating-target object (102) is put between the surface wave excitation bodies. This configuration provides high-frequency heating device (100) capable of heating and browning two faces of heating-target object (102) without using a heater or other heating sources.

FIG. 1



Printed by Jouve, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present invention relates to a high-frequency heating device equipped with a surface wave excitation body having a periodical structure.

BACKGROUND ART

[0002] Such a conventional technique is disclosed that relates to a high-frequency heating device configured to supply high-frequency power to a surface wave excitation body having a periodical structure to heat a heating-target object, such as a food product (e.g., see PTL 1 and PTL 2).

[0003] Surface waves are characterized as being capable of intensely heating a side near a surface wave excitation body. PTL 1 discloses a high-frequency heating device that, by making use of this characteristic, browns a surface of a food product by microwaves sent to a surface wave transmission line.

[0004] PTL 2 discloses a heating cooker having a surface wave excitation body and a radiant heat source opposed to the surface wave excitation body. The heating cooker browns an upper surface of a food product by heating the food product with the radiant heat source.

[0005] Specifically, the high-frequency heating device of PTL 1 intensely heats a zone near the surface wave excitation body owing to the surface wave characteristic and thus can sufficiently heat a food product with a relatively small thickness. Unfortunately, heating by the high-frequency heating device decreases with an increase in distance from the surface wave excitation body and thus may be insufficient for a thick food product. It is difficult to brown a side of a food product remote from the surface wave excitation body irrespective of food thickness.

[0006] The heating cooker of PTL 2 has the radiant heat source opposed to the surface wave excitation body and uses radiant heating to compensate for a zone that is not sufficiently heated by surface wave heating. This configuration enables the heating cooker to heat an entire food product using surface wave excitation and the radiant heat source. The heating cooker can also brown a side of a food product remote from the surface wave excitation body using the radiant heat source. Unfortunately, the heating cooker described above has a complicated structure due to the necessity of having two types of heating sources and hence requires a large amount of electricity.

Citation List

Patent Literature

[0007]

PTL 1: Unexamined Japanese Utility Model Publication No. 56-98

PTL 2: Unexamined Japanese Patent Publication No. H08-210653

SUMMARY OF THE INVENTION

[0008] The present invention provides a high-frequency heating device having a simple configuration and being capable of heating two faces of a heating-target object without using a heater or other heating sources.

[0009] In other words, a high-frequency heating device according to the present invention includes a high-frequency power generation unit configured to generate high-frequency power, a plurality of surface wave excitation bodies configured to propagate the high-frequency power as respective surface waves to heat a heating-target object, a high-frequency power supply unit configured to supply the high-frequency power to the plurality of surface wave excitation bodies, and a stand on which the heating-target object is mounted. The plurality of the surface wave excitation bodies are disposed at locations opposite to each other such that the heating-target object is put between the plurality of surface wave excitation bodies.

[0010] According to this configuration, the high-frequency power is supplied to the plurality of the surface wave excitation bodies, which are disposed opposite to each other such that the heating-target object is put between the surface wave excitation bodies. The high-frequency heating device heats the heating-target object by the high-frequency power propagating as surface waves along the respective surface wave excitation bodies. As a result, the high-frequency heating device having a simple configuration can heat two faces of the heating-target object without using a heater or other heating sources that consume a large quantity of electricity.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

FIG. 1 is a block diagram illustrating a basic configuration of a high-frequency heating device according to a first exemplary embodiment.

FIG. 2 is a block diagram illustrating a configuration of a high-frequency power supply unit in the high-frequency heating device.

FIG. 3A is a drawing illustrating an action performed by the high-frequency heating device according to the first exemplary embodiment.

FIG. 3B is a drawing illustrating an action performed by the high-frequency heating device according to the first exemplary embodiment.

FIG. 3C is a drawing illustrating an action performed by a high-frequency heating device according to the first exemplary embodiment.

FIG. 4 is a block diagram illustrating a basic configuration of a high-frequency heating device according to a second exemplary embodiment.

FIG. 5 is a drawing illustrating an action performed by the high-frequency heating device according to the second exemplary embodiment.

FIG. 6 is a block diagram illustrating a basic configuration of a high-frequency heating device according to a third exemplary embodiment.

FIG. 7 is a drawing illustrating an action performed by the high-frequency heating device according to the third exemplary embodiment.

FIG. 8A is a graph illustrating a change in a degree of surface concentration of electric field in response to a change in frequency of high-frequency power.

FIG. 8B is a graph illustrating a change in a degree of surface concentration of electric field in response to a change in frequency of high-frequency power.

FIG. 8C is a graph illustrating a change in a degree of surface concentration of electric field in response to a change in frequency of high-frequency power.

FIG. 9 is a block diagram illustrating a basic configuration of a high-frequency heating device according to a fourth exemplary embodiment.

FIG. 10 is a drawing illustrating action of surface wave excitation bodies in the high-frequency heating device to heat a heating-target object.

FIG. 11A is a graph illustrating a change in a degree of surface concentration of electric field, with a relationship formed between a frequency of high-frequency power and an exciting frequency of the surface wave excitation body according to the fourth exemplary embodiment.

FIG. 11B is a graph illustrating a change in a degree of surface concentration of electric field, with a relationship formed between a frequency of high-frequency power and an exciting frequency of the surface wave excitation body according to the fourth exemplary embodiment.

FIG. 11C is a graph illustrating a change in a degree of surface concentration of electric field, with a relationship formed between a frequency of high-frequency power and an exciting frequency of the surface wave excitation body according to the fourth exemplary embodiment.

FIG. 12A is a drawing illustrating a change in a field intensity distribution, with a relationship formed between a frequency of high-frequency power and an exciting frequency of the surface wave excitation body according to the fourth exemplary embodiment.

FIG. 12B is a drawing illustrating a change in a field intensity distribution, with a relationship formed between a frequency of high-frequency power and an exciting frequency of the surface wave excitation body according to the fourth exemplary embodiment.

FIG. 12C is a drawing illustrating a change in a field intensity distribution, with a relationship formed between a frequency of high-frequency power and an exciting frequency of the surface wave excitation body according to the fourth exemplary embodiment.

FIG. 13A is a drawing illustrating a change in a field intensity distribution, with a relationship formed between a frequency of high-frequency power supplied to opposed surface wave excitation bodies and excitation frequencies of the surface wave excitation bodies according to the fourth exemplary embodiment.

FIG. 13B is a drawing illustrating a change in a field intensity distribution, with a relationship formed between a frequency of high-frequency power supplied to opposed surface wave excitation bodies and excitation frequencies of the surface wave excitation bodies according to the fourth exemplary embodiment.

FIG. 13C is a drawing illustrating a change in a field intensity distribution, with a relationship formed between a frequency of high-frequency power supplied to opposed surface wave excitation bodies and excitation frequencies of the surface wave excitation bodies according to the fourth exemplary embodiment.

FIG. 13D is a drawing illustrating a change in a field intensity distribution, with a relationship formed between a frequency of high-frequency power supplied to opposed surface wave excitation bodies and excitation frequencies of the surface wave excitation bodies according to the fourth exemplary embodiment.

FIG. 13E is a drawing illustrating a change in a field intensity distribution, with a relationship formed between a frequency of high-frequency power supplied to opposed surface wave excitation bodies and excitation frequencies of the surface wave excitation bodies according to the fourth exemplary embodiment.

FIG. 14 is a block diagram illustrating a basic configuration of a high-frequency heating device according to a fifth exemplary embodiment.

FIG. 15 is a drawing illustrating an action performed by the high-frequency heating device according to the fifth exemplary embodiment.

FIG. 16A is a drawing illustrating a heating action performed by the high-frequency heating device according to the fifth exemplary embodiment, with a relationship formed between a frequency of supplied high-frequency power and each of exciting frequencies of surface wave excitation bodies.

FIG. 16B is a drawing illustrating a heating action performed by the high-frequency heating device according to the fifth exemplary embodiment, with a relationship formed between a frequency of supplied high-frequency power and each of exciting frequencies of surface wave excitation bodies.

FIG. 16C is a drawing illustrating a heating action performed by the high-frequency heating device according to the fifth exemplary embodiment, with a relationship formed between a frequency of supplied high-frequency power and each of exciting frequencies of surface wave excitation bodies.

FIG. 16D is a drawing illustrating a heating action performed by the high-frequency heating device according to the fifth exemplary embodiment, with a relationship formed between a frequency of supplied high-frequency power and each of exciting frequencies of surface wave excitation bodies.

FIG. 16E is a drawing illustrating a heating action performed by the high-frequency heating device according to the fifth exemplary embodiment, with a relationship formed between a frequency of supplied high-frequency power and each of exciting frequencies of surface wave excitation bodies.

FIG. 17 is a block diagram illustrating a basic configuration of a high-frequency heating device according to a sixth exemplary embodiment.

FIG. 18 is a drawing illustrating an action performed by the high-frequency heating device according to the sixth exemplary embodiment.

FIG. 19A is a drawing illustrating a heating action performed by the high-frequency heating device according to the sixth exemplary embodiment, with a relationship formed between frequencies of supplied high-frequency power and exciting frequencies of surface wave excitation bodies.

FIG. 19B is a drawing illustrating a heating action performed by the high-frequency heating device according to the sixth exemplary embodiment, with a relationship formed between frequencies of supplied high-frequency power and exciting frequencies of surface wave excitation bodies.

FIG. 19C is a drawing illustrating a heating action performed by the high-frequency heating device according to the sixth exemplary embodiment, with a relationship formed between frequencies of supplied high-frequency power and exciting frequencies of surface wave excitation bodies.

FIG. 19D is a drawing illustrating a heating action performed by the high-frequency heating device according to the sixth exemplary embodiment, with a relationship formed between frequencies of supplied high-frequency power and exciting frequencies of surface wave excitation bodies.

FIG. 19E is a drawing illustrating a heating action performed by the high-frequency heating device according to the sixth exemplary embodiment, with a relationship formed between frequencies of supplied high-frequency power and exciting frequencies of surface wave excitation bodies.

DESCRIPTION OF EMBODIMENTS

[0012] Some exemplary embodiments of the present invention will be described below with reference to the accompanying drawings. It should be noted that those exemplary embodiments are not intended to limit the present invention.

(First exemplary embodiment)

[0013] With reference to FIG. 1, high-frequency heating device 100 according to a first exemplary embodiment of the present invention will now be described.

[0014] FIG. 1 is a block diagram illustrating a basic configuration of high-frequency heating device 100 according to the first exemplary embodiment.

[0015] With reference to FIG. 1, high-frequency heating device 100 includes first surface wave excitation body 103a, second surface wave excitation body 103b, first high-frequency power supply unit 110a, second high-frequency power supply unit 110b, high-frequency power generation unit 120, and stand 101 on which heating-target object 102 is put. High-frequency heating device 100 heats heating-target object 102 put on stand 101.

[0016] First and second surface wave excitation bodies 103a and 103b are disposed at locations (e.g. upper and lower locations) opposite to each other such that heating-target object 102 is put between the surface wave excitation bodies. In this example, the excitation bodies are disposed at upper and lower locations, and description is given on condition that the first surface wave excitation body is disposed at a downward location while the second surface wave excitation body is disposed at an upward location. A top surface and an undersurface of the heating-target object are defined in the same way. This definition is similarly applied in subsequent exemplary embodiments.

[0017] High-frequency heating device 100 illustrated in FIG. 1 includes two surface wave excitation bodies, two high-frequency power supply units, and one high-frequency power generation unit, for example. However, a configuration of the high-frequency heating device is not limited to this example. The high-frequency heating device may include surface wave excitation bodies, high-frequency power supply units, and high-frequency power generation units in numbers that differ from the numbers described above. For example, the high-frequency heating device may include four surface wave excitation bodies such that a heating-target object is put between the excitation bodies at four sides (e.g. upper and lower sides and right and left sides). At least one set of a high-frequency power generation unit and a high-frequency power supply unit may be provided for one of the surface wave excitation bodies. Alternatively, the high-frequency heating device may include two or more sets of the high-frequency power generation unit and the high-frequency power supply unit.

[0018] With reference to FIG. 1, high-frequency heating device 100 supplies high-frequency power generated by one high-frequency power generation unit 120 to first surface wave excitation body 103a via first high-frequency power supply unit 110a and to second surface wave excitation body 103b via second high-frequency power supply unit 110b. The supplied high-frequency power propagates as a surface wave along first and second surface wave excitation bodies 103a and 103b to heat heating-target object 102.

[0019] In the description hereafter, first surface wave excitation body 103a and second surface wave excitation body 103b may be generically referred to as surface wave excitation body 103, and first high-frequency power supply unit 110a and second high-frequency power supply unit 110b may be generically referred to as high-frequency power supply unit 110, if no particular distinction is drawn.

[0020] High-frequency power generation unit 120 includes a high-frequency transmitter configured to output high-frequency power (e.g. microwave) at a frequency and magnitude appropriate for heating heating-target object 102.

[0021] Specifically, the high-frequency transmitter includes a magnetron and an inverter power supply circuit, for example. Alternatively, the high-frequency transmitter includes a solid oscillator and a power amplifier.

[0022] The magnetron is a kind of oscillation vacuum tube configured to generate a kind of radio wave, i.e., strong, non-coherent microwaves, and is used for purposes with a higher output ranging from several hundred watts to several kilowatts, such as a radar and a microwave oven. To drive the magnetron, a higher voltage of several kilovolts is required. As an ordinary power supply for driving the magnetron, an inverter power supply circuit is therefore used. The inverter power supply circuit includes a converter circuit having a rectification function and an inverter circuit having a voltage raising (or lowering) function and an output frequency conversion function. An inverter power supply circuit is a technique widely used in lighting apparatuses and used for motor controlling.

[0023] On the other hand, the solid oscillator includes a semiconductor oscillation circuit equipped with a feedback circuit including high-frequency electronic components, such as transistors, capacitors, inductors, and resistors. A solid oscillator is a technique widely used in oscillators for purposes with a low power output, such as communication devices.

[0024] Solid oscillators include oscillators having a high-frequency power output of approximately 50 watts, which are used in recent years, as well as include ordinary oscillators having a high-frequency power output ranging from several ten milliwatts to several hundred milliwatts. Such solid oscillators are not therefore appropriate for heating requiring a power output of several hundred watts. A solid oscillator is often used together with a power amplifier including, for example, transistors configured to amplify high-frequency power being output.

[0025] High-frequency power supply unit 110 corresponds to a power coupling unit configured to supply high-frequency power generated by high-frequency power generation unit 120 to surface wave excitation body 103. A configuration of high-frequency power supply unit 110 will be described later.

[0026] Surface wave excitation body 103 includes a metallic periodical structure with impedance elements made of metallic plates arranged periodically, and dielectric plates, for example. For the metallic periodical structure, a stub type surface wave excitation body or an interdigital type surface wave excitation body is used, for example. The stub type surface wave excitation body is formed by disposing a plurality of metallic flat plates at constant intervals on a metallic flat plate in a vertical direction toward a heating-target object. The interdigital type surface wave excitation body is formed by punching a metallic flat plate in an interdigital shape. The dielectric plate may be an alumina plate or a Bakelite plate.

[0027] Surface wave excitation body 103 allows high-frequency power that is supplied from high-frequency power generation unit 120 via high-frequency power supply unit 110 to concentrate around its surface, and propagates the high-frequency power as a surface wave. In the meanwhile, stand 101 is disposed near surface wave excitation body 103, and heating-target object 102 is put on stand 101. This configuration allows heating-target object 102 to be heated by high-frequency power concentrating around the surface of surface wave excitation body 103 and propagating along surface wave excitation body 103.

[0028] With reference to FIG. 2, the configuration of high-frequency power supply unit 110 according to the present exemplary embodiment will now be described by taking a configuration of first high-frequency power supply unit 110a as an example.

[0029] FIG. 2 is a block diagram illustrating an example of the configuration of first high-frequency power supply unit 110a.

[0030] As illustrated in FIG. 2, first high-frequency power supply unit 110a is disposed so as to introduce high-frequency power generated by high-frequency power generation unit 120 to first surface wave excitation body 103a via rectangular wave guide 130.

[0031] Rectangular wave guide 130 is a hollow wave guide mainly used to transmit electromagnetic waves, such as microwaves. The hollow wave guide is an ordinary wave guide made from a metallic tube having a rectangular cross section (e.g. rectangular shape). Electromagnetic waves form an electromagnetic field in accordance with a shape and a size of rectangular wave guide 130, as well as a wavelength or a frequency of the electromagnetic waves, and propagate inside rectangular wave guide 130.

[0032] The high-frequency power generated by high-frequency power generation unit 120 is supplied to first surface wave excitation body 103a via rectangular wave guide 130 and tapered rectangular wave guide 131. Tapered rectangular wave guide 131 is configured to suppress reflection of propagating microwaves at a joint to reduce a loss.

[0033] In other words, as illustrated by a broken line in FIG. 2, first high-frequency power supply unit 110a includes a part of rectangular wave guide 130, tapered rectangular wave guide 131, and a part of first surface wave excitation body 103a.

[0034] The high-frequency power generated by high-frequency power generation unit 120 is therefore introduced, via rectangular wave guide 130, to first high-frequency power supply unit 110a, and then efficiently supplied, via tapered rectangular wave guide 131, to first surface wave excitation body 103a.

[0035] Since second high-frequency power supply unit 110b is similar to first high-frequency power supply unit 110a in configuration and function, description thereof will be omitted.

[0036] First and second high-frequency power supply units 110a and 110b according to the present exemplary embodiment are configured as described above and function as transmission lines for microwaves.

