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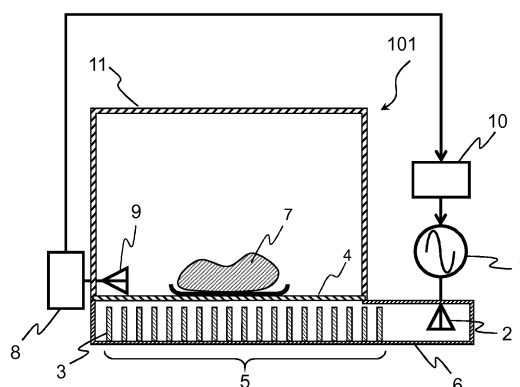
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(54) **MICROWAVE TREATMENT APPARATUS**

(57) A microwave treatment apparatus (101) comprises: a heating chamber (11); an oscillation source (1) that generates a microwave; a base plate disposed in the heating chamber (11) for placing thereon a heated object (7); and a waveguide (6) that guides the microwave into the heating chamber. The microwave treatment apparatus (101) further comprises: a periodic structure (5) disposed in the waveguide for causing the microwave to propagate in a surface wave mode; a detection antenna (9) near the periodic structure (5); a detector that detects an electromagnetic wave received by the detection antenna (9); and a controller (10) that controls the oscillation source (1). The controller (10) recognizes a power distribution of the electromagnetic field near the periodic structure (5) based on the detected electromagnetic wave and causes the oscillation source (1) to set the oscillation frequency to either a first oscillation frequency or a second oscillation frequency according to the power distribution of the electromagnetic field. In this aspect, a desirable power distribution of the electromagnetic field near the periodic structure can be maintained by correcting a characteristic change of the periodic structure.

FIG. 5



Description

TECHNICAL FIELD

[0001] The present disclosure relates to a microwave treatment apparatus with a surface wave transmission line configured using a periodic structure.

BACKGROUND ART

[0002] As a conventional microwave treatment apparatus of this kind, such an apparatus is known that has a wave guide which is provided with a ladder circuit having a ridge portion and a slot portion (see PTL 1, for example). According to this conventional technique, concentration of a power distribution of the electromagnetic field caused by the ladder circuit can be used so as to simultaneously perform both browning and dielectric heating of an object to be heated. Also, concentration of the power distribution of the electromagnetic field can be adjusted by moving the ridge portion.

[0003] Another known microwave treatment apparatus has heating plates constructing a periodic structure so that microwaves are excited by the heating plates (see PTL 2, for example). With this conventional technique, it is possible to adjust the intensity of the surface wave heating by changing the depths of the grooves of the periodic structure to control heating distribution in the vertical direction.

Citation List

Patent Literature

[0004]

PTL 1: Unexamined Japanese Patent Publication No. S49-16944

PTL 2: Unexamined Japanese Patent Publication No. H05-66019

SUMMARY OF THE INVENTION

[0005] According to the conventional technique disclosed in PTL 1, the periodic structure, such as the waveguide having the ladder circuit, allows microwaves to propagate in the surface wave mode so that the power distribution of the electromagnetic field concentrates near the periodic structure.

[0006] In this conventional technique, it is unable to detect changes in electromagnetic field distribution caused due to changes in the characteristics of the periodic structure depending on the shape, kind, volume, etc. of the object to be heated. Therefore, influences of the object to be heated cannot be corrected. As a result, it is unable to maintain the state of the power distribution of the electromagnetic field near the periodic structure.

[0007] The conventional technique disclosed in PTL 2

has a moving mechanism for changing the depths of the grooves of the periodic structure in the space in which microwaves propagate to control the power distribution of the electromagnetic field near the periodic structure.

[0008] In this structure, it is necessary to assure electrical connection between the moving mechanism and the periodic structure to prevent occurrence of electrical discharge. It is also necessary to take measures to prevent leaks of microwaves through a hole which is provided for transmitting a driving power to the moving mechanism. In addition, a motor for driving the moving mechanism is required, so that it is not easy to down-size the apparatus.

[0009] A microwave treatment apparatus in one aspect of the present disclosure comprises: a heating chamber in which an object to be heated is placed; an oscillation source that generates a microwave, an oscillation frequency of the microwave being variable; a base plate that is disposed in the heating chamber for placing thereon the object to be heated; and a waveguide that guides the microwave into the heating chamber.

