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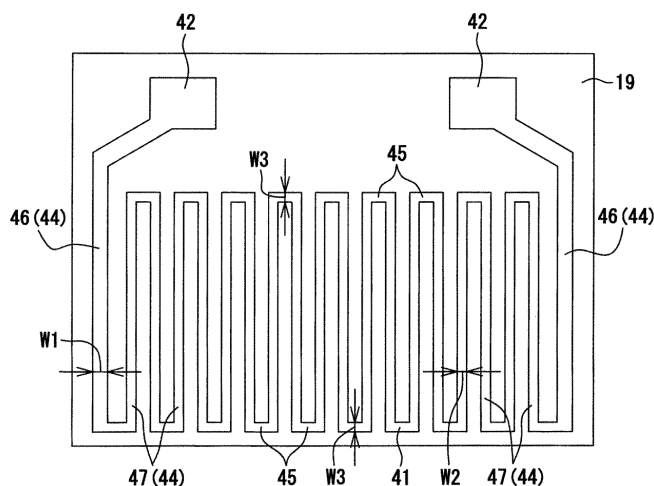
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(54) **CERAMIC HEATER**

(57) A ceramic heater of the present disclosure includes a ceramic sheet which is wrapped around an outer periphery of a support member, and includes a heater wire. The heater wire includes: wiring portions extending along an axial direction of the support member; and a connection portion connecting adjacent wiring portions to each other. The wiring portions include: a pair of outer

wiring portions disposed on opposite sides from each other with a wrapping-ends meeting portion of the ceramic sheet therebetween; and an inner wiring portion disposed, in the ceramic sheet, between the pair of outer wiring portions. Each outer wiring portion has a cross-sectional area larger than that of the inner wiring portion.

FIG.4



Description

CROSS-REFERENCE TO RELATED APPLICATIONS

5 **[0001]** This international patent application claims priority based on Japanese Patent Application No. 2016-051823 filed with the Japanese Patent Office on March 16, 2016 and Japanese Patent Application No. 2016-051824 filed with the Japanese Patent Office on March 16, 2016, and the entire contents of Japanese Patent Application No. 2016-051823 and Japanese Patent Application No. 2016-051824 are incorporated by reference in this international application.

10 TECHNICAL FIELD

[0002] The present disclosure relates to a ceramic heater for use in a warm water washing toilet seat, a fan heater, an electric water heater, a 24-hour bath, a soldering iron, a hair iron, etc. In particular, the present disclosure relates to a ceramic heater having a structure in which a ceramic sheet having a heater wire is wrapped around an outer periphery of a support member.

BACKGROUND ART

20 **[0003]** Generally, a heat exchange unit having a resin container (heat exchanger) is used in a warm water washing toilet seat. A tubular ceramic heater is mounted to the heat exchange unit to warm washing water stored in the heat exchanger.

[0004] As for this type of ceramic heater, a ceramic heater has been known which is formed by wrapping a ceramic sheet, on which a heater wire is printed, around a cylindrical ceramic support member, and integrally firing the ceramic sheet and the support member (e. g., refer to Patent Document 1).

25 PRIOR ART DOCUMENT

PATENT DOCUMENT

30 **[0005]** Patent Document 1: Japanese Patent No. 3038039

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

35 **[0006]** A ceramic heater for a warm water washing toilet seat is used in water at all times, and therefore is hardly energized and heated while it is in a dry state. Meanwhile, when water supply is cut off or piping is in trouble, there is a possibility that the ceramic heater is energized and heated in its dry state. However, since the cross-sectional area (e. g., line width, thickness) of a general heater wire is uniform, if the ceramic heater is heated in its dry state, the heater wire locally generates heat at a wrapping-ends meeting portion of the ceramic sheet, which may cause melting of a glass component present in the ceramic sheet near the heat-generating heater wire. In this case, since electrons become easy to move, partial discharge occurs between a pair of heater wire portions positioned on opposite sides from each other with the wrapping-ends meeting portion therebetween, which may result in dielectric breakdown. Moreover, a ceramic component present in the ceramic sheet is also melted due to a spark that occurs during the partial discharge, which may result in breakage of the ceramic heater.

45 **[0007]** According to one aspect of the present disclosure, it is desirable to provide a ceramic heater capable of improving reliability thereof by inhibiting dielectric breakdown that may occur in a heater wire.