[0037] In other words, high-frequency heating device 100 according to the present exemplary embodiment supplies the high-frequency power generated by one high-frequency power generation unit 120 to first and second surface wave excitation bodies 103a and 103b via respective first and second high-frequency power supply units 110a and 110b. The supplied high-frequency power propagates as a surface wave near surfaces of first and second surface wave excitation bodies 103a and 103b. Two faces of heating-target object 102 put on stand 101, as illustrated in FIG. 1, are heated by high-frequency power propagating along the surface of surface wave excitation body 103. The two faces of heating-target object 102 can be browned. This configuration eliminates the need for a heater or other heating sources.

[0038] Browning a heating-target object by a heater consumes electric power ranging from about 800 W to 1,000 W. Meanwhile, the high-frequency heating device having high-frequency power generation unit 120 according to the present exemplary embodiment allows radio waves to concentrate around the surface of the surface wave excitation body and can efficiently heat a heating-target object by surface waves. As a result, the high-frequency heating device can brown the object by heating even with a low power consumption of about 100 W to 200 W. This configuration enables high-frequency heating device 100 to provide improved energy conservation.

[0039] If a heating-target object is heated by a heating source such as a heater, a surface and an inside of the heating-target object provide a relatively tough texture. Meanwhile, the high-frequency heating device according to the present exemplary embodiment has a surface wave excitation body and thus can heat a heating-target object by microwaves such that the finished heating-target object has a relatively tough surface and a soft texture inside. This configuration provides a product such as a food having a texture different from a texture of the food heated by a device with a heater.

[0040] High-frequency heating device 100 according to the present exemplary embodiment is configured as described above to heat heating-target object 102 such as a food product.

[0041] Next, with reference to FIGS. 3A to 3C, how high-frequency heating device 100 described above heats heating-target object 102 will now be described.

[0042] FIGS. 3A to 3C each schematically illustrate an example field intensity distribution near the surface of surface wave excitation body 103 shown in FIG. 1.

[0043] In other words, FIG. 3A illustrates field intensity distribution 140a near a surface of first surface wave excitation body 103a while the high-frequency power generated by high-frequency power generation unit 120 is supplied only to first surface wave excitation body 103a via first high-frequency power supply unit 110a.

[0044] FIG. 3B illustrates how heating-target object 102 put on stand 101 is heated by field intensity distribution 140b near the surface of first surface wave excitation body 103a in FIG. 3A.

[0045] FIG. 3C illustrates how heating-target object 102 put on stand 101 is heated by field intensity distribution 140c near both the surface of first surface wave excitation body 103a and a surface of second surface wave excitation body 103b, wherein first and second surface wave excitation bodies 103a and 103b face each other through heating-target object 102.

[0046] In FIGS. 3A to 3C, intensity of electric fields in field intensity distributions 140a, 140b, 140c is represented with shading of a color. In this case, the darker the color, the stronger the electric field.

[0047] In the case of FIG. 3A, the high-frequency power generated by high-frequency power generation unit 120 is supplied to first surface wave excitation body 103a via first high-frequency power supply unit 110a. The supplied high-frequency power propagates as a surface wave along first surface wave excitation body 103a. Thus, field intensity distribution 140a shows high intensity near the surface of first surface wave excitation body 103a. The field intensity is distributed such that the electric field exponentially decreases in intensity with an increase in distance from the surface of first surface wave excitation body 103a.

[0048] In the case of FIG. 3B, with heating-target object 102 put on stand 101, the high-frequency power generated by high-frequency power generation unit 120 is supplied to first surface wave excitation body 103a via first high-frequency power supply unit 110a. Thus, in the same way as FIG. 3A, field intensity distribution 140b shows high intensity near the surface of first surface wave excitation body 103a. The field intensity is distributed such that the electric field decreases in intensity with an increase in distance from the surface of first surface wave excitation body 103a. Accordingly, a portion of heating-target object 102 adjacent to first surface wave excitation body 103a (an undersurface zone of heating-target object 102) is locally and strongly heated. On the other hand, a portion of heating-target object 102 remote from first surface wave excitation body 103a (a top surface zone of heating-target object 102) is very weakly or scarcely heated.

[0049] In the case of FIG. 3C, with heating-target object 102 put on stand 101, first and second surface wave excitation bodies 103a and 103b face each other through heating-target object 102. The high-frequency power generated by high-frequency power generation unit 120 is supplied to first surface wave excitation body 103a via first high-frequency power supply unit 110a and to second surface wave excitation body 103b via second high-frequency power supply unit 110b. Thus, field intensity distribution 140c in a space between first surface wave excitation body 103a and second surface wave excitation body 103b shows high intensity near the surfaces of first and second surface wave excitation bodies 103a and 103b. The field intensity is distributed such that the electric field decreases in intensity with an increase in distance from each of these surfaces. Accordingly, the portions of heating-target object 102 adjacent to first and second surface wave excitation bodies 103a and 103b (the top surface and the undersurface zones of heating-target object 102) are locally and strongly heated. On the other hand, a middle zone of the space between first and second surface wave excitation bodies 103a and 103b (an intermediate layer of heating-target object 102) is weakly heated. This configuration enables heating of the two faces of heating-target object 102 put on stand 101. The heating device can also brown mainly the top surface and the undersurface zones of heating-target object 102.

[0050] In the present exemplary embodiment, every surface wave excitation body 103 preferably has an identical exciting frequency. This makes design and configuration of high-frequency heating device 100 simpler. The identical exciting frequency enables all surface wave excitation bodies 103 to heat respective faces (e.g. the top surface and the undersurface) of heating-target object 102 evenly. This improves the quality of a finished food product.

[0051] The exciting frequency of surface wave excitation body 103 is determined based on a material used, a physical structural size, and other factors. For example, when a stub type surface wave excitation body is used, by changing heights of a plurality of metallic flat plates arranged on a metallic flat plate, or by changing the intervals of the metallic flat plates, the exciting frequency can be changed. In general, the exciting frequency of surface wave excitation body 103 increases when the heights of the metallic flat plates are lowered, or when the intervals of the metallic flat plates are narrowed. By adjusting the heights or the intervals of the metallic flat plates, surface wave excitation body 103 having a desired exciting frequency can therefore be formed.

[0052] Thus, in the present exemplary embodiment, the exciting frequency of surface wave excitation body 103 is adjusted by a technique such as the method described above so that every surface wave excitation body 103 has an identical exciting frequency.

[0053] In the present exemplary embodiment described above, first and second high-frequency power supply units 110a and 110b are disposed at an identical side relative to first and second surface wave excitation bodies 103a and 103b and thus the high-frequency power generated by high-frequency power generation unit 120 is supplied from an identical direction, for example. However, a configuration of these parts is not limited to this example. The high-frequency power may be supplied to first and second surface wave excitation bodies 103a and 103b from opposing directions or other directions, for example. This improves flexibility in the disposition of components and increases product design versatility.

(Second exemplary embodiment)

[0054] With reference to FIG. 4, high-frequency heating device 200 according to a second exemplary embodiment of the present invention will now be described.

[0055] In the present exemplary embodiment, components of high-frequency heating device 200 having functions identical to those of components in the first exemplary embodiment are denoted by the same numerals or symbols, and descriptions thereof will be omitted. In addition, descriptions of effects identical to those in the first exemplary embodiment will be omitted.

[0056] FIG. 4 is a block diagram illustrating a basic configuration of high-frequency heating device 200 according to the second exemplary embodiment.

[0057] As illustrated in FIG. 4, high-frequency heating device 200 differs from high-frequency heating device 100 of the first exemplary embodiment in that high-frequency power generated by high-frequency power generation unit 220 is supplied only to first surface wave excitation body 203a via high-frequency power supply unit 210.

[0058] In common with the first exemplary embodiment, high-frequency heating device 200 includes first surface wave excitation body 203a, second surface wave excitation body 203b, high-frequency power supply unit 210, and high-frequency power generation unit 220.

[0059] In high-frequency heating device 200 shown in FIG. 4, in common with the first exemplary embodiment, a number of surface wave excitation bodies, a number of high-frequency power supply units, and a number of high-frequency power generation units are not limited to the numbers described above.

[0060] High-frequency heating device 200 according to the present exemplary embodiment supplies the high-frequency power generated by high-frequency power generation unit 220 only to first surface wave excitation body 203a via high-frequency power supply unit 210. The supplied high-frequency power propagates as a surface wave along first surface wave excitation body 203a to heat an undersurface of heating-target object 102. At the same time, a part of high-frequency power propagating as a surface wave along first surface wave excitation body 203a is supplied by spatial coupling to second surface wave excitation body 203b disposed opposite to first surface wave excitation body 203a. The supplied high-frequency power propagates as a surface wave along second surface wave excitation body 203b to heat a top surface of heating-target object 102.

[0061] In the description hereafter, first surface wave excitation body 203a and second surface wave excitation body 203b may be generically referred to as surface wave excitation body 203 if no particular distinction is drawn.

[0062] As described above, high-frequency heating device 200 according to the present exemplary embodiment supplies the high-frequency power generated by high-frequency power generation unit 220 only to first surface wave excitation body 203a via high-frequency power supply unit 210. At the same time, a part of high-frequency power is supplied by spatial coupling to second surface wave excitation body 203b, which is disposed such that heating-target object 102 is put between second surface wave excitation body 203b and the other surface wave excitation body. The supplied high-frequency power propagates as a surface wave along first and second surface wave excitation bodies 203a and 203b. With this simple configuration, the high-frequency power works to heat two faces of heating-target object 102 put on stand 101 as illustrated in FIG. 4. The two faces of heating-target object 102 can be browned. This configuration eliminates the need for a heater or other heating sources.

[0063] Next, with reference to FIG. 5, how high-frequency heating device 200 described above heats heating-target object 102 will now be described in detail.

[0064] FIG. 5 schematically illustrates high-frequency power propagating as a surface wave along first surface wave excitation body 203a and second surface wave excitation body 203b shown in FIG. 4, and an example field intensity distribution near surfaces of the first and second surface wave excitation bodies.

[0065] In other words, FIG. 5 illustrates high-frequency power propagating as a surface wave along first and second surface wave excitation bodies 203a and 203b while the high-frequency power generated by high-frequency power generation unit 220 is supplied via high-frequency power supply unit 210. FIG. 5 also schematically illustrates a field intensity distribution formed near the surfaces of first and second surface wave excitation bodies 203a and 203b due to the propagating high-frequency power.

[0066] As illustrated in FIG. 5, the high-frequency power generated by high-frequency power generation unit 220 is supplied to first surface wave excitation body 203a via high-frequency power supply unit 210. As a result, high-frequency power 250a propagating as a surface wave along first surface wave excitation body 203a forms field intensity distribution 240a where a concentration of electric field intensity is observed near the surface of first surface wave excitation body 203a. At the same time, because of spatial coupling of electromagnetic waves, a part of high-frequency power is supplied to second surface wave excitation body 203b, which faces first surface wave excitation body 203a such that heating-target object 102 is put between the surface wave excitation bodies. The supplied part of high-frequency power makes up high-frequency power 250b and propagates as a surface wave along second surface wave excitation body 203b. As a result, high-frequency power 250b forms field intensity distribution 240b where a concentration of electric field intensity is observed near the surface of second surface wave excitation body 203b.

[0067] In other words, high-frequency heating device 200 according to the present exemplary embodiment supplies high-frequency power, for example, only to first surface wave excitation body 203a, i.e., one of surface wave excitation bodies 203 that face each other through heating-target object 102. The supplied high-frequency power propagates as a surface wave along first and second surface wave excitation bodies 203a and 203b and works to heat two faces of heating-target object 102 put on stand 101 illustrated in FIG. 5. The two faces of heating-target object 102 can be browned. This configuration eliminates the need for a heater or other heating sources.

[0068] This configuration enables a reduction in a number of high-frequency power supply units since the high-frequency heating device supplies high-frequency power from the high-frequency power generation unit only to one of the surface wave excitation bodies. In other words, this simplified configuration enables heating of two faces of a heating-target object.

[0069] In common with the first exemplary embodiment, this configuration contributes to a substantial reduction in power consumption compared to a device including a heater. This enables high-frequency heating device 200 to provide improved energy conservation.

[0070] In common with the first exemplary embodiment, this configuration provides a food product having a texture different from a texture of the food product heated by a device with a heater.

[0071] In the exemplary embodiment described above, high-frequency power is supplied from high-frequency power generation unit 220 only to first surface wave excitation body 203a via high-frequency power supply unit 210, for example. However, a configuration of these parts is not limited to this example. High-frequency power may be supplied only to second surface wave excitation body 203b, for example. This configuration produces an effect similar to that shown in the present exemplary embodiment.

(Third exemplary embodiment)

[0072] With reference to FIG. 6, high-frequency heating device 300 according to a third exemplary embodiment of the present invention will now be described.

[0073] In the present exemplary embodiment, components of high-frequency heating device 300 having functions identical to those of components in any of the first and the second exemplary embodiments are denoted by the same numerals or symbols, and descriptions thereof will be omitted. In addition, descriptions of effects identical to those in any of the first and the second exemplary embodiments will be omitted.

[0074] FIG. 6 is a block diagram illustrating a basic configuration of high-frequency heating device 300 according to the third exemplary embodiment.

[0075] As illustrated in FIG. 6, high-frequency heating device 300 differs from the high-frequency heating devices of the first and the second exemplary embodiments in that first high-frequency power generation unit 320a and second high-frequency power generation unit 320b are disposed so as to correspond to respective first surface wave excitation body 303a and second surface wave excitation body 303b and that high-frequency power is supplied from these high-frequency power generation units.

[0076] High-frequency heating device 300 includes first surface wave excitation body 303a, second surface wave excitation body 303b, first high-frequency power supply unit 310a, second high-frequency power supply unit 310b, first high-frequency power generation unit 320a, and second high-frequency power generation unit 320b.

[0077] In high-frequency heating device 300 shown in FIG. 6, in common with the first and the second exemplary embodiments, a number of surface wave excitation bodies, a number of high-frequency power supply units, and a number of high-frequency power generation units are not limited to the numbers described above.

[0078] High-frequency heating device 300 according to the present exemplary embodiment supplies high-frequency power generated by first high-frequency power generation unit 320a to first surface wave excitation body 303a via first high-frequency power supply unit 310a. The supplied high-frequency power propagates as a surface wave along first surface wave excitation body 303a to heat an undersurface of heating-target object 102. At the same time, a part of high-frequency power propagating as a surface wave along first surface wave excitation body 303a is supplied by spatial coupling to second surface wave excitation body 303b disposed opposite to first surface wave excitation body 303a. The supplied high-frequency power propagates as a surface wave along second surface wave excitation body 303b to heat a top surface of heating-target object 102.

[0079] Meanwhile, high-frequency power generated by second high-frequency power generation unit 320b is supplied to second surface wave excitation body 303b via second high-frequency power supply unit 310b. The supplied high-frequency power propagates as a surface wave along second surface wave excitation body 303b to heat the top surface of heating-target object 102. At the same time, a part of high-frequency power propagating as a surface wave along second surface wave excitation body 303b is supplied by spatial coupling to first surface wave excitation body 303a disposed opposite to second surface wave excitation body 303b. The supplied high-frequency power propagates as a surface wave along first surface wave excitation body 303a to heat the undersurface of heating-target object 102.

[0080] In the description hereafter, first surface wave excitation body 303a and second surface wave excitation body 303b, first high-frequency power supply unit 310a and second high-frequency power supply unit 310b, and first high-frequency power generation unit 320a and second high-frequency power generation unit 320b may be generically referred to as surface wave excitation body 303, high-frequency power supply unit 310, and high-frequency power generation unit 320, respectively, if no particular distinction is drawn.

[0081] As described above, in high-frequency heating device 300 according to the present exemplary embodiment, first and second surface wave excitation bodies 303a and 303b are disposed at locations opposite to each other such that heating-target object 102 is put between the surface wave excitation bodies. The high-frequency heating device supplies the high-frequency power generated by first high-frequency power generation unit 320a to first surface wave excitation body 303a via first high-frequency power supply unit 310a. Similarly, the high-frequency heating device supplies the high-frequency power generated by second high-frequency power generation unit 320b to second surface wave excitation body 303b via second high-frequency power supply unit 310b. In the meanwhile, a part of high-frequency power generated by second high-frequency power generation unit 320b is supplied by spatial coupling to first surface wave excitation body 303a. Similarly, a part of high-frequency power generated by first high-frequency power generation unit 320a is supplied by spatial coupling to second surface wave excitation body 303b. The supplied high-frequency power propagates as a surface wave along first and second surface wave excitation bodies 303a and 303b. This enables heating of two faces of heating-target object 102 put on stand 101 shown in FIG. 6. The two faces of heating-target object 102 can be browned. This configuration eliminates the need for a heater or other heating sources.

[0082] Next, with reference to FIG. 7, how high-frequency heating device 300 described above heats heating-target object 102 will now be described in detail.

[0083] FIG. 7 schematically illustrates high-frequency power propagating as a surface wave along first surface wave excitation body 303a and second surface wave excitation body 303b shown in FIG. 6, and an example field intensity distribution near surfaces of the first and second surface wave excitation bodies.

[0084] In other words, FIG. 7 illustrates high-frequency power propagating as a surface wave along first surface wave excitation body 303a while high-frequency power generated by first high-frequency power generation unit 320a is supplied to first surface wave excitation body 303a via first high-frequency power supply unit 310a. FIG. 7 also illustrates high-frequency power propagating as a surface wave along second surface wave excitation body 303b while high-frequency power generated by second high-frequency power generation unit 320b is supplied to second surface wave excitation body 303b via second high-frequency power supply unit 310b. In addition, FIG. 7 schematically illustrates a field intensity distribution formed near the surfaces of first and second surface wave excitation bodies 303a and 303b due to the propagating high-frequency power.