[0010] The microwave treatment apparatus further comprises: a periodic structure that is disposed in the waveguide for causing the microwave to propagate in a surface wave mode; a detection antenna disposed near the periodic structure; a detector that detects an electromagnetic wave received by the detection antenna; and a controller that controls the oscillation source.

[0011] The controller also recognizes a power distribution of an electromagnetic field near the periodic structure based on the electromagnetic wave detected by the detector and causes the oscillation source to set the oscillation frequency to one of at least a first oscillation frequency and a second oscillation frequency which is different from the first oscillation frequency according to the power distribution of the electromagnetic field.

[0012] According to this aspect, it is possible to control the power distribution of the electromagnetic field near the periodic structure by changing the oscillation frequency. It is possible to maintain a desirable power distribution of the electromagnetic field near the periodic structure by detecting and correcting changes in characteristics of the periodic structure caused by influences of the object to be heated. As a result, it is possible to make heated objects of various shapes, kinds and volumes desirably turn brown.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

FIG. 1 is a schematic sectional view illustrating a configuration of a microwave treatment apparatus in accordance with a first exemplary embodiment.

FIG. 2 is a perspective view illustrating an inner structure of a waveguide of the microwave treatment apparatus in accordance with the first exemplary embodiment.

FIG. 3 is a diagram illustrating a frequency characteristic of leakage power in accordance with the first exemplary embodiment.

FIG. 4 is a diagram illustrating a power distribution of an electromagnetic field near a periodic structure in accordance with the first exemplary embodiment.

FIG. 5 is a schematic sectional view illustrating a configuration of a microwave treatment apparatus in accordance with a second exemplary embodiment.

DESCRIPTION OF EMBODIMENTS

[0014] A microwave treatment apparatus in one aspect of the present disclosure comprises: a heating chamber in which an object to be heated is placed; an oscillation source that generates a microwave, an oscillation frequency of the microwave being variable; a base plate that is disposed in the heating chamber for placing thereon the object to be heated; and a waveguide that guides the microwave into the heating chamber.

[0015] The microwave treatment apparatus further comprises: a periodic structure that is disposed in the waveguide for causing the microwave to propagate in a surface wave mode; a detection antenna disposed near the periodic structure; a detector that detects an electromagnetic wave received by the detection antenna; and a controller that controls the oscillation source.

[0016] The controller also recognizes a power distribution of an electromagnetic field near the periodic structure based on the electromagnetic wave detected by the detector and causes the oscillation source to set the oscillation frequency to one of at least a first oscillation frequency and a second oscillation frequency which is different from the first oscillation frequency according to the power distribution of the electromagnetic field.

[0017] A microwave treatment apparatus in a second aspect of the present disclosure is configured, according to the first aspect, such that the controller, while causing the oscillation source to vary the oscillation frequency, identifies a frequency at which concentration of the power distribution of the electromagnetic field near the periodic structure becomes maximum based on the electromagnetic wave detected by the detector, and causes the oscillation source to set the identified frequency as the first oscillation frequency.

[0018] A microwave treatment apparatus in a third aspect of the present disclosure is configured, according to the first aspect, such that the controller, while causing the oscillation source to vary the oscillation frequency, identifies a frequency at which concentration of the power distribution of the electromagnetic field near the periodic structure becomes minimum based on the electromagnetic wave detected by the detector, and causes the oscillation source to set the identified frequency as the second oscillation frequency.

[0019] A microwave treatment apparatus in a fourth aspect of the present disclosure is configured, according to the first aspect, such that the controller causes the

oscillation source to change the oscillation frequency depending on a condition of the object to be heated during when the object to be heated is being heated.

[0020] A microwave treatment apparatus in a fifth aspect of the present disclosure is configured, according to the first aspect, such that the controller causes the oscillation source to set the oscillation frequency to a frequency between the first oscillation frequency and the second oscillation frequency.

[0021] Hereinafter, exemplary embodiments of the present disclosure will be described with reference to the drawings.