MEANS FOR SOLVING THE PROBLEM

50 **[0008]** One aspect of the present disclosure is a ceramic heater including a support member made of ceramic, and a ceramic sheet which is wrapped around an outer periphery of the support member, and includes a heater wire. The heater wire includes a plurality of wiring portions and a connection portion. The plurality of wiring portions include a pair of outer wiring portions, and an inner wiring portion. Each outer wiring portion has a cross-sectional area larger than that of the inner wiring portion.

55 **[0009]** The plurality of wiring portions are configured to extend along the axial direction of the support member. The connection portion is configured to connect adjacent wiring portions. The pair of outer wiring portions are disposed on opposite sides from each other with a wrapping-ends meeting portion of the ceramic sheet therebetween. The inner

wiring portion is disposed, in the ceramic sheet, between the pair of outer wiring portions.

[0010] In this ceramic heater, the cross-sectional area of each of the pair of outer wiring portions positioned on opposite sides from each other with the wrapping-ends meeting portion of the ceramic sheet therebetween, is set to be larger than the cross-sectional area of the inner wiring portion disposed, in the ceramic sheet, between the pair of outer wiring portions, whereby electric resistance of the outer wiring portion becomes smaller than that of the inner wiring portion. Thus, local heat generation of the heater wire can be suppressed at the wrapping-ends meeting portion where the outer wiring portions are positioned. As a result, melting of a glass component present in the ceramic sheet near the outer wiring portions is suppressed, thereby inhibiting dielectric breakdown between the pair of outer wiring portions, and inhibiting breakage of the ceramic heater. Therefore, reliability of the ceramic heater can be improved.

[0011] As an example of the structure in which the cross-sectional area of the outer wiring portion is larger than that of the inner wiring portion, a structure in which the line width of the outer wiring portion is larger than that of the inner wiring portion is considered. That is, when the line width of each of the pair of outer wiring portions is set to be larger than that of the inner wiring portion, electric resistance of the outer wiring portion becomes smaller than that of the inner wiring portion, whereby local heat generation of the heater wire can be suppressed.

[0012] The line width of the outer wiring portion may be set to be larger than 1.07 times and smaller than 2.4 times the line width of the inner wiring portion. When the line width of the outer wiring portion is set to be larger than 1.07 times the line width of the inner wiring portion, it is possible to suppress local heat generation of the outer wiring portion, and inhibit occurrence of dielectric breakdown between the pair of outer wiring portions positioned on opposite sides from each other with the wrapping-ends meeting portion therebetween. Meanwhile, when the line width of the outer wiring portion is set to be smaller than 2.4 times the line width of the inner wiring portion, it is possible to suppress local temperature reduction in the outer wiring portion, thereby inhibiting reduction in thermal uniformity.

[0013] As an example of the structure in which the cross-sectional area of the outer wiring portion is larger than that of the inner wiring portion, a structure in which the thickness of the outer wiring portion is larger than that of the inner wiring portion is considered. That is, when the thickness of each of the pair of outer wiring portions is set to be larger than that of the inner wiring portion, electric resistance of the outer wiring portion becomes smaller than that of the inner wiring portion.

[0014] The thickness of the outer wiring portion may be set to be larger than 1.25 times and smaller than 2.4 times the thickness of the inner wiring portion. When the thickness of the outer wiring portion is set to be larger than 1.25 times the thickness of the inner wiring portion, it is possible to suppress local heat generation of the outer wiring portion, and inhibit occurrence of dielectric breakdown between the pair of outer wiring portions positioned on opposite sides from each other with the wrapping-ends meeting portion therebetween. Meanwhile, when the thickness of the outer wiring portion is set to be smaller than 2.4 times the thickness of the inner wiring portion, it is possible to suppress local temperature reduction in the outer wiring portion, thereby inhibiting reduction in thermal uniformity.

[0015] Another aspect of the present disclosure is a ceramic heater including a support member made of ceramic, and a ceramic sheet which is wrapped around an outer periphery of the support member, and includes a heater wire. The heater wire includes a plurality of wiring portions and a connection portion. The plurality of wiring portions include a pair of outer wiring portions, and an inner wiring portion. A center portion of each outer wiring portion has a cross-sectional area larger than that of the inner wiring portion.

[0016] The plurality of wiring portions are configured to extend along the axial direction of the support member. The connection portion is configured to connect adjacent wiring portions. The pair of outer wiring portions are disposed on opposite sides from each other with a wrapping-ends meeting portion of the ceramic sheet therebetween. The inner wiring portion is disposed, in the ceramic sheet, between the pair of outer wiring portions.