[0085] As illustrated in FIG. 7, the high-frequency power generated by first high-frequency power generation unit 320a is supplied to first surface wave excitation body 303a via first high-frequency power supply unit 310a. Thus, as described in the second exemplary embodiment, high-frequency power 350a propagating as a surface wave along first surface wave excitation body 303a forms a field intensity distribution where a concentration of electric field intensity is observed near the surface of first surface wave excitation body 303a. At the same time, because of spatial coupling of electromagnetic waves, a part of high-frequency power propagating as a surface wave along first surface wave excitation body 303a makes up high-frequency power 350b that is supplied to and propagates along second surface wave excitation body 303b. Propagating high-frequency power 350b forms a field intensity distribution where a concentration of electric field intensity is observed near the surface of second surface wave excitation body 303b.

[0086] Meanwhile, high-frequency power generated by second high-frequency power generation unit 320b is supplied to second surface wave excitation body 303b via second high-frequency power supply unit 310b. As a result, high-frequency power 350c propagating as a surface wave along second surface wave excitation body 303b forms a field intensity distribution where a concentration of electric field intensity is observed near the surface of second surface wave excitation body 303b. At the same time, because of spatial coupling of electromagnetic waves, a part of high-frequency power propagating as a surface wave along second surface wave excitation body 303b makes up high-frequency power 350d that is supplied to and propagates along first surface wave excitation body 303a. Propagating high-frequency power 350d forms a field intensity distribution where a concentration of electric field intensity is observed near the surface of first surface wave excitation body 303a.

[0087] In this case, high-frequency power 351a propagating as a surface wave along first surface wave excitation body 303a is a sum of high-frequency power 350a supplied from first high-frequency power generation unit 320a and high-frequency power 350d supplied from second surface wave excitation body 303b by spatial coupling. Accordingly, field intensity distribution 343a near the surface of first surface wave excitation body 303a is a sum of the field intensity distribution formed from high-frequency power 350a and the field intensity distribution formed from high-frequency power 350d supplied by spatial coupling.

[0088] Similarly, high-frequency power 351b propagating as a surface wave along second surface wave excitation body 303b is a sum of high-frequency power 350c supplied from second high-frequency power generation unit 320b and high-frequency power 350b supplied from first surface wave excitation body 303a by spatial coupling. Accordingly, field intensity distribution 343b near the surface of second surface wave excitation body 303b is a sum of the field intensity distribution formed from high-frequency power 350c and the field intensity distribution formed from high-frequency power 350b supplied by spatial coupling.

[0089] In other words, high-frequency heating device 300 according to the present exemplary embodiment supplies high-frequency power 351a, 351b individually to respective first surface wave excitation body 303a and second surface wave excitation body 303b that face each other through heating-target object 102.

[0090] Simultaneously, the high-frequency heating device can change a balance between the field intensity distributions caused by high-frequency power 351a propagating along first surface wave excitation body 303a and high-frequency power 351b propagating along second surface wave excitation body 303b. Thus, the high-frequency heating device can change a balance of food-product heating unevenness and extent, and thereby heat two faces of heating-target object 102 put on stand 101 in FIG. 7 in a variety of patterns. The high-frequency heating device can also brown the two faces of heating-target object 102 freely.

[0091] In the present exemplary embodiment, in common with the first and second exemplary embodiments, high-frequency power may be supplied to first and second surface wave excitation bodies 303a and 303b from opposing directions or other directions.

[0092] In the exemplary embodiments described above, the high-frequency power generation unit of the high-frequency heating device generates high-frequency power at a fixed frequency, for example. However, a configuration of the high-frequency power generation unit is not limited to this example. The high-frequency power generation unit may include, as described later, a high-frequency oscillator that generates high-frequency power at a set variable frequency, for example.

[0093] The high-frequency oscillator for generating a variable frequency can be implemented by using a variable voltage element (e.g., a varactor diode) as an element determining a resonance frequency of a resonant circuit configuring the semiconductor oscillation circuit described above. The variable frequency high-frequency oscillator is generally referred to as a voltage controlled oscillator (VCO). Since a technique of a VCO is already known, its detailed description is omitted. In this case, a controller is provided to the high-frequency oscillator to supply voltage information corresponding to a frequency to the VCO. A frequency of the high-frequency oscillator can therefore be changed.

[0094] The variable frequency high-frequency oscillator may be a phase locked loop (PLL) oscillator including a reference signal generator and a phase comparator. Since a technique of a PLL oscillator is already known, its detailed description is omitted. In this case, a controller is provided to the PLL oscillator to supply an information signal corresponding to a frequency to the phase comparator. A frequency of the PLL oscillator can therefore be changed.

[0095] In other words, in response to a change in the frequency of high-frequency power supplied to a surface wave excitation body, a field intensity distribution formed near a surface of the surface wave excitation body can change as illustrated in FIGS. 8A to 8C.

[0096] FIGS. 8A to 8C each schematically illustrate an example of a change in a degree of surface concentration of electric field formed near a surface of a surface wave excitation body in response to a change in frequency of high-frequency power supplied to the surface wave excitation body.

[0097] Specifically, FIGS. 8A to 8C are graphs that each illustrate a change in field intensity relative to the distance from the surface of a surface wave excitation body, with a relationship formed between frequency fp of high-frequency power supplied to the surface wave excitation body and exciting frequency fc of the surface wave excitation body. In each of FIGS. 8A to 8C, the horizontal axis represents a distance from the surface of the surface wave excitation body, while the vertical axis represents field intensity. In the drawings, a steeper inclination in the graph indicates a higher concentration of the electric field close to the surface of the surface wave excitation body. The distance from the surface of the surface wave excitation body is a distance from a surface of the surface wave excitation body adjacent to a heating-target object to a point in a direction toward the heating-target object.

[0098] In FIG. 8A, graph 361 illustrates a degree of field intensity relative to the distance from the surface of the surface wave excitation body when frequency fp of high-frequency power supplied to the surface wave excitation body is lower than exciting frequency fc of the surface wave excitation body. In FIG. 8B, graph 362 illustrates a degree of field intensity when frequency fp of high-frequency power is approximately equal to exciting frequency fc. In FIG. 8C, graph 363 illustrates a degree of field intensity when frequency fp of high-frequency power is higher than exciting frequency fc.

[0099] First, as illustrated in FIG. 8B, when frequency fp of high-frequency power and exciting frequency fc are set approximately identical to each other, graph 362 illustrating the degree of field intensity relative to the distance from the surface of the surface wave excitation body has a greatest inclination. In other words, a highest concentration of electric field intensity is observed close to the surface of the surface wave excitation body. As a result, the field intensity is very high close to the surface of the surface wave excitation body and sharply decreases with an increase in the distance from the surface of the surface wave excitation body. This enables the high-frequency heating device to locally heat the surface of the heating-target object. Thus, the relationship between frequency fp and exciting frequency fc described above is appropriate for browning the heating-target object.

[0100] As illustrated in FIG. 8A, when frequency fp of high-frequency power is set lower than exciting frequency fc, graph 361 has a gentle inclination compared with the inclination of graph 362 in FIG. 8B. In other words, a lower concentration of electric field intensity is observed close to the surface of the surface wave excitation body. As a result, despite a relatively high field intensity close to the surface of the surface wave excitation body, the field intensity does not sharply decrease even with an increase in the distance from the surface of the surface wave excitation body. This enables high-frequency power to reach a position slightly away from the surface of the surface wave excitation body. Thus, the relationship between frequency fp and exciting frequency fc described above is appropriate for heating a heating-target object without allowing the heating-target object to get browned.

[0101] As illustrated in FIG. 8C, when frequency fp of high-frequency power is set higher than exciting frequency fc, graph 363 has almost no inclination. In other words, virtually no concentration of electric field intensity is observed close to the surface of the surface wave excitation body. This means that high-frequency power supplied to the surface wave excitation body is radiated into a space inside the high-frequency heating device, for example, without propagating as a surface wave along the surface wave excitation body. Thus, the relationship between frequency fp and exciting frequency fc described above is appropriate for relatively evenly heating a whole heating-target object.

[0102] As described above, if the high-frequency power generation unit according to any of the exemplary embodiments described above includes a variable frequency high-frequency oscillator, a heating pattern on heating-target object 102 can be flexibly changed. This configuration enables the high-frequency heating device to heat two faces of heating-target object 102 put on stand 101 in various finishes. The high-frequency heating device can also brown heating-target object 102 freely and suitably.

[0103] Although, in the exemplary embodiments described above, purposes of the high-frequency heating device have not been specifically described, a basic configuration similar to an ordinary cooking microwave oven may be applied, for example.

(Fourth exemplary embodiment)

[0104] With reference to FIG. 9, high-frequency heating device 400 according to a fourth exemplary embodiment of the present invention will now be described.

[0105] FIG. 9 is a block diagram illustrating a basic configuration of high-frequency heating device 400 according to the fourth exemplary embodiment.

[0106] As illustrated in FIG. 9, high-frequency heating device 400 is similar in basic configuration to high-frequency heating device 100 of the first exemplary embodiment described with reference to FIG. 1. Thus, elements such as components and effects identical to those in the first exemplary embodiment are denoted by the same numerals or symbols, and descriptions thereof will be omitted.

[0107] However, high-frequency heating device 400 differs from the high-frequency heating device of the first exemplary embodiment in that high-frequency heating device 400 includes first surface wave excitation body 403a and second surface wave excitation body 403b having mutually different exciting frequencies.

[0108] In other words, high-frequency heating device 400 of the present exemplary embodiment, as illustrated in FIG. 9, includes first surface wave excitation body 403a, second surface wave excitation body 403b, first high-frequency power supply unit 110a, second high-frequency power supply unit 110b, and high-frequency power generation unit 120. First and second surface wave excitation bodies 403a and 403b are disposed such that heating-target object 102 is put between the surface wave excitation bodies. At the same time, first and second surface wave excitation bodies 403a and 403b have different exciting frequencies as described above.

[0109] In the description hereafter, first surface wave excitation body 403a and second surface wave excitation body 403b may be generically referred to as surface wave excitation body 403 if no particular distinction is drawn.

[0110] High-frequency heating device 400 supplies high-frequency power generated by one high-frequency power generation unit 120 to first surface wave excitation body 403a via first high-frequency power supply unit 110a. Simultaneously, the high-frequency heating device supplies high-frequency power to second surface wave excitation body 403b via second high-frequency power supply unit 110b. The supplied high-frequency power propagates as a surface wave along first and second surface wave excitation bodies 403a and 403b, which have different exciting frequencies, to heat two faces of heating-target object 102.

[0111] In common with the first exemplary embodiment, high-frequency power generation unit 120 includes a magnetron and an inverter power supply circuit, for example. Alternatively, the high-frequency power generation unit includes a solid oscillator and a power amplifier.

[0112] In common with the first exemplary embodiment, surface wave excitation body 403 includes a metallic periodical structure with impedance elements made of metallic plates arranged periodically (e.g., a stub type surface wave excitation body and an interdigital type surface wave excitation body), and dielectric plates, for example.

[0113] As described above, an exciting frequency of surface wave excitation body 403 is determined based on a material used, a physical structural size, and other factors. By adjusting the heights or the intervals of the metallic flat plates, for example, surface wave excitation body 403 having a desired exciting frequency can therefore be formed.

[0114] Specifically, forming a stub type surface wave excitation body involves inserting dielectric bodies under a mechanical control into gaps between metallic flat plates arranged at constant intervals on a metallic flat plate. The exciting frequency of the surface wave excitation body can therefore be changed.

[0115] In this case, a dielectric constant of a dielectric body may be changed under an electrical control, instead of the mechanical control, to change an exciting frequency of a surface wave excitation body. The exciting frequency of surface wave excitation body 403 can therefore be relatively greatly changed. This enables a high-frequency heating device to greatly change a heating state in a thickness direction of a heating-target object by letting high-frequency power propagate along a plurality of surface wave excitation bodies 403 having different exciting frequencies. A range of the heating state can therefore be expanded as desired by a user to variously heat the heating-target object.

[0116] High-frequency heating device 400 according to the present exemplary embodiment is configured as described above.

[0117] In other words, high-frequency heating device 400 according to the present exemplary embodiment supplies high-frequency power generated by one high-frequency power generation unit 120 to first and second surface wave excitation bodies 403a and 403b having mutually different exciting frequencies via respective first and second high-frequency power supply units 110a and 110b. The supplied high-frequency power propagates as surface waves of different exciting frequencies near respective surfaces of first and second surface wave excitation bodies 403a and 403b. Thus, as described later, different states of high-frequency power propagating along first and second surface wave excitation bodies 403a and 403b can be combined. This configuration enables the high-frequency heating device to heat two faces of heating-target object 102 put on stand 101 as shown in FIG. 9 in a variety of patterns using a combination of different states of high-frequency power. This in turn allows heating-target object 102 to be heated and finished in a state, such as reduced heating unevenness, as desired by a user. The high-frequency heating device can also brown the two faces of heating-target object 102 in accordance with a desire of a user.

[0118] In common with the first to the third exemplary embodiments, high-frequency heating device 400 according to the present exemplary embodiment can brown heating-target object 102 by consuming less electric power than a device including a heater. Thus, high-frequency heating device 400 is excellent in energy conservation. Heating-target object 102 heated by the high-frequency heating device has a texture different from a texture of a food product heated by a heater.

[0119] High-frequency heating device 400 according to the present exemplary embodiment is configured as described above.

[0120] Next, with reference to FIG. 10, how high-frequency heating device 400 described above heats heating-target object 102 will now be described.

[0121] FIG. 10 schematically illustrates an example field intensity distribution near the surface of surface wave excitation body 403 shown in FIG. 9.

[0122] In other words, FIG. 10 illustrates action of high-frequency power propagating as a surface wave along surface wave excitation body 403 to heat heating-target object 102 while high-frequency power generated by high-frequency power generation unit 120 is supplied via high-frequency power supply unit 110. FIG. 10 also schematically illustrates a field intensity distribution formed near surfaces of first and second surface wave excitation bodies 403a and 403b due to the propagating high-frequency power.

[0123] In high-frequency heating device 400, as illustrated in FIG. 10, heating-target object 102 is put on stand 101, and first surface wave excitation body 403a and second surface wave excitation body 403b face each other through heating-target object 102. In the meanwhile, the high-frequency heating device supplies high-frequency power generated by high-frequency power generation unit 120 to first surface wave excitation body 403a via first high-frequency power supply unit 110a. Simultaneously, the high-frequency heating device supplies high-frequency power to second surface wave excitation body 403b via second high-frequency power supply unit 110b. Due to the supplied high-frequency power, field intensity distribution 441a and field intensity distribution 441b are formed near respective surfaces of first and second surface wave excitation bodies 403a and 403b. This configuration allows two faces of heating-target object 102 to be heated.

[0124] In FIG. 10, intensity of electric fields in field intensity distributions 441a and 441b is represented with shading of a color. In this case, the darker the color, the stronger the electric field.

[0125] Specifically, as illustrated in FIG. 10, with heating-target object 102 put on stand 101, first and second surface wave excitation bodies 403a and 403b face each other through heating-target object 102. High-frequency power generated by high-frequency power generation unit 120 is supplied to first surface wave excitation body 403a via first high-frequency power supply unit 110a and to second surface wave excitation body 403b via second high-frequency power supply unit 110b. At the same time, field intensity distributions 441a and 441b near the surfaces of first and second surface wave excitation bodies 403a and 403b show high intensity in regions close to the surfaces of first and second surface wave excitation bodies 403a and 403b. The field intensity in field intensity distributions 441a and 441b is distributed such that the electric field decreases in intensity with an increase in distance from each of these surfaces. Accordingly, the portions of heating-target object 102 adjacent to first and second surface wave excitation bodies 403a and 403b, i.e., a top surface zone and an undersurface zone of heating-target object 102, are locally and strongly heated. On the other hand, a middle zone of the space between first and second surface wave excitation bodies 103a and 103b, i.e., an intermediate layer of heating-target object 102, is weakly heated.

[0126] This configuration enables heating of the two faces of heating-target object 102 put on stand 101. The heating device can also brown mainly the top surface zone and the undersurface zone of heating-target object 102.

[0127] In high-frequency heating device 400 according to the present exemplary embodiment, high-frequency power generation unit 120 includes a high-frequency transmitter that generates high-frequency power at a set variable frequency.

[0128] Thus, in response to a change in the frequency of high-frequency power supplied to surface wave excitation body 403, a field intensity distribution formed near the surface of surface wave excitation body 403 can be changed as illustrated in FIGS. 11A to 11C and FIGS. 12A to 12C.

[0129] FIGS. 11A to 11C each schematically illustrate a change in a degree of surface concentration of electric field formed near a surface of a surface wave excitation body, with a relationship formed between a frequency of high-frequency power supplied to the surface wave excitation body and an exciting frequency of the surface wave excitation body.

[0130] In other words, FIGS. 11A to 11C are graphs that each illustrate a degree of field intensity relative to the distance from the surface of surface wave excitation body 403, with a relationship formed between frequency fp of high-frequency power supplied to surface wave excitation body 403 and exciting frequency fc of surface wave excitation body 403. In each of FIGS. 11A to 11C, the horizontal axis represents a distance from the surface of the surface wave excitation body, while the vertical axis represents field intensity. In the drawings, a steeper inclination in the graph indicates a higher concentration of the electric field close to the surface of the surface wave excitation body.

[0131] FIGS. 12A to 12C each illustrate a change of a field intensity distribution formed near a surface of a surface wave excitation body, with a relationship formed between a frequency of high-frequency power supplied to the surface wave excitation body and an exciting frequency of the surface wave excitation body. In FIGS. 12A to 12C, in common with FIG. 10, intensity of electric fields in field intensity distributions is represented with shading of a color. Specifically, the darker the color, the stronger the electric field.