FIRST EXEMPLARY EMBODIMENT

[0022] FIG. 1 is a schematic sectional view illustrating a configuration of microwave treatment apparatus 100, and more particularly configurations of waveguide 6 and heating chamber 11, in accordance with a first exemplary embodiment. FIG. 2 is a perspective view illustrating an inner structure of waveguide 6 disposed in microwave treatment apparatus 100.

[0023] As shown in FIGS. 1 and 2, microwave treatment apparatus 100 has oscillation source 1, antenna 2, metal plates 3, base plate 4, periodic structure 5, waveguide 6, and heating chamber 11.

[0024] Oscillation source 1 generates a microwave. An oscillation frequency of the microwave generated by oscillation source 1 is variable. Controller 10 is configured by a microcomputer, and controls oscillation source 1 to cause oscillation source 1 to change the oscillation frequency of the microwave. Oscillation source 1 may have an oscillator and a semiconductor amplifier. The oscillation frequency of oscillation source 1 having the oscillator and the amplifier can be easily controlled by controller 10.

[0025] Waveguide 6 is disposed at a position below heating chamber 11 to be close to base plate 4 and extends from a mounting position of antenna 2 to the position below heating chamber 11. Metal plates 3 are a plurality of metal plates which are perpendicular to an inner wall of waveguide 6. The plurality of metal plates are arranged at constant intervals within waveguide 6 to construct periodic structure 5.

[0026] In a condition that the heights, intervals, etc. of metal plates 3 are optimized, the microwave becomes a slow wave and propagates along the upper sides of metal plates 3 in a surface wave mode in the area in which periodic structure 5 is constructed. As a result, the power distribution of the electromagnetic field concentrates near the upper sides of metal plates 3.

[0027] When object 7, which is an object to be heated, is placed on base plate 4, object 7 is close to periodic structure 5. Since waveguide 6 is open on a side facing base plate 4, object 7 is heated from the bottom due to concentration of the power distribution of the electromagnetic field near the upper sides of metal plates 3.

[0028] Operations and actions of the microwave treatment apparatus configured as above will be described.

[0029] FIG. 3 illustrates leakage power from periodic structure 5 in a frequency range from 2.4 GHz to 2.5 GHz. Referring to FIG. 3, the horizontal axis indicates the oscillation frequency of oscillation source 1 and the vertical axis indicates the leakage power measured at a position apart by a specified distance from periodic structure 5.

[0030] In a case where the power distribution of the electromagnetic field does not concentrate near periodic structure 5 and microwaves diffuse into space, the leakage power will be large. In the case where the power distribution of the electromagnetic field concentrates near periodic structure 5 and microwaves do not diffuse into space, the leakage power will be small.

[0031] As shown in FIG. 3, the leakage power varies depending on the oscillation frequency of oscillation source 1. In a condition that the heights and intervals of metal plates 3 are optimized and the oscillation frequency is properly set, the microwave becomes a slow wave in the area in which periodic structure 5 is disposed and propagates along the upper sides of metal plates 3 in the surface wave mode. As a result, the power distribution of the electromagnetic field concentrates near the upper sides of metal plates 3.

[0032] FIG. 4 illustrates a power distribution of an electromagnetic field near periodic structure 5. Referring to FIG. 4, the horizontal axis indicates the power of the electromagnetic field, and the vertical axis indicates the vertical distance (i.e., the height) from periodic structure 5. In FIG. 4, the graph indicated by a solid line shows a power distribution of an electromagnetic field generated by a microwave at 2.41 GHz, and the graph indicated by a dotted line shows a power distribution of an electromagnetic field generated by a microwave at 2.46 GHz.

[0033] In both cases shown in FIG. 3 and FIG. 4, as seen from the figures, the power of the electromagnetic field becomes maximum near periodic structure 5 and decreases as the distance from periodic structure increases.

[0034] At the oscillation frequency at which the leakage power becomes minimum (2.41 GHz), the power distribution of the electromagnetic field concentrates more intensely near periodic structure 5, and sharply decreases as the distance from periodic structure 5 increases. On the other hand, at the oscillation frequency at which the leakage power becomes maximum (2.46 GHz), concentration of the power distribution of the electromagnetic field near periodic structure 5 becomes moderate, and gradually decreases as the distance from periodic structure 5 increases, so that the power of the electromagnetic field distributes over a wide area.