[0017] In this ceramic heater, the cross-sectional area of the center portion of each of the pair of outer wiring portions positioned on opposite sides from each other with the wrapping-ends meeting portion of the ceramic sheet therebetween, is set to be larger than the cross-sectional area of the inner wiring portion disposed, in the ceramic sheet, between the pair of outer wiring portions, whereby electric resistance of the center portion of the outer wiring portion becomes smaller than that of the inner wiring portion. Thus, local heat generation of the heater wire can be suppressed at the wrapping-ends meeting portion where the outer wiring portions are positioned. As a result, melting of a glass component present in the ceramic sheet near the center portions of the outer wiring portions is suppressed, thereby inhibiting dielectric breakdown between the pair of outer wiring portions, and inhibiting breakage of the ceramic heater. Therefore, reliability of the ceramic heater can be improved.

[0018] As an example of the structure in which the cross-sectional area of the center portion of the outer wiring portion is larger than that of the inner wiring portion, a structure in which the line width of the center portion of the outer wiring portion is larger than that of the inner wiring portion is considered. That is, when the line width of the center portion of each of the pair of outer wiring portions is set to be larger than that of the inner wiring portion, electric resistance of the center portion of the outer wiring portion becomes smaller than that of the inner wiring portion, whereby local heat generation of the heater wire can be suppressed.

[0019] The line width of the center portion may be set to be larger than 1.07 times and not larger than 2.0 times the

line width of the inner wiring portion. When the line width of the center portion is set to be larger than 1.07 times the line width of the inner wiring portion, it is possible to suppress local heat generation of the outer wiring portion, and inhibit occurrence of dielectric breakdown between the pair of outer wiring portions positioned on opposite sides from each other with the wrapping-ends meeting portion therebetween. Meanwhile, when the line width of the center portion is set to be not larger than 2.0 times the line width of the inner wiring portion, it is possible to suppress local temperature reduction in the outer wiring portion, thereby inhibiting reduction in thermal uniformity.

[0020] The above-described ceramic heater includes the support member made of ceramic, and the ceramic sheet wrapped around the outer periphery of the support member. Preferred examples of ceramic that forms the support member and the ceramic sheet may include alumina, aluminum nitride, silicon nitride, boron nitride, zirconia, titania, and mullite. In particular, the support member and the ceramic sheet may contain alumina. In this case, a ceramic heater having excellent heat resistance, chemical resistance, and strength can be produced at reduced costs. The ceramic sheet includes a heater element (heater wire) formed of tungsten, molybdenum, tantalum, or the like. The heater wire may contain, as a main component, at least one of tungsten and molybdenum. In this case, the heater wire can be reliably adhered to the ceramic sheet, whereby reliability of the ceramic heater is further improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

[FIG. 1] Front view of a ceramic heater according to a first embodiment.

[FIG. 2] Plan view showing the ceramic heater according to the first embodiment.

[FIG. 3] Cross-sectional view taken along a line III-III in FIG. 1.

[FIG. 4] Explanatory diagram showing a developed ceramic sheet according to the first embodiment.

[FIG. 5] FIGS. 5A, 5B, 5C, and FIG. 5D being explanatory diagrams showing a ceramic heater production method according to the first embodiment.

[FIG. 6] Explanatory diagram showing a developed ceramic sheet according to a second embodiment.

[FIG. 7] Front view of a ceramic heater according to a third embodiment.

[FIG. 8] Plan view showing the ceramic heater according to the third embodiment.

[FIG. 9] Cross-sectional view taken along a line IX-IX in FIG. 7.

[FIG. 10] Explanatory diagram showing a developed ceramic sheet according to the third embodiment.

[FIG. 11] FIGS. 11A, 11B, 11C, and 11D being explanatory diagrams showing a ceramic heater production method according to the third embodiment.

[FIG. 12] Cross-sectional view of a major part including portions of a support member and a ceramic sheet according to a fourth embodiment.

[FIG. 13] Explanatory diagram showing a developed ceramic sheet according to the fourth embodiment.