[0132] Specifically, in FIG. 11A, graph 451 illustrates a degree of field intensity relative to a distance from the surface of surface wave excitation body 403 when frequency fp of high-frequency power supplied to surface wave excitation body 403 is approximately equal (including equal) to exciting frequency fc of surface wave excitation body 403. FIG. 12A illustrates field intensity distribution 461 formed near the surface of surface wave excitation body 403 of FIG. 11A.

[0133] In FIG. 11B, graph 452 illustrates a degree of field intensity relative to a distance from the surface of surface wave excitation body 403 when frequency fp of high-frequency power is lower than exciting frequency fc. FIG. 12B illustrates field intensity distribution 462 formed near the surface of surface wave excitation body 403 described in FIG. 11B.

[0134] In FIG. 12C, graph 453 illustrates a degree of field intensity relative to a distance from the surface of surface wave excitation body 403 when frequency fp of high-frequency power is higher than exciting frequency fc. FIG. 12C illustrates field intensity distribution 463 formed near the surface of surface wave excitation body 403 described in FIG. 11C.

[0135] First, as illustrated in FIG. 11A, when frequency fp of high-frequency power and exciting frequency fc are set approximately equal (including equal) to each other, graph 451 illustrating the degree of field intensity relative to the distance from the surface of surface wave excitation body 403 has a greatest inclination. In this case, as illustrated in FIG. 12A, field intensity distribution 461 is formed such that a concentration of electric field intensity is observed close to the surface of surface wave excitation body 403. As a result, the field intensity is very high close to the surface of surface wave excitation body 403 and sharply decreases with an increase in the distance from the surface of surface wave excitation body 403. This enables the high-frequency heating device to locally heat the surface of heating-target object 102. Thus, the relationship between frequency fp and exciting frequency fc described above is appropriate for browning the surface of heating-target object 102.

[0136] As illustrated in FIG. 11B, when frequency fp of high-frequency power is set lower than exciting frequency fc, graph 452 has a gentle inclination compared with the inclination of graph 451 in FIG. 11A. In this case, as illustrated in FIG. 12B, field intensity distribution 462 near the surface of surface wave excitation body 403 shows a lower concentration of the electric field close to the surface of surface wave excitation body 403, so that high-frequency power reaches a longer distance from the surface of surface wave excitation body 403. As a result, despite a relatively high field intensity close to the surface of surface wave excitation body 403, the field intensity does not sharply decrease even with an increase in the distance from the surface of surface wave excitation body 403. In other words, high-frequency power can reach a position slightly away from the surface of surface wave excitation body 403. Thus, the relationship between frequency fp and exciting frequency fc described above is appropriate for heating heating-target object 102 without allowing the heating-target object to get browned.

[0137] As illustrated in FIG. 11C, when frequency fp of high-frequency power is set higher than exciting frequency fc, graph 453 has almost no inclination. In this case, as illustrated in FIG. 12C, no concentration of the electric field is observed close to the surface of surface wave excitation body 403, and field intensity distribution 463 shows spread of electric field intensity throughout a space. This means that high-frequency power supplied to surface wave excitation body 403 is radiated into the space without propagating as a surface wave along surface wave excitation body 403. Thus, the relationship between frequency fp and exciting frequency fc described above is appropriate for relatively evenly heating whole heating-target object 102.

[0138] In other words, in response to a change in the magnitude relationship between frequency fp of high-frequency power and exciting frequency fc of surface wave excitation body 403, a state of high-frequency power propagating as a surface wave along surface wave excitation body 403 changes, and a field intensity distribution caused by high-frequency power changes.

[0139] Thus, high-frequency heating device 400 according to the present exemplary embodiment includes surface wave excitation bodies 403 having different exciting frequencies to heat heating-target object 102 by taking advantage of any of the above-described relationships between frequency fp of high-frequency power and exciting frequency fc of surface wave excitation body 403.

[0140] Specifically, high-frequency heating device 400 includes first surface wave excitation body 403a excited at exciting frequency fc1 and second surface wave excitation body 403b excited at exciting frequency fc2. This configuration allows a variety of field intensity distributions to be formed as shown in FIGS. 12A to 12C and enables the high-frequency heating device to heat heating-target object 102 in a variety of patterns.

[0141] With reference to FIGS. 13A to 13E, the following description is given of field intensity distributions that are each formed near the surfaces of surface wave excitation bodies 403 having different exciting frequencies in response to a change in the frequency of high-frequency power supplied to surface wave excitation bodies 403.

[0142] FIGS. 13A to 13E each illustrate a change in a field intensity distribution formed near the surfaces of first and second surface wave excitation bodies 403a and 403b in high-frequency heating device 400 of FIG. 9, with a magnitude relationship formed between frequency fp of high-frequency power and each of exciting frequency fc1 of first surface wave excitation body 403a and exciting frequency fc2 of second surface wave excitation body 403b. In these drawings, as described above, intensity of electric fields in field intensity distributions is represented with shading of a color. The darker the color, the stronger the electric field.

[0143] FIG. 13A illustrates field intensity distribution 471 formed near the surfaces of first and second surface wave excitation bodies 403a and 403b when frequency fp of high-frequency power is approximately equal (including equal) to exciting frequency fc1 of first surface wave excitation body 403a and is higher than exciting frequency fc2 of second surface wave excitation body 403b. FIG. 13B illustrates field intensity distribution 472 formed when frequency fp is higher than exciting frequency fc1 and is approximately equal (including equal) to exciting frequency fc2. FIG. 13C illustrates field intensity distribution 473 formed when frequency fp is approximately equal (including equal) to exciting frequency fc1 and is lower than exciting frequency fc2. FIG. 13D illustrates field intensity distribution 474 formed when frequency fp is lower than exciting frequency fc1 and is approximately equal (including equal) to exciting frequency fc2. FIG. 13E illustrates field intensity distribution 475 formed when frequency fp is higher than exciting frequencies fc1 and fc2.

[0144] In this case, if field intensities in the distributions formed near the surfaces of first and second surface wave excitation bodies 403a and 403b are represented by any of "high", "medium", and "low", relationships between the field intensities are as described below.

[0145] Specifically, in FIG. 13A, the field intensity near the surface of first surface wave excitation body 403a is "high", and the field intensity near the surface of second surface wave excitation body 403b is "low". In FIG. 13B, the field intensity near the surface of first surface wave excitation body 403a is "low", and the field intensity near the surface of second surface wave excitation body 403b is "high". In FIG. 13C, the field intensity near the surface of first surface wave excitation body 403a is "high", and the field intensity near the surface of second surface wave excitation body 403b is "medium". In FIG. 13D, the field intensity near the surface of first surface wave excitation body 403a is "medium", and the field intensity near the surface of second surface wave excitation body 403b is "high". In FIG. 13E, the field intensity near the surface of first surface wave excitation body 403a is "low", and the field intensity near the surface of second surface wave excitation body 403b is "low".

[0146] As illustrated in FIGS. 13A to 13E, if first and second surface wave excitation bodies 403a and 403b are disposed such that heating-target object 102 is put between the surface wave excitation bodies, field intensity distributions are formed as described below. Specifically, in accordance with different magnitude relationships between each of exciting frequencies fc1 and fc2 and frequency fp of high-frequency power, field intensity distributions similar to any of the field intensity distributions as in the case of only first surface wave excitation body 403a illustrated in FIGS. 12A to 12C are formed close to the respective surfaces of first and second surface wave excitation bodies 403a and 403b.

[0147] In other words, high-frequency heating device 400 according to the present exemplary embodiment can make a choice among combinations of frequency fp of high-frequency power, exciting frequency fc1 of first surface wave excitation body 403a, and exciting frequency fc2 of second surface wave excitation body 403b in magnitude relationship. This configuration enables the high-frequency heating device to have an arbitrary combination of filed intensity distributions near first and second surface wave excitation bodies 403a and 403b along which high-frequency power propagates as surface waves. As a result, the high-frequency heating device can heat heating-target object 102 in a variety of patterns to suit a purpose desired by a user.

[0148] A combination of medium" and "medium" field intensities or a combination of all "high", "medium", and "low" field intensities, for example, may be selected despite no such illustration in FIGS. 13A to 13E. This allows the high-frequency heating device to heat heating-target object 102 in an increased variety of patterns.

[0149] In the exemplary embodiment described above, exciting frequency fc1 of first surface wave excitation body 403a and exciting frequency fc2 of second surface wave excitation body 103b differ from each other. Thus, in FIG. 13E, the "low" field intensity close to the surface of first surface wave excitation body 403a and the "low" field intensity close to the surface of second surface wave excitation body 403b normally cause field intensity distributions that slightly differ from each other based on respective differences from frequency fp of high-frequency power.

[0150] As described above, exciting frequency fc1 of first surface wave excitation body 403a and exciting frequency fc2 of second surface wave excitation body 403b may be set in advance by adjusting the heights, the intervals or other dimensions of the metallic flat plates of these surface wave excitation bodies. At least one of first and second surface wave excitation bodies 403a and 403b may be a surface wave excitation body having a variable exciting frequency. This enables more detailed control of heating states near respective surface wave excitation bodies. This in turn allows the high-frequency heating device to heat a heating-target object and produce an improvement in finished quality.

[0151] In the present exemplary embodiment, in common with the exemplary embodiments described above, high-frequency power may be supplied to first and second surface wave excitation bodies 403a and 403b from opposing directions or other directions.

(Fifth exemplary embodiment)

[0152] With reference to FIG. 14, high-frequency heating device 500 according to a fifth exemplary embodiment of the present invention will now be described.

[0153] FIG. 14 is a block diagram illustrating a basic configuration of high-frequency heating device 500 according to the fifth exemplary embodiment.

[0154] As illustrated in FIG. 14, high-frequency heating device 500 is similar in basic configuration to high-frequency heating device 200 of the second exemplary embodiment described with reference to FIG. 4. Thus, elements such as components and effects identical to those in the second exemplary embodiment are denoted by the same numerals or symbols, and descriptions thereof will be omitted.

[0155] However, high-frequency heating device 500 differs from the high-frequency heating device of the second exemplary embodiment in that high-frequency heating device 500 includes first surface wave excitation body 503a and second surface wave excitation body 503b having mutually different exciting frequencies.

[0156] In other words, in common with the second exemplary embodiment, high-frequency heating device 500 illustrated in FIG. 14 includes first surface wave excitation body 503a, second surface wave excitation body 503b, high-frequency power supply unit 210, and high-frequency power generation unit 220. First and second surface wave excitation bodies 503a and 503b are disposed at locations opposite to each other such that heating-target object 102 is put between the surface wave excitation bodies. At the same time, first and second surface wave excitation bodies 503a and 503b have different exciting frequencies as described above.

[0157] In the description hereafter, first surface wave excitation body 503a and second surface wave excitation body 503b may be generically referred to as surface wave excitation body 503 if no particular distinction is drawn.

[0158] High-frequency heating device 500 supplies high-frequency power generated by high-frequency power generation unit 220 only to first surface wave excitation body 203a via high-frequency power supply unit 210. The supplied high-frequency power propagates as a surface wave along first surface wave excitation body 503a to heat an undersurface of heating-target object 102. At the same time, a part of high-frequency power propagating as a surface wave along first surface wave excitation body 503a is supplied by spatial coupling to second surface wave excitation body 503b disposed opposite to first surface wave excitation body 503a. The supplied high-frequency power propagates as a surface wave along second surface wave excitation body 503b to heat a top surface of heating-target object 102.

[0159] In other words, high-frequency heating device 500 according to the present exemplary embodiment supplies high-frequency power generated by high-frequency power generation unit 220 only to first surface wave excitation body 503a, for example, via high-frequency power supply unit 210. First surface wave excitation body 503a is one of first surface wave excitation body 503a and first surface wave excitation body 503a having mutually different exciting frequencies. At the same time, a part of high-frequency power is supplied by spatial coupling to second surface wave excitation body 503b, which is disposed such that heating-target object 102 is put between second surface wave excitation body 503b and the other surface wave excitation body. The supplied high-frequency power propagates as surface waves of different exciting frequencies near respective surfaces of first and second surface wave excitation bodies 503a and 503b, and hence the high-frequency heating device heats two faces of heating-target object 102.

[0160] The high-frequency heating device in this case, in common with the fourth exemplary embodiment, can make a choice among combinations of frequency fp of supplied high-frequency power, exciting frequency fc1 of first surface wave excitation body 503a, and exciting frequency fc2 of second surface wave excitation body 503b forming different magnitude relationships. This configuration enables the high-frequency heating device to have an arbitrary combination of filed intensity distributions near first and second surface wave excitation bodies 503a and 503b along which high-frequency power propagates as surface waves. As a result, the high-frequency heating device can heat the two faces of heating-target object 102 in a variety of patterns to suit purposes. In other words, the heating-target object can be heated and finished in a state desired by a user with heating unevenness reduced. The high-frequency heating device can also brown the two faces of heating-target object 102. This configuration eliminates the need for a heater or other heating sources.

[0161] High-frequency heating device 500 according to the present exemplary embodiment is configured as described above.

[0162] With reference to FIG. 15, how high-frequency heating device 500 described above heats heating-target object 102 will now be described.

[0163] FIG. 15 schematically illustrates an example of action of high-frequency power propagating as surface waves along first and second surface wave excitation bodies 503a and 503b to heat heating-target object 102 while high-frequency power generated by high-frequency power generation unit 220 is supplied via high-frequency power supply unit 210 to first surface wave excitation body 503a shown in FIG. 14.

[0164] In high-frequency heating device 500, as illustrated in FIG. 15, heating-target object 102 is put on stand 101, and first surface wave excitation body 503a and second surface wave excitation body 503b face each other through heating-target object 102. In the meanwhile, the high-frequency heating device supplies high-frequency power generated by high-frequency power generation unit 220 to first surface wave excitation body 503a via high-frequency power supply unit 210. The supplied high-frequency power makes up high-frequency power 550a and propagates as a surface wave along first surface wave excitation body 203a. Simultaneously, a part of high-frequency power makes up high-frequency power 550b and is radiated from first surface wave excitation body 503a to second surface wave excitation body 503b by spatial coupling. Radiated high-frequency power 550b makes up high-frequency power 550c and propagates as a surface wave along second surface wave excitation body 503b.

[0165] High-frequency power 550a and high-frequency power 550c propagating as surface waves form field intensity distributions near respective surfaces of first and second surface wave excitation bodies 503a and 503b. This configuration enables heating of the two faces of heating-target object 102.

[0166] In common with the fourth exemplary embodiment, sizes of propagating or radiated high-frequency power 550a, 550b, 550c can greatly change, as illustrated in FIGS. 16A to 16E, in accordance with the magnitude relationship between frequency fp of high-frequency power and each of exciting frequency fc1 of first surface wave excitation body 503a and exciting frequency fc2 of second surface wave excitation body 503b.

[0167] FIGS. 16A to 16E each schematically illustrate high-frequency power propagating as surface waves along first surface wave excitation body 503a and second surface wave excitation body 503b shown in FIGS. 14 and 15 and an example of field intensity distributions near surfaces of the surface wave excitation bodies, with a magnitude relationship formed between frequency fp of high-frequency power and each of exciting frequency fc1 and exciting frequency fc2.

[0168] In other words, FIGS. 16A to 16E each illustrate high-frequency power propagating as a surface wave along first surface wave excitation body 503a, high-frequency power radiated into a space toward second surface wave excitation body 503b, and high-frequency power propagating as a surface wave along second surface wave excitation body 503b, while high-frequency power generated by high-frequency power generation unit 220 is supplied to first surface wave excitation body 503a via high-frequency power supply unit 210. In addition, FIGS. 16A to 16E each illustrate an example of field intensity distributions formed near the surfaces of first and second surface wave excitation bodies 503a and 503b due to the propagating high-frequency power. In FIGS. 16A to 16E, intensity of electric fields in the field intensity distributions is represented with shading of a color. In this case, the darker the color, the stronger the electric field.

[0169] Modes of surface concentration of electric field and field intensity distribution formed near surface wave excitation body 503 in accordance with the magnitude relationship between frequency fp of high-frequency power and each of exciting frequencies fc1, fc2 shown in FIGS. 16A to 16E are similar to those in the fourth exemplary embodiment described with FIGS. 11A to 12C, and hence descriptions thereof will be omitted.

[0170] FIG. 16A illustrates high-frequency power and a field intensity distribution formed when frequency fp of high-frequency power and exciting frequency fc1 of first surface wave excitation body 503a are approximately equal (including equal) to each other. In this state, high-frequency power 551a propagating as a surface wave forms field intensity distribution 571a such that electric field intensity is highly concentrated close to the surface of first surface wave excitation body 503a. In this case, virtually no high-frequency power is radiated from propagating high-frequency power 551a into a space and hence no high-frequency power is supplied to second surface wave excitation body 503b regardless of exciting frequency fc2 of second surface wave excitation body 503b. As a result, a portion of heating-target object 102 adjacent to first surface wave excitation body 503a is heated with increased intensity.

[0171] FIG. 16B illustrates high-frequency power and a field intensity distribution formed when frequency fp of high-frequency power is higher than exciting frequency fc1 of first surface wave excitation body 503a and is approximately equal (including equal) to exciting frequency fc2 of second surface wave excitation body 503b. In this state, almost all of supplied high-frequency power is radiated as high-frequency power 552b into a space without propagating as a surface wave along first surface wave excitation body 503a. Because of high-frequency power 552b radiated into the space, high-frequency power 552c propagates as a surface wave close to the surface of second surface wave excitation body 503b. Propagating high-frequency power 552c forms field intensity distribution 572b such that electric field intensity is highly concentrated close to the surface of second surface wave excitation body 503b. Thus, a portion of heating-target object 102 adjacent to second surface wave excitation body 503b is heated with increased intensity.