[0035] Hereinafter, the frequency at which the leakage power becomes minimum in the range from 2.4 GHz to 2.5 GHz will be referred to as a first oscillation frequency. Also, the frequency at which the leakage power becomes maximum in the same frequency range will be referred to as a second oscillation frequency. The concentration of the power distribution of the electromagnetic field becomes maximum when the oscillation frequency is the

first oscillation frequency. Also, the concentration of the power distribution of the electromagnetic field becomes minimum when the oscillation frequency is the second oscillation frequency.

[0036] In other words, the power distribution of the electromagnetic field can be concentrated near periodic structure 5 by setting the oscillation frequency to the first oscillation frequency. Also, the power distribution of the electromagnetic field can be diffused to a space distant from periodic structure 5 by setting the oscillation frequency to the second oscillation frequency. The leakage power varies continuously with the change in the oscillation frequency.

[0037] According to the present exemplary embodiment, the power distribution of the electromagnetic field near periodic structure 5 can be controlled by setting the oscillation frequency to the first oscillation frequency, the second oscillation frequency or a frequency between the first and second oscillation frequencies.

[0038] The oscillation frequency of oscillation source 1 can be easily and safely set by an electric signal from controller 10. Accordingly, it is not necessary for changing the power distribution of the electromagnetic field to stop oscillation source 1. Also, since it is not necessary to have a mechanism for setting the oscillation frequency of oscillation source 1, the apparatus can be made small-sized.

SECOND EXEMPLARY EMBODIMENT

[0039] Hereinafter, microwave treatment apparatus 101 in accordance with a second exemplary embodiment of the present disclosure will be described.

[0040] FIG. 5 is a schematic sectional view illustrating a configuration of microwave treatment apparatus 101. In the description of the present exemplary embodiment, the parts which are the same as or correspond to those of the first exemplary embodiment are indicated by like reference marks, and duplicate description on them will be omitted.

[0041] As shown in FIG. 5, detection antenna 9 is disposed in heating chamber 11 at a position near periodic structure 5. Detector 8 detects an electromagnetic wave received by detection antenna 9. Controller 10 has a capability of recognizing the power distribution of the electromagnetic field near periodic structure 5 according to the electromagnetic wave detected by detector 8.

[0042] Detection antenna 9 may be disposed at a position at which microwaves that propagate along periodic structure 5 in the surface wave mode can be detected. Detection antenna 9 may be disposed at a position at which microwaves that are radiated to space can be detected.

[0043] When object 7, which is an object to be heated, is placed on base plate 4, object 7 is close to periodic structure 5. Object 7 placed on base plate 4 exerts influences on microwaves propagating near the ends of metal plates 3 to disturb their propagation in the surface wave

mode. The influences on microwaves differ depending on the shape, kind, volume, temperature, etc. of object 7.

[0044] According to the present exemplary embodiment, while controller 10 causes oscillation source 1 to vary the oscillation frequency, detector 8 detects the power distribution of the electromagnetic field near periodic structure 5.

[0045] Based on the detected power distribution of the electromagnetic field, controller 10 obtains a frequency characteristic of the leakage power indicating the power distribution state of the electromagnetic field under the condition including the influences of object 7, as shown by the graph in FIG. 3. Based on the obtained frequency characteristic of the leakage power, controller 10 determines the first and second oscillation frequencies.

[0046] In this manner, microwave treatment apparatus 101 can obtain a desirable heating performance in which the change in frequency characteristic of periodic structure 5 caused by object 7 is corrected.

[0047] According to the present exemplary embodiment, controller 10 can cause, during when object 7 is being heated, oscillation source 1 to change the oscillation frequency depending on the condition of object 7 so that the power distribution of the electromagnetic field near periodic structure changes. As a result, it is possible to make heated objects 7 of various shapes, kinds and volumes desirably turn brown.

INDUSTRIAL APPLICABILITY

[0048] The microwave treatment apparatuses according to the present disclosure are applicable to heating apparatuses using dielectric heating, such, for example, as electronic ranges, waste disposers, and the like.