DESCRIPTION OF REFERENCE NUMERALS

[0022] 11...ceramic heater, 17...support member, 19,61...ceramic sheet, 20...wrapping-ends meeting portion, 41,62...heater wire, 44...wiring portion, 45,67...connection portion, 46,63...outer wiring portion, 47,66...inner wiring portion, 64...center portion of outer wiring portion, W1...line width of outer wiring portion, W2,W6...line width of inner wiring portion, W4...line width of center portion, 111...ceramic heater, 117...support member, 119,161...ceramic sheet, 120,168...wrapping-ends meeting portion, 141,162...heater wire, 144...wiring portion, 145,167...connection portion, 146,163...outer wiring portion, 147,166...inner wiring portion, 164...center portion of outer wiring portion, T1...thickness of outer wiring portion, T2,T4...thickness of inner wiring portion, T3...thickness of center portion

MODES FOR CARRYING OUT THE INVENTION

[0023] [First embodiment] Hereinafter, a ceramic heater and a production method therefor according to a first embodiment of the present disclosure will be described with reference to the drawings.

[0024] A ceramic heater 11 according to the present embodiment is used in, for example, a heat exchanger of a heat exchange unit of a warm water washing toilet seat, for the purpose of warming washing water.

[0025] As shown in FIGS. 1 and 2, the ceramic heater 11 includes: a cylindrical ceramic heater body 13 made of ceramic; and an annular flange 15 made of metal, externally fitted to the heater body 13. The flange 15 is an annular member formed by bending a metal plate such as a stainless-steel plate. The flange 15 has a recessed (cup-shaped) center portion.

[0026] In the present embodiment, as shown in FIG. 2, in the recessed portion of the flange 15, a space surrounded by an outer peripheral surface 14 of the heater body 13 and an inner surface of the flange 15 serves as a glass reservoir

35. The glass reservoir 35 is filled with glass 33, and the heater body 13 and the flange 15 are welded and fixed via the glass 33. In FIG. 2, the glass 33 is shown by hatching.

[0027] As shown in FIGS. 1 to 3, the heater body 13 is composed of: a cylindrical support member 17 made of ceramic; and a ceramic sheet 19 wrapped around the outer periphery of the support member 17. In the present embodiment, the support member 17 and the ceramic sheet 19 are formed by using ceramic such as alumina (Al_2O_3). The thermal expansion coefficient of alumina is within a range of $50 \times 10^{-7}/\text{K}$ to $90 \times 10^{-7}/\text{K}$, and is $70 \times 10^{-7}/\text{K}$ (30°C to 380°C) in the present embodiment. In the present embodiment, the support member 17 has an outer diameter set to 12 mm, an inner diameter set to 8 mm, and a length set to 65 mm. The ceramic sheet 19 has a thickness set to 0.5 mm, and a length set to 60 mm. The ceramic sheet 19 does not completely cover the outer periphery of the support member 17. Therefore, a slit 21 is formed at a wrapping-ends meeting portion 20 of the ceramic sheet 19. The slit 21 extends along an axial direction of the support member 17, and exposes an outer peripheral surface of the support member 17. The slit 21 of the present embodiment has a width set to 1 mm, and a depth set to 0.5 mm.

[0028] As shown in FIGS. 3 and 4, inside the ceramic sheet 19, a heater wire 41 having a meandering pattern and a pair of internal terminals 42 are formed. In the present embodiment, the heater wire 41 and the internal terminals 42 contain tungsten (W) as a main component. The internal terminals 42 are electrically connected to external terminals 43 (refer to FIG. 1) formed on an outer peripheral surface of the ceramic sheet 19, through via conductors (not shown) or the like.

[0029] The heater wire 41 includes: a plurality of wiring portions 44 extending along the axial direction of the support member 17; and connection portions 45 each connecting adjacent wiring portions 44 to each other. The plurality of wiring portions 44 include a pair of outer wiring portions 46, and a plurality of inner wiring portions 47. The pair of outer wiring portions 46 are disposed on opposite sides from each other with the wrapping-ends meeting portion 20 (refer to FIG. 3) of the ceramic sheet 19 therebetween. A first end (upper end in FIG. 4) of each outer wiring portion 46 is connected to an internal terminal 42, and a second end (lower end in FIG. 4) of the outer wiring portion 46 is connected to an inner wiring portion 47 via a connection portion 45. The internal terminals 42 are disposed between the pair of outer wiring portions 46 when the ceramic sheet 19 is viewed in the thickness direction.

[0030] As shown in FIGS. 3 and 4, in the ceramic sheet 19, the inner wiring portions 47 are disposed between the pair of outer wiring portions 46. A first end (upper end in FIG. 4) of each inner wiring portion 47 is connected to a first end of an adjacent inner wiring portion 47 via a connection portion 45. A second end (lower end in FIG. 4) of each inner wiring portion 47 is connected to a second end of an adjacent inner wiring portion 47 or to a second end of an adjacent outer wiring portion 46, via a connection portion 45.