[0172] FIG. 16C illustrates high-frequency power and a field intensity distribution formed when frequency fp of high-frequency power is lower than both exciting frequency fc1 of first surface wave excitation body 503a and exciting frequency fc2 of second surface wave excitation body 503b. In this state, high-frequency power supplied to first surface wave excitation body 503a makes up high-frequency power 553a and propagates as a surface wave close to the surface of first surface wave excitation body 503a. Propagating high-frequency power 553a forms field intensity distribution 573a such that a moderate concentration of electric field intensity is observed close to the surface of first surface wave excitation body 503a. Simultaneously, high-frequency power supplied to first surface wave excitation body 503a is radiated as high-frequency power 553b into a space. High-frequency power 553b radiated into the space makes up high-frequency power 553c and propagates as a surface wave close to the surface of second surface wave excitation body 503b. Propagating high-frequency power 553a forms field intensity distribution 573b such that a low concentration of electric field intensity is observed close to the surface of second surface wave excitation body 503b. This configuration allows two faces of heating-target object 102 to be heated. Heating-target object 102 is heated such that a portion of the heating-target object adjacent to first surface wave excitation body 503a is heated with relatively increased intensity and a portion adjacent to second surface wave excitation body 503b is heated with relatively decreased intensity.

[0173] FIG. 16D illustrates high-frequency power and a field intensity distribution formed when frequency fp of high-frequency power is lower than exciting frequency fc1 of first surface wave excitation body 203a and is approximately equal (including equal) to exciting frequency fc2 of second surface wave excitation body 503b. In this state, high-frequency power supplied to first surface wave excitation body 503a makes up high-frequency power 554a and propagates as a surface wave close to the surface of first surface wave excitation body 503a. Propagating high-frequency power 554a forms field intensity distribution 574a such that a low concentration of electric field intensity is observed close to the surface of first surface wave excitation body 503a. Simultaneously, high-frequency power supplied to first surface wave excitation body 503a is radiated as high-frequency power 554b into a space. High-frequency power 554b radiated into the space makes up high-frequency power 554c and propagates as a surface wave close to the surface of second surface wave excitation body 503b. Propagating high-frequency power 554c forms field intensity distribution 574b such that a moderate concentration of electric field intensity is observed close to the surface of second surface wave excitation body 503b. This configuration allows the two faces of heating-target object 102 to be heated. Heating-target object 102 is heated such that a portion of the heating-target object adjacent to first surface wave excitation body 503a is heated with relatively decreased intensity and a portion adjacent to second surface wave excitation body 503b is heated with relatively increased intensity.

[0174] FIG. 16E illustrates high-frequency power and a field intensity distribution formed when frequency fp of high-frequency power is higher than both exciting frequency fc1 of first surface wave excitation body 503a and exciting frequency fc2 of second surface wave excitation body 503b. In this state, almost all of high-frequency power supplied to first surface wave excitation body 503a is radiated as high-frequency power 555b into a space without propagating as a surface wave along first surface wave excitation body 503a. High-frequency power 555b radiated into the space does not propagate as a surface wave along second surface wave excitation body 503b. Thus, any field intensity distribution showing a concentration of electric field intensity close to any of the surfaces of first and second surface wave excitation bodies 503a and 503b is not formed. Accordingly, radiated high-frequency power 555b forms field intensity distribution 575 between first and second surface wave excitation bodies 503a and 503b. This configuration enables heating of entire heating-target object 102 in a similar manner to heating by a microwave oven.

[0175] Differences in field intensity among field intensity distributions 571a, 572b, 573a, 573b, 574a, 574b, 575 described above with FIGS. 16A to 16E will now be summarized.

[0176] In this case, approximate differences are as described below although field intensity distributions are partly dependent on a size of a space in which heating-target object 102 is put and an amount of high-frequency power radiated into the space. As described below, field intensity distribution 575 shows lowest field intensity.

[0177] The differences in field intensity are: field intensity distribution 571a $\approx$ field intensity distribution 572b > field intensity distribution 573a $\approx$ field intensity distribution 574b > field intensity distribution 574a $\approx$ field intensity distribution 573b > field intensity distribution 575.

[0178] As illustrated in FIGS. 16A to 16E, if first and second surface wave excitation bodies 503a and 503b are disposed such that heating-target object 102 is put between the surface wave excitation bodies, field intensity distributions are formed as described below. Specifically, in accordance with different magnitude relationships between frequency fp of high-frequency power and each of exciting frequencies fc1 and fc2, a variety of field intensity distributions can be formed close to the surfaces of first and second surface wave excitation bodies 503a and 503b.

[0179] In other words, high-frequency heating device 500 according to the present exemplary embodiment can make a choice among combinations of frequency fp of high-frequency power, exciting frequency fc1 of first surface wave excitation body 503a, and exciting frequency fc2 of second surface wave excitation body 503b in magnitude relationship. This configuration enables the high-frequency heating device to have an arbitrary combination of filed intensity distributions near surface wave excitation bodies 503 along which high-frequency power propagates as surface waves. As a result, the high-frequency heating device can heat heating-target object 102 in a variety of patterns to suit a purpose desired by a user.

[0180] The high-frequency heating device may choose any combination of frequency fp of high-frequency power and exciting frequencies fc1, fc2 in magnitude relationship other than the combinations shown in FIGS. 16A to 16E. This allows the high-frequency heating device to heat heating-target object 102 in an increased variety of patterns.

[0181] In other words, the above-described combinations of frequency fp of high-frequency power, exciting frequency fc1 of first surface wave excitation body 503a, and exciting frequency fc2 of second surface wave excitation body 503b are shown by way of example. Thus, the high-frequency heating device may have any other combination of frequency fp and exciting frequencies fc1, fc2. This enables the high-frequency heating device to adjust heating of heating-target object 102 in heating strength, finish, and other parameters in an increased variety of patterns to suit a preference of a user.

[0182] In common with the fourth exemplary embodiment, exciting frequency fc1 of first surface wave excitation body 503a and exciting frequency fc2 of second surface wave excitation body 503b may be set in advance such that these surface wave excitation bodies possess desired exciting frequencies by adjusting the heights, the intervals or other dimensions of the metallic flat plates of these surface wave excitation bodies. At least one of first and second surface wave excitation bodies 503a and 503b may be a surface wave excitation body having a variable exciting frequency. This produces effects in terms of two aspects, i.e., various heating patterns by frequency adjustment, as well as the simplified device configuration described above by spatial coupling.

[0183] In the present exemplary embodiment, in common with the second exemplary embodiment described above, high-frequency power may be supplied from high-frequency power generation unit 220 to second surface wave excitation body 503b disposed above heating-target object 102.

(Sixth exemplary embodiment)

[0184] With reference to FIG. 17, high-frequency heating device 600 according to a sixth exemplary embodiment of the present invention will now be described.

[0185] FIG. 17 is a block diagram illustrating a configuration of high-frequency heating device 600 according to the sixth exemplary embodiment.

[0186] As illustrated in FIG. 17, high-frequency heating device 600 is similar in basic configuration to high-frequency heating device 300 of the third exemplary embodiment described with reference to FIG. 7. Thus, elements such as components and effects identical to those in the third exemplary embodiment are denoted by the same numerals or symbols, and descriptions thereof will be omitted.

[0187] However, high-frequency heating device 600 differs from the high-frequency heating device of the third exemplary embodiment in that high-frequency heating device 600 includes first surface wave excitation body 603a and second surface wave excitation body 603b having mutually different exciting frequencies.

[0188] In other words, in common with the third exemplary embodiment, high-frequency heating device 600 illustrated in FIG. 17 includes first surface wave excitation body 603a, second surface wave excitation body 603b, first high-frequency power supply unit 310a, second high-frequency power supply unit 310b, first high-frequency power generation unit 320a, and second high-frequency power generation unit 320b. First and second surface wave excitation bodies 603a and 603b are disposed at locations opposite to each other such that heating-target object 102 is put between the surface wave excitation bodies. At the same time, first and second surface wave excitation bodies 603a and 603b have different exciting frequencies as described above.

[0189] In the description hereafter, first surface wave excitation body 603a and second surface wave excitation body 603b may be generically referred to as surface wave excitation body 603 if no particular distinction is drawn.

[0190] High-frequency heating device 600 supplies high-frequency power generated by first high-frequency power generation unit 320a to first surface wave excitation body 603a via first high-frequency power supply unit 310a. The supplied high-frequency power propagates as a surface wave along first surface wave excitation body 603a to heat an undersurface of heating-target object 102. At the same time, a part of high-frequency power propagating as a surface wave along first surface wave excitation body 603a is supplied by spatial coupling to second surface wave excitation body 603b disposed opposite to first surface wave excitation body 603a. The supplied high-frequency power propagates as a surface wave along second surface wave excitation body 603b to heat a top surface of heating-target object 102.

[0191] Meanwhile, high-frequency power generated by second high-frequency power generation unit 320b is supplied to second surface wave excitation body 603b via second high-frequency power supply unit 310b. The supplied high-frequency power propagates as a surface wave along second surface wave excitation body 603b to heat the top surface of heating-target object 102. At the same time, a part of high-frequency power propagating as a surface wave along second surface wave excitation body 603b is supplied by spatial coupling to first surface wave excitation body 303a disposed opposite to second surface wave excitation body 603b. The supplied high-frequency power propagates as a surface wave along first surface wave excitation body 603a to heat the undersurface of heating-target object 102.

[0192] In other words, in high-frequency heating device 600 according to the present exemplary embodiment, first and second surface wave excitation bodies 603a and 603b having mutually different exciting frequencies are disposed at locations opposite to each other such that heating-target object 102 is put between the surface wave excitation bodies. The high-frequency heating device supplies high-frequency power generated by first high-frequency power generation unit 320a to first surface wave excitation body 603a via first high-frequency power supply unit 310a. Simultaneously, a part of high-frequency power is supplied to second surface wave excitation body 603b by spatial coupling. The supplied high-frequency power propagates as surface waves near surfaces of first and second surface wave excitation bodies 603a and 603b, which have different exciting frequencies, to heat two faces of heating-target object 102.

[0193] Meanwhile, the high-frequency heating device supplies high-frequency power generated by second high-frequency power generation unit 320b to second surface wave excitation body 603b via second high-frequency power supply unit 310b. Simultaneously, a part of high-frequency power is supplied to first surface wave excitation body 603a by spatial coupling. The supplied high-frequency power propagates as surface waves near the surfaces of first and second surface wave excitation bodies 603a and 603b, which have different exciting frequencies, to heat the two faces of heating-target object 102.

[0194] The high-frequency heating device in this case, in common with the fourth and fifth exemplary embodiments, can make a choice among combinations of frequency fp of high-frequency power, exciting frequency fc1 of first surface wave excitation body 603a, and exciting frequency fc2 of second surface wave excitation body 603b forming different magnitude relationships. This configuration enables the high-frequency heating device to have an arbitrary combination of filed intensity distributions near first and second surface wave excitation bodies 603a and 603b along which high-frequency power propagates as surface waves. As a result, the high-frequency heating device can heat the two faces of heating-target object 102 in a variety of patterns to suit purposes. In other words, the heating-target object can be heated and finished in a state desired by a user with heating unevenness reduced. The high-frequency heating device can also brown the two faces of heating-target object 102. This configuration eliminates the need for a heater or other heating sources.

[0195] High-frequency heating device 600 according to the present exemplary embodiment is configured as described above.

[0196] With reference to FIG. 18, how high-frequency heating device 600 described above heats heating-target object 102 will now be described.

[0197] FIG. 18 schematically illustrates an example of action of high-frequency power propagating as surface waves along first and second surface wave excitation bodies 603a and 603b shown in FIG. 17 to heat heating-target object 102.

[0198] In other words, FIG. 18 schematically illustrates action of high-frequency power propagating as a surface wave along first surface wave excitation body 603a to heat heating-target object 102 while high-frequency power generated by first high-frequency power generation unit 320a is supplied to first surface wave excitation body 603a via first high-frequency power supply unit 310a. FIG. 18 also schematically illustrates action of high-frequency power propagating as a surface wave along second surface wave excitation body 603b to heat heating-target object 102 while high-frequency power generated by second high-frequency power generation unit 320b is supplied to second surface wave excitation body 603b via second high-frequency power supply unit 310b.

[0199] In high-frequency heating device 600, as illustrated in FIG. 18, heating-target object 102 is put on stand 101, and first surface wave excitation body 603a and second surface wave excitation body 603b face each other through heating-target object 102.

[0200] The high-frequency heating device supplies high-frequency power generated by first high-frequency power generation unit 320a to first surface wave excitation body 603a via first high-frequency power supply unit 310a. The supplied high-frequency power makes up high-frequency power 650a and propagates as a surface wave along first surface wave excitation body 603a. Simultaneously, a part of high-frequency power makes up high-frequency power 650b and is radiated from first surface wave excitation body 603a to second surface wave excitation body 603b by spatial coupling. Radiated high-frequency power 650b propagates as a surface wave along second surface wave excitation body 603b.

[0201] Similarly, the high-frequency heating device supplies high-frequency power generated by second high-frequency power generation unit 320b to second surface wave excitation body 603b via second high-frequency power supply unit 310b. The supplied high-frequency power makes up high-frequency power 650c and propagates as a surface wave along second surface wave excitation body 603b. Simultaneously, a part of high-frequency power makes up high-frequency power 650d and is radiated from second surface wave excitation body 603b to first surface wave excitation body 603a by spatial coupling. Radiated high-frequency power 650d propagates as a surface wave along first surface wave excitation body 603a.

[0202] In other words, as illustrated in FIG. 18, high-frequency power supplied to first surface wave excitation body 603a is divided into high-frequency power 650a and high-frequency power 650b. High-frequency power 650a propagates as a surface wave along first surface wave excitation body 603a, whereas high-frequency power 650b is radiated into a space toward second surface wave excitation body 603b.

[0203] Meanwhile, high-frequency power supplied to second surface wave excitation body 603b is divided into high-frequency power 650c and high-frequency power 650d. High-frequency power 650c propagates as a surface wave along second surface wave excitation body 603b, whereas high-frequency power 650d is radiated into a space toward first surface wave excitation body 603a.

[0204] High-frequency power 650a and high-frequency power 650c propagating as surface waves along first surface wave excitation body 603a and second surface wave excitation body 603b form field intensity distributions near respective surfaces of first and second surface wave excitation bodies 603a and 603b. This configuration enables heating of the two faces of heating-target object 102.

[0205] In the meanwhile, sizes of propagating high-frequency power 650a, 650b, 650c, and 650d can greatly change, as illustrated in FIGS. 19A to 19E, in accordance with a magnitude relationship between frequencies fp1, fp2 of high-frequency power supplied to first and second surface wave excitation bodies 603a and 603b, and exciting frequency fc1 of first surface wave excitation body 603a and exciting frequency fc2 of second surface wave excitation body 603b.

[0206] FIGS. 19A to 19E each schematically illustrate high-frequency power propagating as surface waves along first surface wave excitation body 603a and second surface wave excitation body 603b shown in FIGS. 17 and 18 and an example of field intensity distributions near surfaces of the surface wave excitation bodies, with a magnitude relationship formed between frequencies fp1, fp2 of high-frequency power and exciting frequencies fc1, fc2.

[0207] In other words, FIGS. 19A to 19E each illustrate high-frequency power propagating as a surface wave along first surface wave excitation body 603a and high-frequency power radiated into a space toward second surface wave excitation body 603b while high-frequency power generated by first high-frequency power generation unit 320a is supplied to first surface wave excitation body 603a via first high-frequency power supply unit 310a. In addition, the drawings each illustrate an example of a field intensity distribution formed near the surface of first surface wave excitation body 603a.

[0208] Similarly, FIGS. 19A to 19E each illustrate high-frequency power propagating as a surface wave along second surface wave excitation body 303b and high-frequency power radiated into a space toward first surface wave excitation body 303a while high-frequency power generated by second high-frequency power generation unit 320b is supplied to second surface wave excitation body 603b via second high-frequency power supply unit 310b. In addition, the drawings each illustrate an example of a field intensity distribution formed near the surface of second surface wave excitation body 603b. In FIGS. 19A to 19E, intensity of electric fields in the field intensity distributions is represented with shading of a color. In this case, the darker the color, the stronger the electric field.

[0209] Modes of surface concentration of electric field and field intensity distribution formed near surface wave excitation body 603 in accordance with the magnitude relationship between frequencies fp1, fp2 of high-frequency power and exciting frequencies fc1, fc2 shown in FIGS. 19A to 19E are similar to those in the fourth exemplary embodiment described with FIGS. 11A to 12C, and hence descriptions thereof will be omitted.

[0210] FIG. 19A illustrates high-frequency power and a field intensity distribution formed when frequency fp1 of high-frequency power supplied to first surface wave excitation body 603a and exciting frequency fc of first surface wave excitation body 603a are approximately equal (including equal) to each other and when frequency fp2 of high-frequency power supplied to second surface wave excitation body 603b and exciting frequency fc2 of second surface wave excitation body 603b are approximately equal (including equal) to each other. In this state, high-frequency power 651a, 651c propagating as respective surface waves form field intensity distributions 671a, 671b such that a relatively high concentration of electric field intensity is observed close to the surfaces of first and second surface wave excitation bodies 603a and 603b. In this case, a substantially low amount of high-frequency power is radiated into a space from first and second surface wave excitation bodies 603a and 603b. As a result, portions of heating-target object 102 adjacent to respective first and second surface wave excitation bodies 603a and 603b, i.e., the two faces of the heating-target object, are heated with moderate intensity.