REFERENCE MARKS IN THE DRAWINGS

[0049]

1	oscillation source
2	antenna
3	metal plate
4	base plate
5	periodic structure
6	waveguide
7	object to be heated
8	detector
9	detection antenna
10	controller
11	heating chamber
100, 101	microwave treatment apparatus

Claims

1. A microwave treatment apparatus comprising:

a heating chamber in which an object to be heated

is placed;

an oscillation source that generates a microwave, an oscillation frequency of the microwave being variable;

a base plate that is disposed in the heating chamber and allows the object to be heated to be placed on the base plate;

a waveguide that guides the microwave into the heating chamber;

a periodic structure that is disposed in the waveguide and causes the microwave to propagate in a surface wave mode;

a detection antenna disposed near the periodic structure;

a detector that detects an electromagnetic wave received by the detection antenna; and

a controller that controls the oscillation source and recognizes a power distribution of an electromagnetic field near the periodic structure based on the electromagnetic wave detected by the detector, wherein the controller causes the oscillation source to set the oscillation frequency to one of at least a first oscillation frequency and a second oscillation frequency which is different from the first oscillation frequency according to the power distribution of the electromagnetic wave.

2. The microwave treatment apparatus according to claim 1, wherein the controller, while causing the oscillation source to vary the oscillation frequency, identifies a frequency at which concentration of the power distribution of the electromagnetic field near the periodic structure becomes maximum based on the electromagnetic wave detected by the detector, and sets the identified frequency as the first oscillation frequency.

3. The microwave treatment apparatus according to claim 1, wherein the controller, while causing the oscillation source to vary the oscillation frequency, identifies a frequency at which concentration of the power distribution of the electromagnetic field near the periodic structure becomes minimum based on the electromagnetic wave detected by the detector, and sets the identified frequency as the second oscillation frequency.

4. The microwave treatment apparatus according to claim 1, wherein the controller causes the oscillation source to change the oscillation frequency depending on a condition of the object to be heated when the object to be heated is being heated.

5. The microwave treatment apparatus according to claim 1, wherein the controller sets a frequency between the first oscillation frequency and the second oscillation frequency as the oscillation frequency.