[0211] FIG. 19B illustrates high-frequency power and a field intensity distribution formed when frequencies fp1 and fp2 of high-frequency power are equal (including equal) to each other and are approximately equal (including equal) to exciting frequency fc1 of first surface wave excitation body 603a and when these frequencies are higher than exciting frequency fc2 of second surface wave excitation body 603b. In this state, high-frequency power supplied to first surface wave excitation body 603a makes up high-frequency power 652a that propagates as a surface wave along first surface wave excitation body 603a because of a substantially low amount of the high-frequency power being radiated into a space toward second surface wave excitation body 603b. On the other hand, high-frequency power supplied to second surface wave excitation body 603b makes up high-frequency power 652d that is radiated into a space toward first surface wave excitation body 603a because of virtually none of the high-frequency power propagating as a surface wave along second surface wave excitation body 603b. High-frequency power 652d radiated into the space makes up high-frequency power 652e that propagates as a surface wave along first surface wave excitation body 303a. As a result, both high-frequency power 652a, 652e form field intensity distribution 672a such that a very high concentration of electric field intensity is observed close to the surface of first surface wave excitation body 603a. Accordingly, only a portion of heating-target object 102 adjacent to first surface wave excitation body 603a is very strongly heated.

[0212] FIG. 19C illustrates high-frequency power and a field intensity distribution formed when frequencies fp1 and fp2 of high-frequency power are equal to each other and are approximately equal (including equal) to exciting frequency fc2 and when these frequencies are higher than exciting frequency fc1. In this state, high-frequency power supplied to second surface wave excitation body 603b makes up high-frequency power 653c that propagates as a surface wave along second surface wave excitation body 603b because of a substantially low amount of the high-frequency power being radiated into a space toward first surface wave excitation body 603a. High-frequency power supplied to first surface wave excitation body 603a makes up high-frequency power 653b that is radiated into a space toward second surface wave excitation body 603b because of virtually none of the high-frequency power propagating as a surface wave along first surface wave excitation body 603a. High-frequency power 653b radiated into the space makes up high-frequency power 653e that propagates as a surface wave along second surface wave excitation body 603b. As a result, both high-frequency power 653c, 653e form field intensity distribution 673b such that a very high concentration of electric field intensity is observed close to the surface of second surface wave excitation body 603b. Accordingly, only a portion of heating-target object 102 adjacent to second surface wave excitation body 603b is very strongly heated.

[0213] FIG. 19D illustrates high-frequency power and a field intensity distribution formed when frequency fp1 of high-frequency power is approximately equal (including equal) to exciting frequency fc1 and when frequency fp2 of high-frequency power is lower than exciting frequencies fc1 and fc2. In this state, high-frequency power supplied to first surface wave excitation body 603a makes up high-frequency power 654a that propagates as a surface wave along first surface wave excitation body 603a because of a relatively low amount of the high-frequency power being radiated into a space toward second surface wave excitation body 603b. High-frequency power supplied to second surface wave excitation body 603b is divided into high-frequency power 654c that propagates as a surface wave along second surface wave excitation body 603b and high-frequency power 654d that is radiated into a space toward first surface wave excitation body 603a. High-frequency power 654d radiated into the space makes up high-frequency power 654e that propagates as a surface wave along first surface wave excitation body 603a. As a result, both high-frequency power 654a, 654e propagating as respective surface waves form field intensity distribution 674a such that a high concentration of electric field intensity is observed close to the surface of first surface wave excitation body 603a. In addition, high-frequency power 654c forms field intensity distribution 674b such that a low concentration of electric field intensity is observed close to the surface of second surface wave excitation body 603b. Accordingly, the two faces of heating-target object 102 is heated such that a portion of the heating-target object adjacent to first surface wave excitation body 603a is heated with high intensity and a portion adjacent to second surface wave excitation body 603b is heated with low intensity.

[0214] FIG. 19E illustrates high-frequency power and a field intensity distribution formed when frequencies fp1 and fp2 of high-frequency power are higher than exciting frequencies fc1 and fc2. In this state, high-frequency power supplied to first and second surface wave excitation bodies 603a and 603b makes up respective high-frequency power 655b, 655d that are radiated into a space without propagating as surface waves along first and second surface wave excitation bodies 603a and 603b. Thus, any field intensity distribution showing a concentration of electric field intensity close to the surface of surface wave excitation body 603 is not formed. The radiated high-frequency power forms field intensity distribution 675 between first and second surface wave excitation bodies 603a and 603b. This configuration enables heating of entire heating-target object 102 in a similar manner to heating by a microwave oven.

[0215] Differences in field intensity among field intensity distributions 671a, 671b, 672a, 673b, 674a, 674b, 675 shown in FIGS. 19A to 19E will now be summarized.

[0216] In this case, approximate differences are as described below although field intensity distributions are partly dependent on a size of a space in which heating-target object 102 is put and an amount of high-frequency power radiated into the space. As described below, field intensity distribution 675 shows lowest field intensity.

[0217] The differences in field intensity are: field intensity distribution 672a ≈ field intensity distribution 673b > field intensity distribution 674a > field intensity distribution 671a ≈ field intensity distribution 671b > field intensity distribution 674b > field intensity distribution 675.

[0218] As illustrated in FIGS. 19A to 19E, if first and second surface wave excitation bodies 603a and 603b are disposed such that heating-target object 102 is put between the surface wave excitation bodies, field intensity distributions are formed as described below. Specifically, in accordance with different magnitude relationships between frequencies fp1, fp2 of high-frequency power, exciting frequency fc1 of first surface wave excitation body 603a, and exciting frequency fc2 of second surface wave excitation body 303b, an increased variety of field intensity distributions can be formed close to the surfaces of first and second surface wave excitation bodies 603a and 603b.

[0219] In other words, high-frequency heating device 600 according to the present exemplary embodiment can make a choice among combinations of frequencies fp1, fp2 of high-frequency power supplied to first and second surface wave excitation bodies 303a and 603b, exciting frequency fc1 of first surface wave excitation body 603a, and exciting frequency fc2 of second surface wave excitation body 303b in magnitude relationship. This configuration enables the high-frequency heating device to have an arbitrary combination of filed intensity distributions near surface wave excitation bodies 603 along which high-frequency power propagates as surface waves. As a result, the high-frequency heating device can heat heating-target object 102 in a variety of patterns to suit a purpose desired by a user.

[0220] The high-frequency heating device may choose any combination of frequencies fp1, fp2 of high-frequency power and exciting frequencies fc1, fc2 in magnitude relationship other than the combinations shown in FIGS. 19A to 19E. This allows the high-frequency heating device to heat heating-target object 102 in an increased variety of patterns.

[0221] In other words, the above-described combinations of frequencies fp1, fp2 of high-frequency power, exciting frequency fc1 of first surface wave excitation body 603a, and exciting frequency fc2 of second surface wave excitation body 603b are shown by way of example. Thus, the high-frequency heating device may have any other combination of frequencies fp1, fp2 and exciting frequencies fc1, fc2. This enables the high-frequency heating device to adjust heating of heating-target object 102 in heating strength, finish, and other parameters in an increased variety of patterns to suit a preference of a user.

[0222] In common with the fourth and fifth exemplary embodiments, exciting frequency fc1 of first surface wave excitation body 603a and exciting frequency fc2 of second surface wave excitation body 603b may be set in advance such that these surface wave excitation bodies possess desired exciting frequencies by adjusting the heights, the intervals, or other dimensions of the metallic flat plates of these surface wave excitation bodies. At least one of first and second surface wave excitation bodies 603a and 603b may be a surface wave excitation body having a variable exciting frequency. This produces a variety of effects in heating a heating-target object.

[0223] In the present exemplary embodiment, in common with the exemplary embodiments described above, high-frequency power may be supplied to surface wave excitation body 603 from opposing directions or other directions.

[0224] In high-frequency heating devices 400, 500, and 600 according to the fourth to the sixth exemplary embodiments, high-frequency power generation units 120, 220, 320a, and 320b may each include a high-frequency oscillator that generates high-frequency power at a set variable frequency as described in the third exemplary embodiment.

[0225] As described above, a variable frequency high-frequency oscillator is, for example, a VCO or a PLL oscillator including a reference signal generator and a phase comparator. A high-frequency heating device equipped with a single high-frequency power generation unit having this configuration can generate high-frequency power at a plurality of frequencies. As a result, the high-frequency heating device can readily and freely set a magnitude relationship, as described above, between a frequency of high-frequency power supplied to a surface wave excitation body and an exciting frequency of the surface wave excitation body.

[0226] In other words, the high-frequency heating device can freely change heating patterns dependent on combinations of states of high-frequency power that propagates as surface waves along a plurality of surface wave excitation bodies. Consequently, the high-frequency heating device having a simple configuration can heat two faces of heating-target object 102 put on stand 101 into a finish state desired by a user with heating unevenness reduced. The high-frequency heating device can also brown the two faces of heating-target object 102.

[0227] Although the high-frequency heating device according to the present invention has been described based on the exemplary embodiments, the present invention is not limited to the exemplary embodiments. Without departing from the gist of the present invention, any modifications conceivable by those skilled in the art to the exemplary embodiments, as well as any forms configured by combining components in different exemplary embodiments are also included within the scope of the present invention.

[0228] As described above, a high-frequency heating device according to the present invention includes the high-frequency power generation unit configured to generate high-frequency power, a plurality of the surface wave excitation bodies configured to propagate the high-frequency power as respective surface waves to heat a heating-target object, the high-frequency power supply unit configured to supply the high-frequency power to the plurality of surface wave excitation bodies, and the stand on which the heating-target object is mounted. The plurality of the surface wave excitation bodies are disposed at locations opposite to each other such that the heating-target object is put between the plurality of surface wave excitation bodies. As a result, the high-frequency heating device having a simple configuration can heat two faces of the heating-target object without using a heater or other heating sources that consume a large quantity of electricity.

[0229] A high-frequency heating device according to the present invention may include a plurality of surface wave excitation bodies having different exciting frequencies. This configuration enables the high-frequency heating device to arbitrarily combine filed intensity distributions formed near the respective surface wave excitation bodies along which high-frequency power propagates as surface waves and thereby heat the heating-target object. As a result, the high-frequency heating device having a simple configuration can heat two faces of the heating-target object into a finish state desired by a user.

[0230] In a high-frequency heating device according to the present invention, a high-frequency power generation unit may supply the high-frequency power only to at least one of a plurality of surface wave excitation bodies. This configuration enables a reduction in a number of high-frequency power supply units. As a result, the high-frequency heating device having a simplified configuration can heat two faces of the heating-target object.

[0231] A high-frequency heating device according to the present invention may include a plurality of high-frequency power generation units corresponding to a plurality of surface wave excitation bodies, so that the plurality of the high-frequency power generation units supply high-frequency power to the plurality of the surface wave excitation bodies. This configuration enables more detailed control of heating states near the respective surface wave excitation bodies. This in turn allows the high-frequency heating device to heat a heating-target object and produce improvement in finished quality.

[0232] In a high-frequency heating device according to the present invention, a high-frequency power generation unit may include a high-frequency oscillator that generates high-frequency power at a set variable frequency. This configuration allows the high-frequency power generation unit to supply high-frequency power at a variable frequency to a surface wave excitation body. Thus, a state of high-frequency power propagating as a surface wave along the surface wave excitation body can change. This enables the high-frequency heating device to readily change how a heating-target object is heated in response to a preference of a user.

INDUSTRIAL APPLICABILITY

[0233] The present invention provides a high-frequency heating device having a simple configuration and being capable of heating and browning two faces of a heating-target object without using other heating sources. Thus, the present invention is useful for microwave heaters and other cooking appliances that are required to fulfill the same function of the high-frequency heating device.

REFERENCE MARKS IN THE DRAWINGS

[0234]

100, 200, 300, 400, 500, 600: high-frequency heating device
101: stand
102: heating-target object
103, 203, 303, 403, 503, 603: surface wave excita-

tion body
103a, 203a, 303a, 403a, 503a, 603a: first surface wave excitation body
103b, 203b, 303b, 403b, 503b, 603b: second surface wave excitation body
110, 210, 310: high-frequency power supply unit
110a, 310a: first high-frequency power supply unit
110b, 310b: second high-frequency power supply unit
120, 220, 320: high-frequency power generation unit
130: rectangular wave guide
131: tapered rectangular wave guide
140a, 140b, 140c, 240a, 240b, 343a, 343b, 441a, 441b, 461, 462, 463, 471, 472, 473, 474, 475, 571a, 572b, 573a, 573b, 574a, 574b, 575, 671a, 671b, 672a, 672b, 673b, 674a, 674b, 675: field intensity distribution
250a, 250b, 350a, 350b, 350c, 350d, 351a, 351b, 550a, 550b, 550c, 551a, 552b, 552c, 553a, 553b, 553c, 554a, 554b, 554c, 555b, 650a, 650b, 650c, 650d, 651a, 651c, 652a, 652d, 652e, 653b, 653c, 653e, 654a, 654c, 654d, 654e, 655b, 655d: high-frequency power
320a: first high-frequency power generation unit
320b: second high-frequency power generation unit

Claims

1. A high-frequency heating device comprising:

   a high-frequency power generation unit configured to generate high-frequency power;
   a plurality of surface wave excitation bodies configured to propagate the high-frequency power as respective surface waves to heat a heating-target object;
   a high-frequency power supply unit configured to supply the high-frequency power to the plurality of surface wave excitation bodies; and
   a stand on which the heating-target object is mounted,
   wherein the plurality of surface wave excitation bodies are disposed at locations opposite to each other in such a manner that the heating-target object is put between the plurality of surface wave excitation bodies.

2. The high-frequency heating device according to claim 1, wherein the plurality of surface wave excitation bodies have different exciting frequencies.

3. The high-frequency heating device according to claim 1, wherein the high-frequency power generation unit supplies the high-frequency power only to at least one of the plurality of surface wave excitation bodies.

4. The high-frequency heating device according to claim 1, including a plurality of the high-frequency power generation units corresponding to the plurality of surface wave excitation bodies,
   wherein the plurality of the high-frequency power generation units supply the high-frequency power to the plurality of surface wave excitation bodies.

5. The high-frequency heating device according to claim 1, wherein the high-frequency power generation unit includes a high-frequency oscillator that generates high-frequency power at a set variable frequency.

FIG. 1

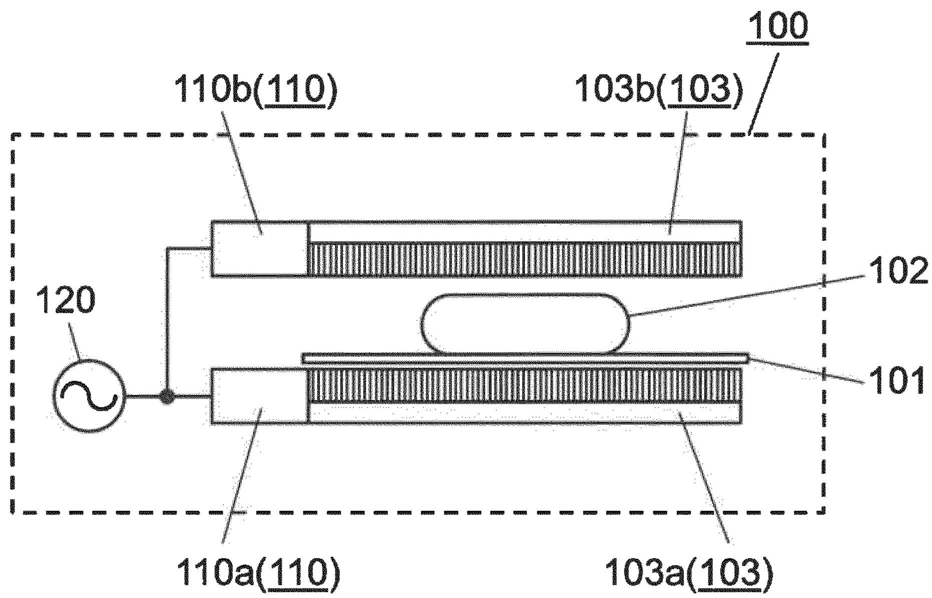

100
110b(110)
103b(103)
102
120
101
110a(110)
103a(103)

FIG. 2

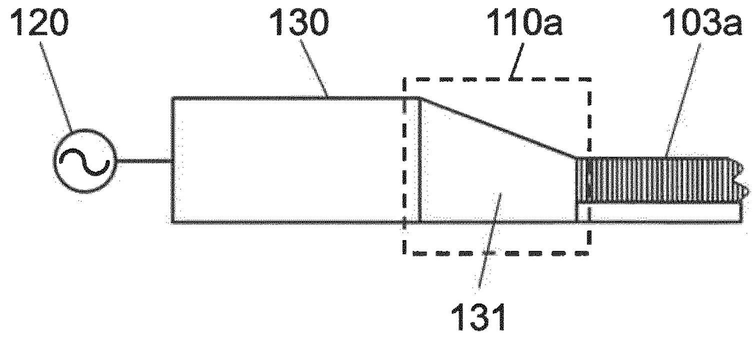

120
130
110a
103a
131

FIG. 3A

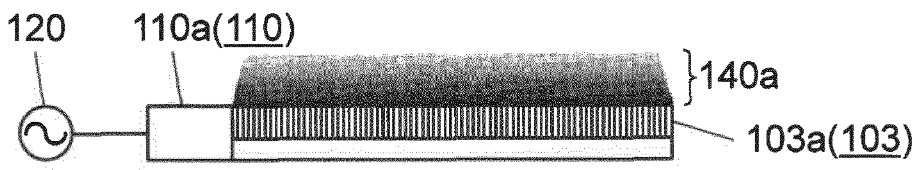


FIG. 3B

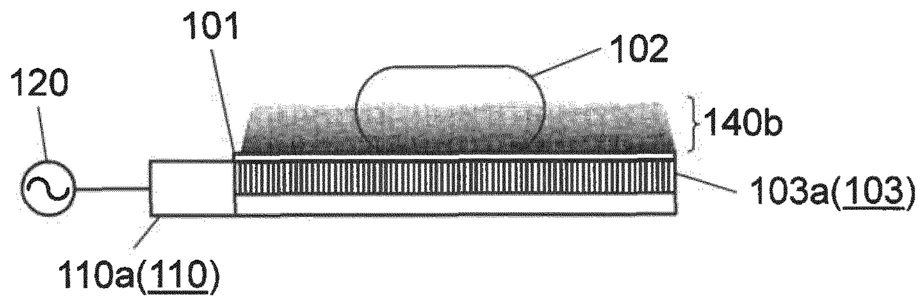


FIG. 3C

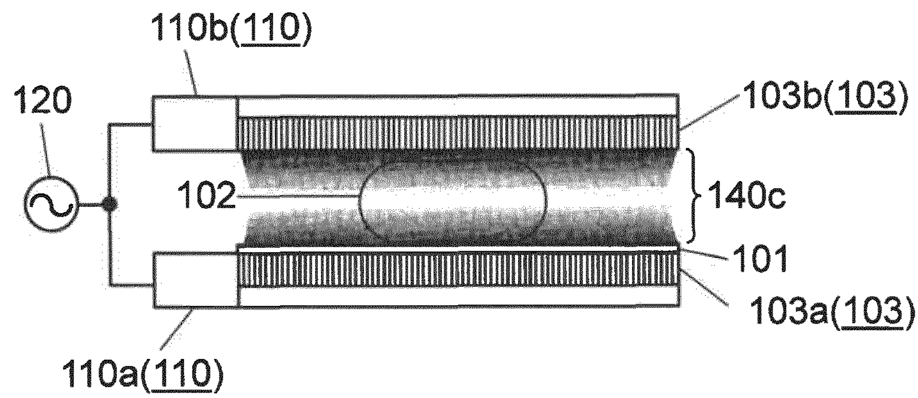


FIG. 4

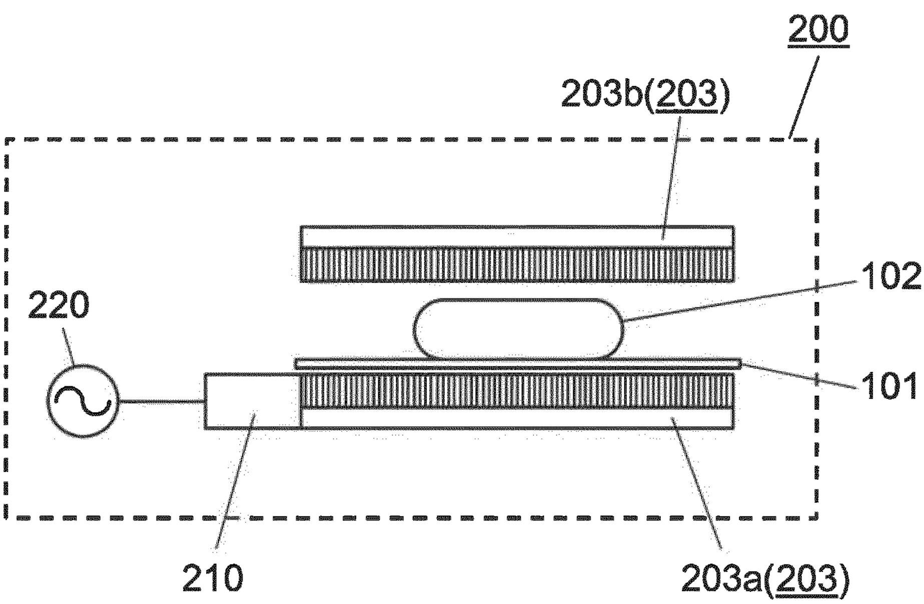


FIG. 5

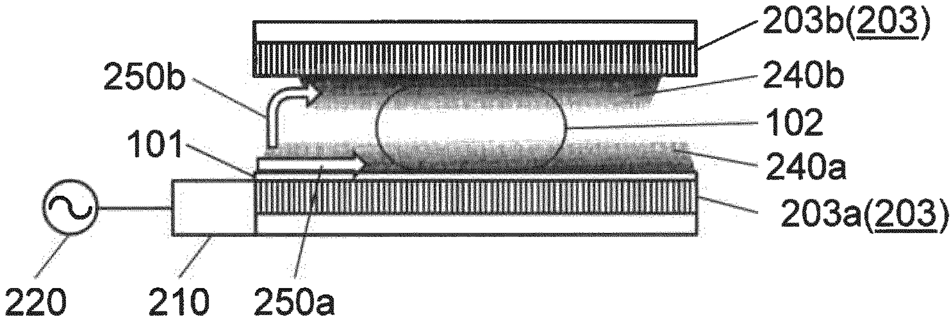

203b(203)
250b
240b
102
101
240a
203a(203)
220
210
250a

FIG. 6

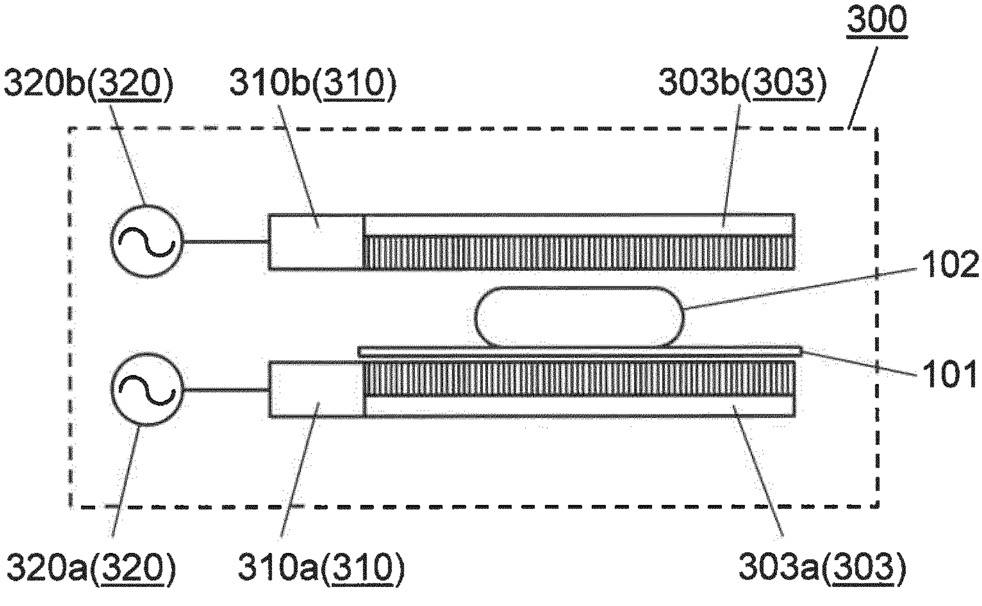

300
320b(320)
310b(310)
303b(303)
102
101
320a(320)
310a(310)
303a(303)

FIG. 7

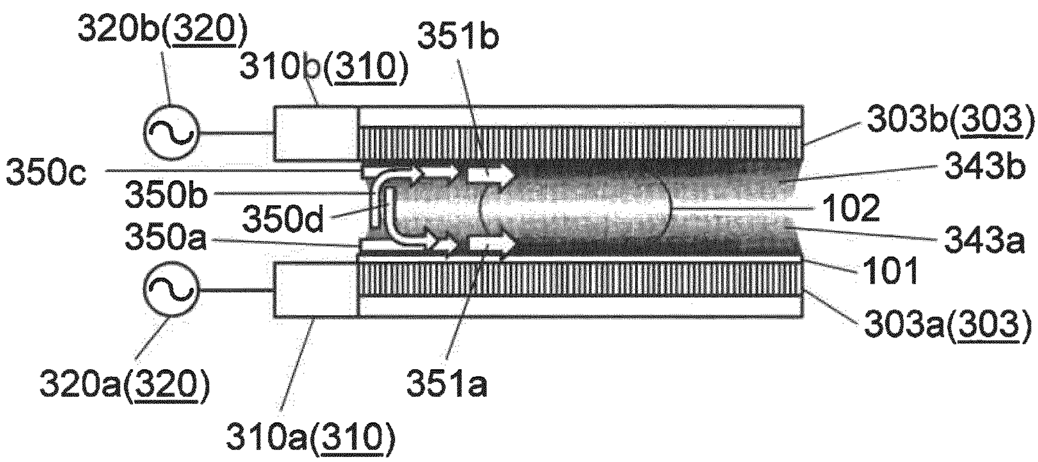

320b(320)
310b(310)
351b
303b(303)
350c
343b
350b
350d
102
350a
343a
101
303a(303)
320a(320)
351a
310a(310)