FIG. 1

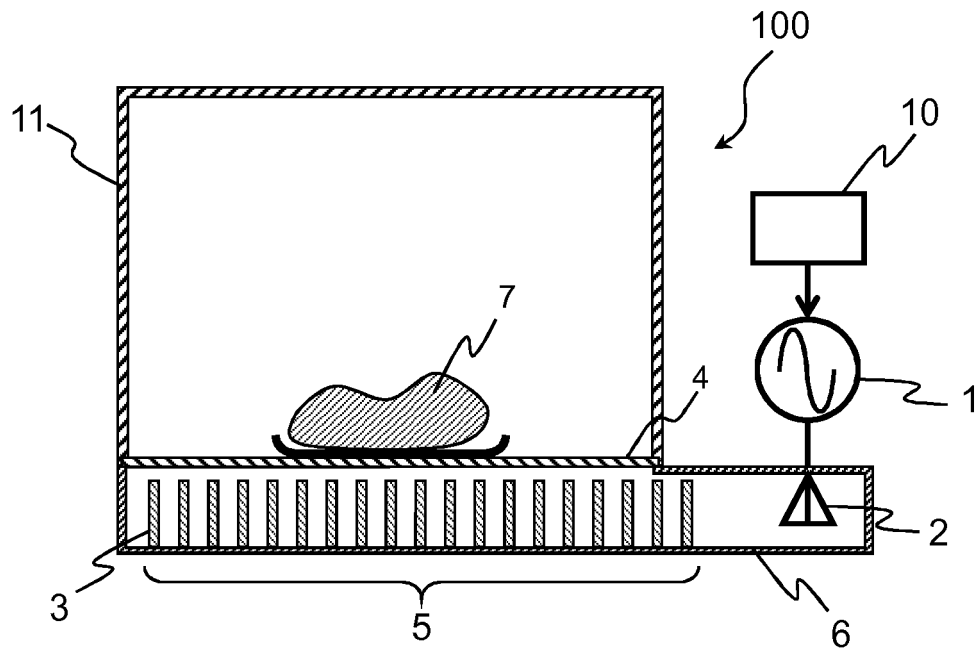


FIG. 2

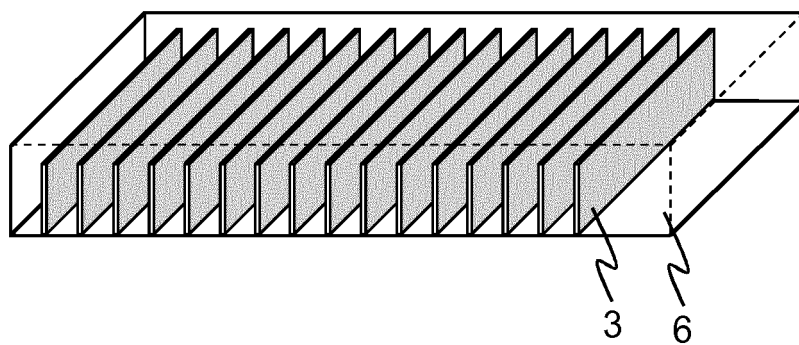


FIG. 3

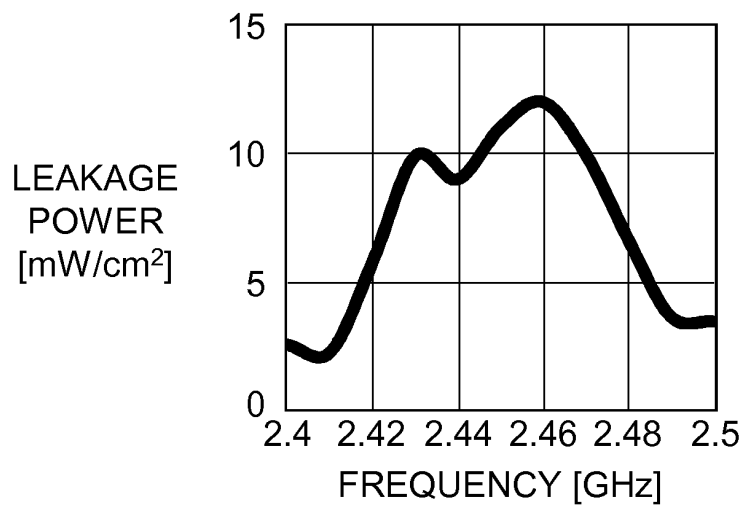


FIG. 4

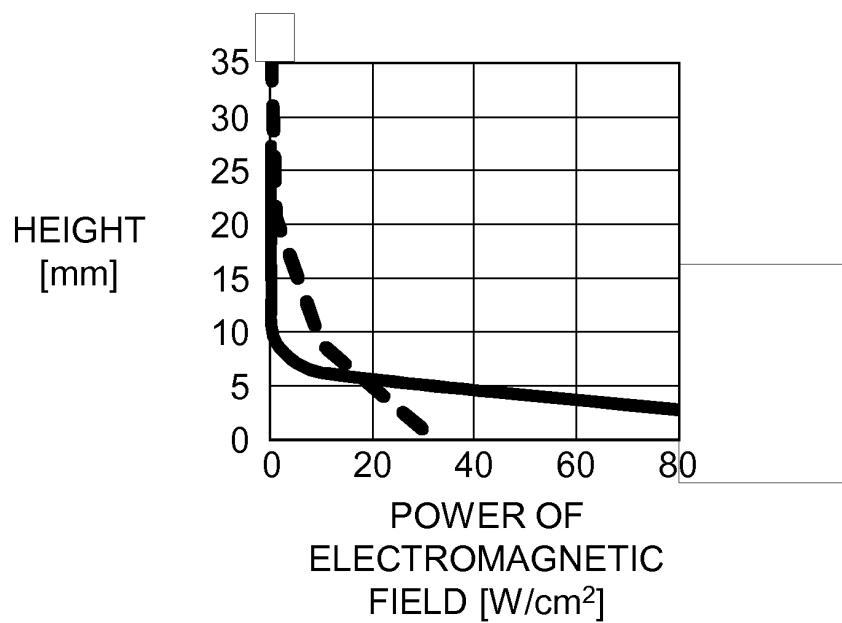
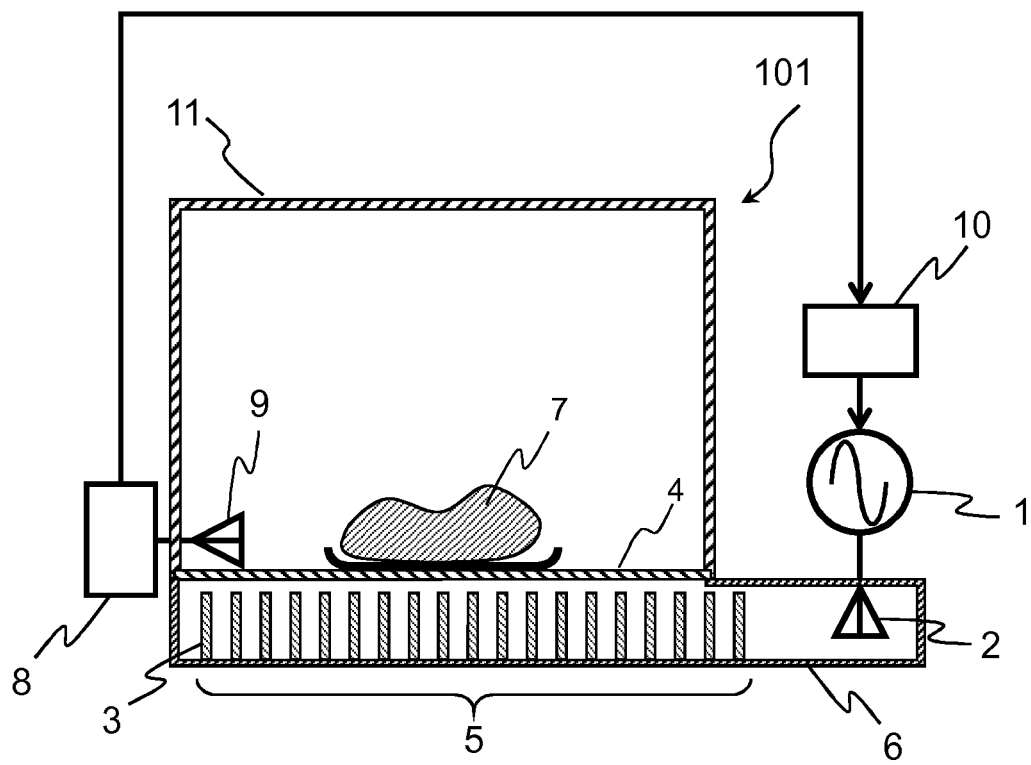


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/009910

A. CLASSIFICATION OF SUBJECT MATTER

H05B6/74(2006.01)i, H05B6/68(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, H05B6/68

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.
A	JP 2015-162273 A (Panasonic Corp.), 07 September 2015 (07.09.2015), paragraphs [0020] to [0025]; fig. 3	1-5
A	WO 2011/004561 A1 (Panasonic Corp.), 13 January 2011 (13.01.2011), entire text; all drawings	1-5
A	WO 2009/157110 A1 (Panasonic Corp.), 30 December 2009 (30.12.2009), entire text; all drawings	1-5
A	JP 2015-220189 A (Panasonic Intellectual Property Management Co., Ltd.), 07 December 2015 (07.12.2015), paragraphs [0031] to [0094]; fig. 1 to 7	1-5

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

* Special categories of cited documents:

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Date of the actual completion of the international search
05 June 2017 (05.06.17)Date of mailing of the international search report
13 June 2017 (13.06.17)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2017/009910

5	JP 2015-162273 A	2015.09.07	(Family: none)
10	WO 2011/004561 A1	2011.01.13	JP 5400885 B US 2012/0111856 A1 entire text; all drawings EP 2453716 A1 CN 102474925 A RU 2012104702 A
15	WO 2009/157110 A1	2009.12.30	JP 5080647 B US 2011/0108548 A1 entire text; all drawings EP 2306785 A1 CN 102067723 A RU 2011102571 A KR 10-2011-0025174 A
20	JP 2015-220189 A	2015.12.07	(Family: none)
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP S4916944 B [0004]
- JP H0566019 B [0004]