FIG. 8A

fp<fc

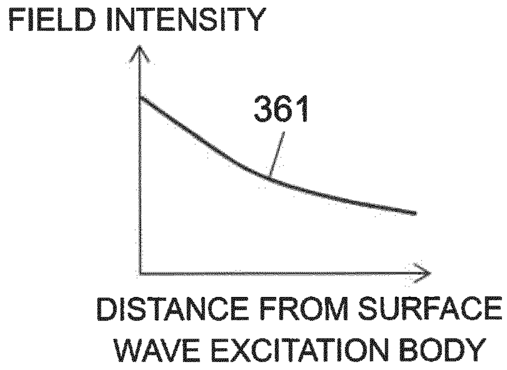


FIG. 8B

fp ≈ fc

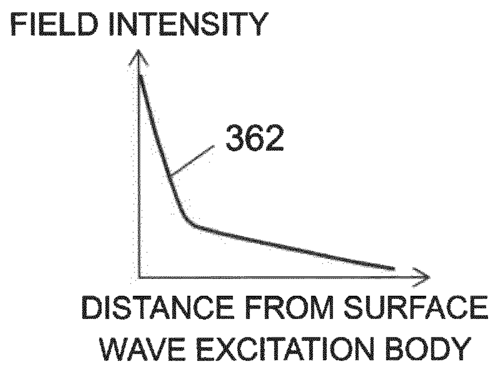


FIG. 8C

fp>fc

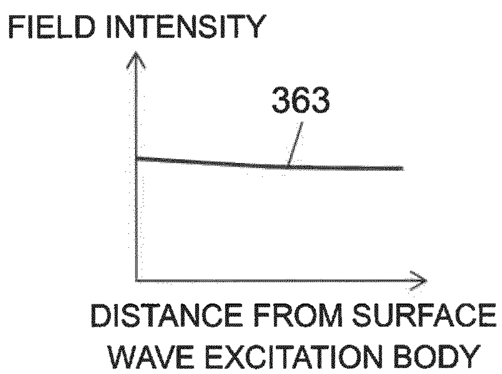


FIG. 9

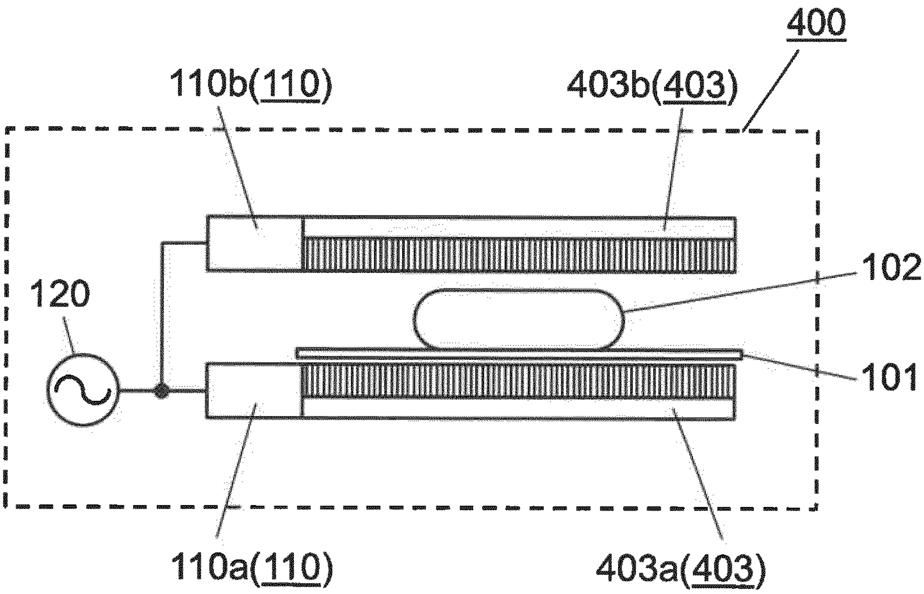


FIG. 10

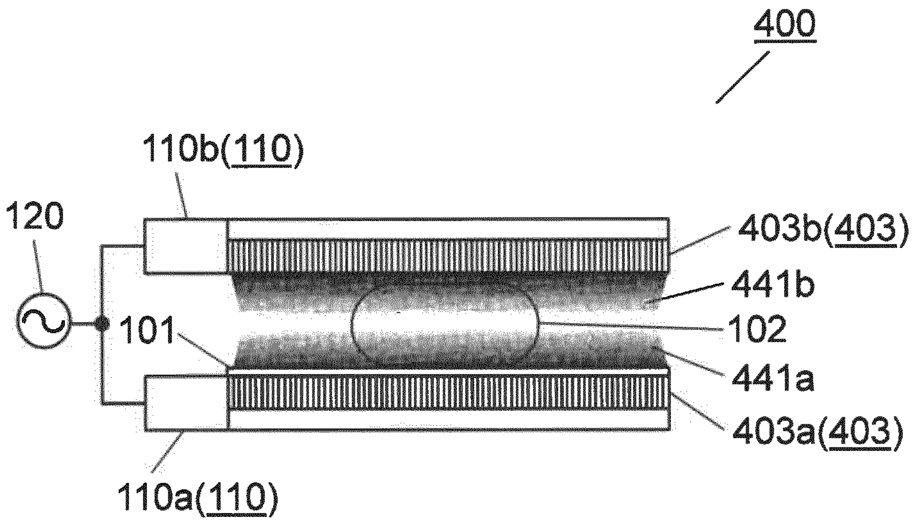


FIG. 11A

fp ≈ fc

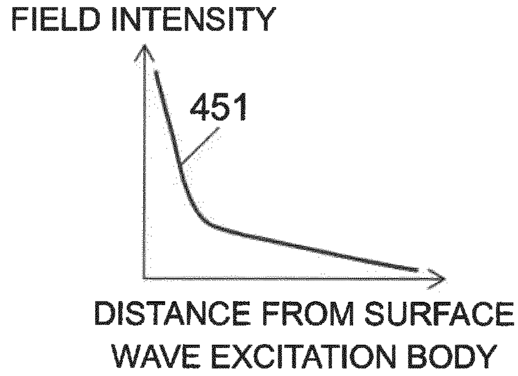


FIG. 11B

fp<fc

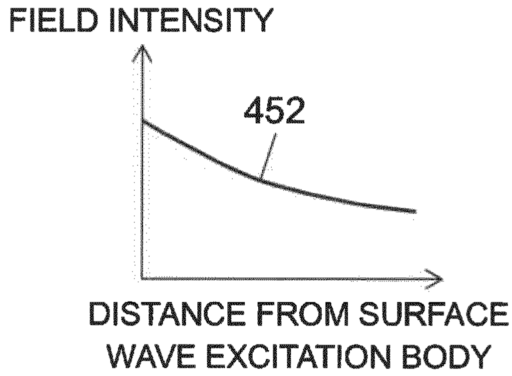


FIG. 11C

fp>fc

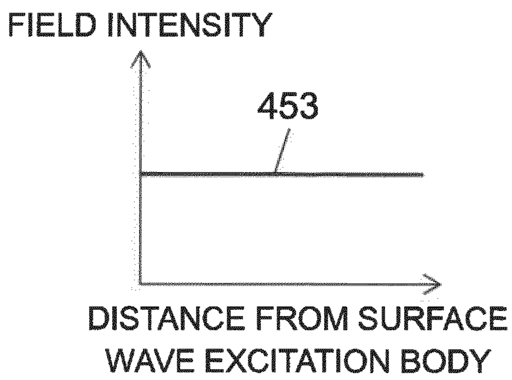


FIG. 12A

fp ≈ fc

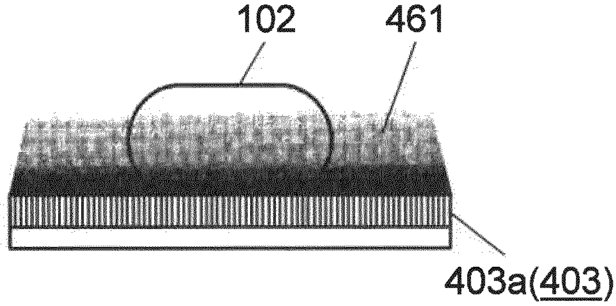


FIG. 12B

fp<fc

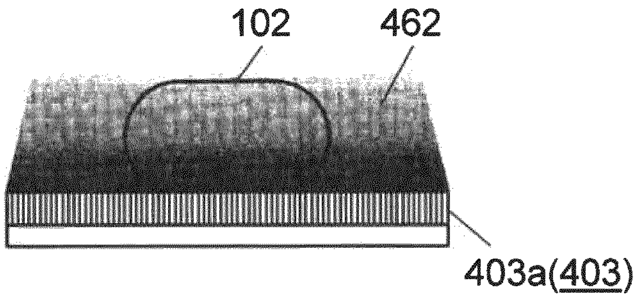


FIG. 12C

fp>fc

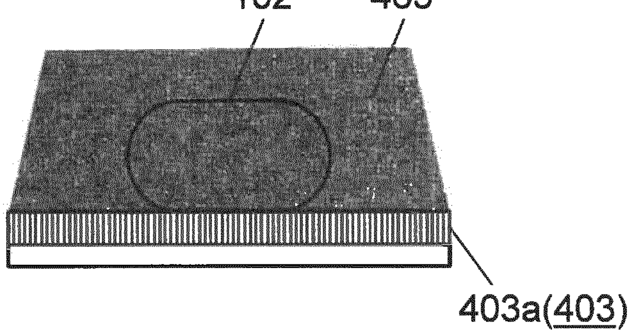


FIG. 13A

fp ≈ fc1
fp>fc2

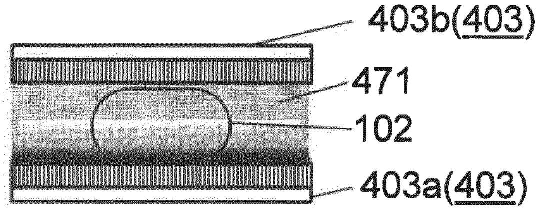


FIG. 13B

fp>fc1
fp ≈ fc2

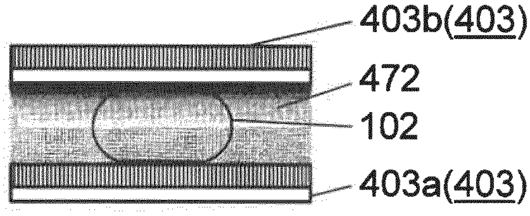


FIG. 13C

fp ≈ fc1
fp<fc2

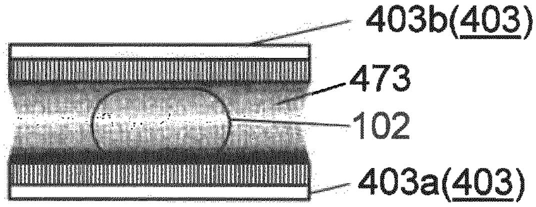


FIG. 13D

fp<fc1
fp ≈ fc2

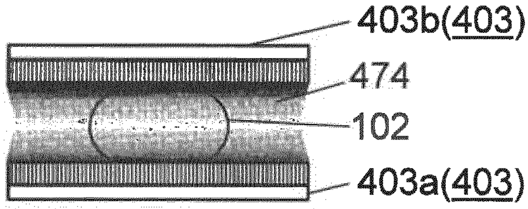


FIG. 13E

fp>fc1
fp>fc2

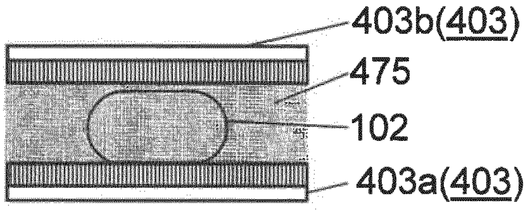


FIG. 14

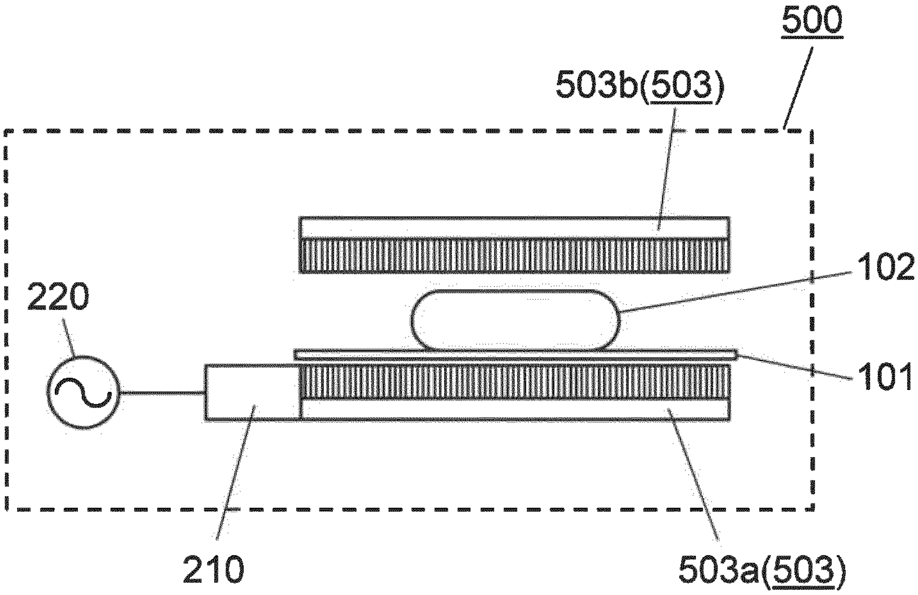

500
503b(503)
102
220
101
210
503a(503)

FIG. 15

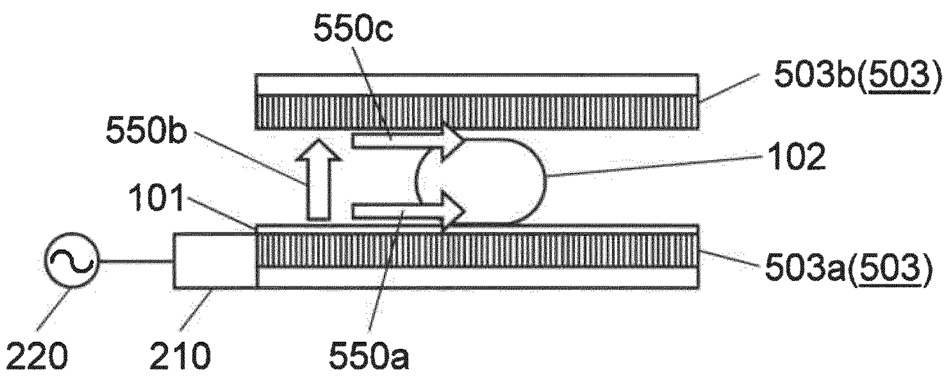

550c
503b(503)
550b
102
101
503a(503)
220
210
550a

FIG. 16A

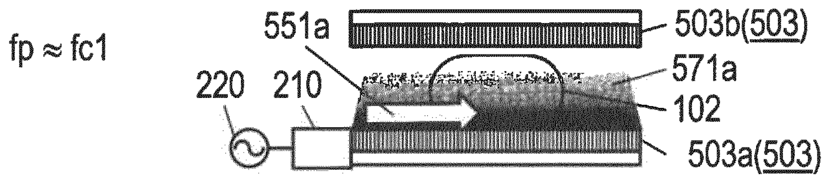


FIG. 16B

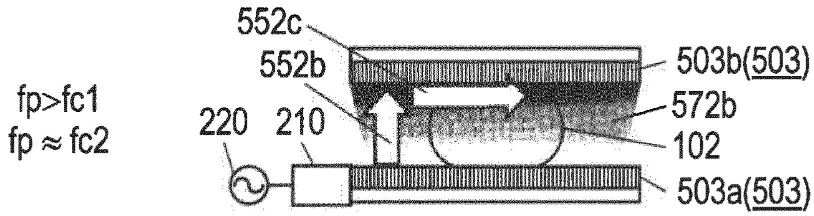


FIG. 16C

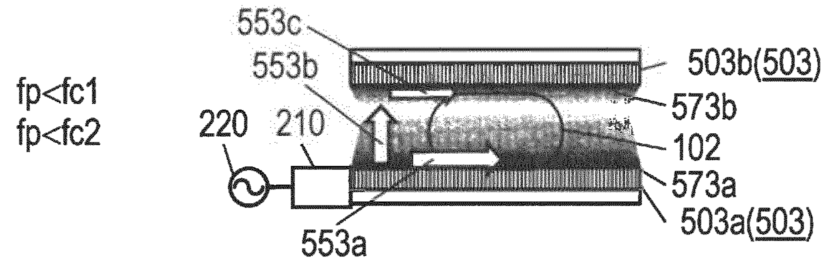


FIG. 16D

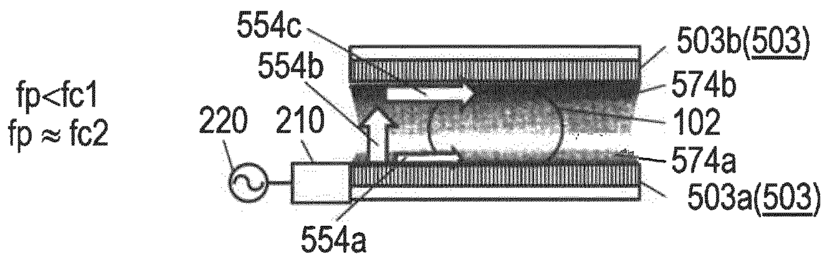


FIG. 16E

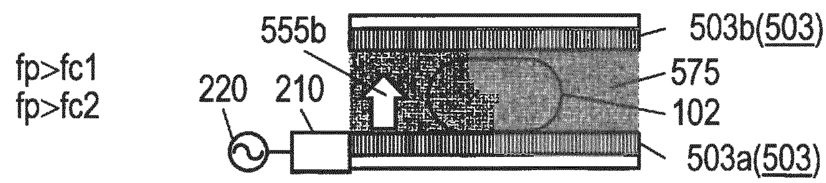


FIG. 17

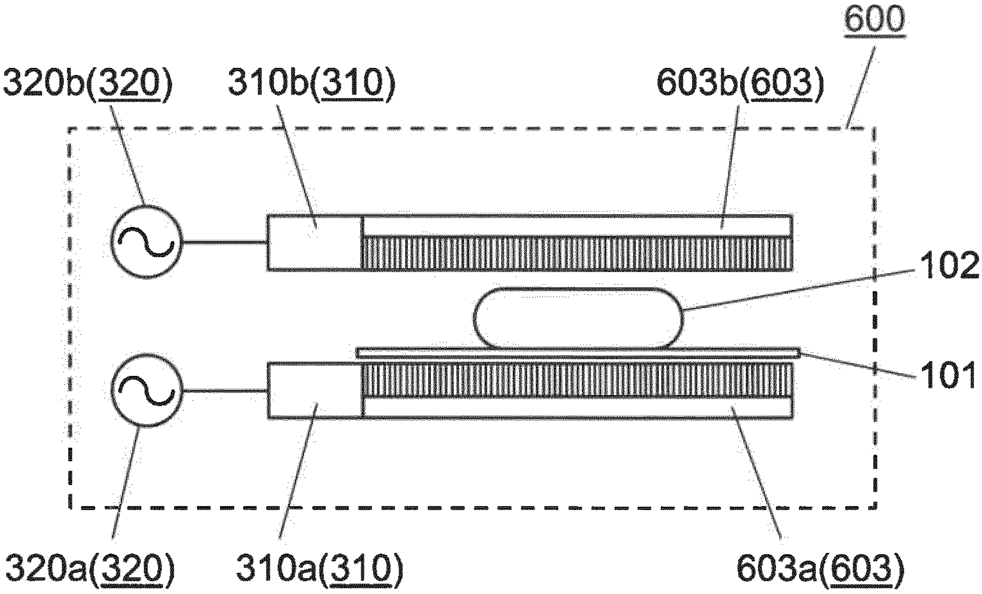

600
320b(320)
310b(310)
603b(603)
102
101
320a(320)
310a(310)
603a(603)

FIG. 18

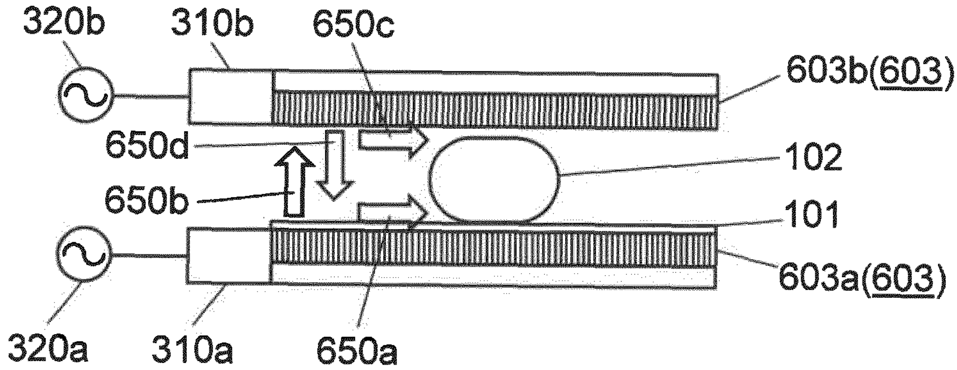

320b
310b
650c
603b(603)
650d
102
650b
101
603a(603)
320a
310a
650a

FIG. 19A

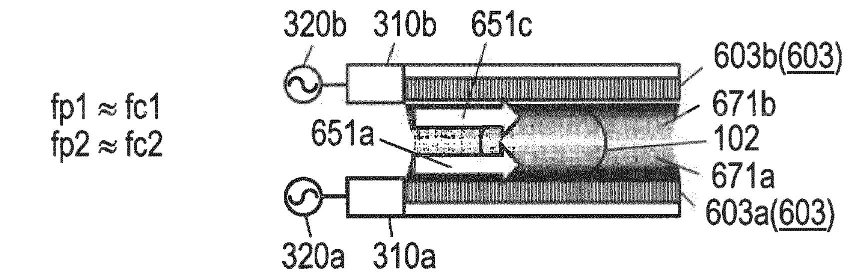


FIG. 19B

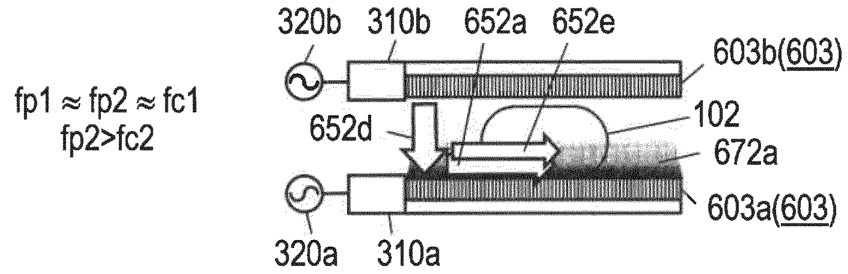


FIG. 19C

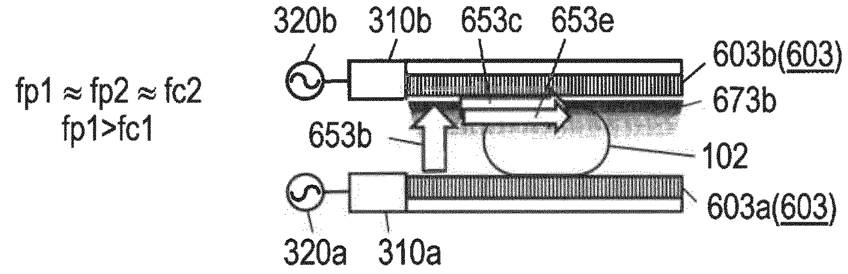


FIG. 19D

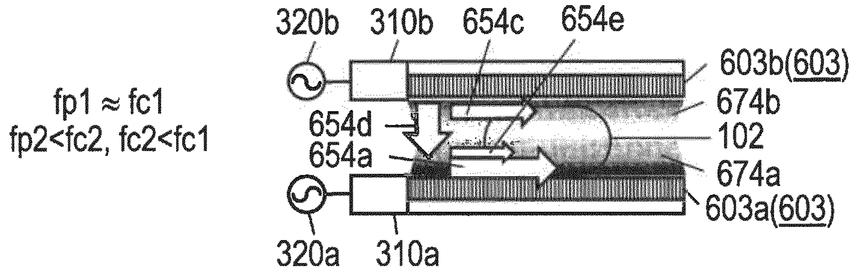
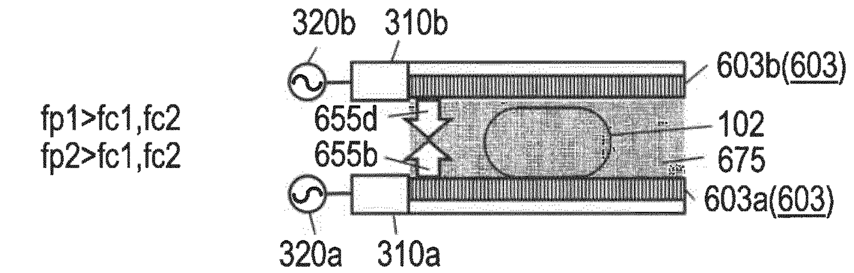


FIG. 19E



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/022618

A. CLASSIFICATION OF SUBJECT MATTER
H05B6/74(2006.01)i, *H05B6/70*(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)
H05B6/74, H05B6/70

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	1996-2017
Kokai Jitsuyo Shinan Koho	1971-2017	Toroku Jitsuyo Shinan Koho	1994-2017

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.
X Y	JP 6-260276 A (Matsushita Electric Industrial Co., Ltd.), 16 September 1994 (16.09.1994), paragraphs [0011] to [0021]; fig. 1 to 5 (Family: none)	1-3 5
X Y	JP 2000-150136 A (NEC Corp.), 30 May 2000 (30.05.2000), paragraphs [0009] to [0011], [0014]; fig. 1 to 2 (Family: none)	1,4 5
Y	JP 2009-32638 A (Panasonic Corp.), 12 February 2009 (12.02.2009), paragraph [0047]; fig. 1 (Family: none)	5

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 September 2017 (07.09.17)	19 September 2017 (19.09.17)

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

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/022618

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 2009-16149 A (Panasonic Corp.), 22 January 2009 (22.01.2009), paragraphs [0047], [0081]; fig. 2 (Family: none)	5
A	JP 31-8089 B1 (Kunihiro SUETAKE), 17 September 1956 (17.09.1956), page 1, right column, line 1 to page 2, right column, line 2; fig. 1 to 3 (Family: none)	1-5

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 56000098 A **[0007]**
- JP H08210653 B **[0007]**