[0031] Each outer wiring portion 46 of the present embodiment has a line width $W1$ set to 0.66 mm and a thickness set to 15 μm . Each inner wiring portion 47 of the present embodiment has a line width $W2$ set to 0.60 mm and a thickness set to 15 μm . Likewise, each connection portion 45 of the present embodiment has a line width $W3$ set to 0.60 mm and a thickness set to 15 μm . That is, the line width $W1$ of the outer wiring portion 46 is larger than the line width $W2$ of the inner wiring portion 47 and the line width $W3$ of the connection portion 45. Specifically, the line width $W1$ of the outer wiring portion 46 is set to be 1.1 times the line width $W2$ of the inner wiring portion 47 and the line width $W3$ of the connection portion 45. The line width $W2$ of the inner wiring portion 47 is equal to the line width $W3$ of the connection portion 45. Since the thickness of the outer wiring portion 46 is equal to the thickness of the inner wiring portion 47 and to the thickness of the connection portion 45, the cross-sectional area of the outer wiring portion 46 is larger than the cross-sectional area of the inner wiring portion 47 and the cross-sectional area of the connection portion 45.

[0032] Next, a method of producing the ceramic heater 11 of the present embodiment will be described.

[0033] First, a clayey slurry containing alumina as a main component is put in a conventionally known extruder (not shown), and the slurry is molded into a tubular member. Then, the molded tubular member is dried, and thereafter is subjected to pre-firing in which the cylindrical member is heated to a predetermined temperature (e. g., about 1000°C), thereby obtaining the support member 17 (refer to FIG. 5A).

[0034] Using a ceramic material containing alumina powder as a main component, first and second ceramic green sheets 51 and 52, which will become the ceramic sheet 19, are formed. As for a method of forming the ceramic green sheets, a known formation method such as a doctor blade method can be adopted. Then, using a conventionally known paste printing apparatus (not shown), a conductive paste (tungsten paste in the present embodiment) is printed on the surface of the first ceramic green sheet 51. As a result, an unfired electrode 53, which will become the heater wire 41 and the internal terminals 42, is formed on the surface of the first ceramic green sheet 51 (refer to FIG. 5B). The line width of the unfired electrode 53 is adjusted to be, for example, a width obtained by adding an amount of shrinkage at firing to the line width of the heater wire 41.

[0035] After drying of the conductive paste, the second ceramic green sheet 52 is stacked on the printed surface (surface on which the unfired electrode 53 is formed) of the first ceramic green sheet 51, and a pressing force is applied in the sheet stacking direction. As a result, the ceramic green sheets 51 and 52 are unified, thereby forming a green-sheet stacked body 54 (refer to FIG. 5C). Further, using the paste printing apparatus, a conductive paste is printed on the surface of the second ceramic green sheet 52. As a result, an unfired electrode 55, which will become the external

terminals 43, is formed on the surface of the second ceramic green sheet 52.

[0036] Next, a ceramic paste (alumina paste) is applied to one side of the green-sheet stacked body 54, and the green-sheet stacked body 54 is wrapped around the outer peripheral surface of the support member 17 so as to be adhered to the support member 17 (refer to FIG. 5D). At this time, the size of the green-sheet stacked body 54 is adjusted so that the opposing ends of the green-sheet stacked body 54 do not overlap each other. Next, a drying process, a degreasing process, etc. are performed according to conventionally known techniques, and thereafter, co-firing is performed in which the green-sheet stacked body 54 (the ceramic green sheets 51 and 52, and the unfired electrodes 53 and 55) is heated to a predetermined temperature (e. g., about 1400°C to 1600°C) at which alumina and tungsten in the green-sheet stacked body 54 can be sintered. As a result, alumina in the ceramic green sheets 51 and 52 and tungsten in the conductive paste are simultaneously sintered, whereby the green-sheet stacked body 54 becomes the ceramic sheet 19, the unfired electrode 53 becomes the heater wire 41 and the internal terminals 42, and the unfired electrode 55 becomes the external terminals 43. Thereafter, the external terminals 43 are plated with nickel to obtain the heater body 13.

[0037] Next, a plate member made of stainless steel is press-formed using a die, thereby forming the cup-shaped flange 15. Then, the flange 15 is externally fitted to the heater body 13 at a predetermined position. Thereafter, the heater body 13 and the flange 15 are welded and fixed via the glass 33 to complete the ceramic heater 11.

<Experimental example>

[0038] Hereinafter, an example of an experiment performed to evaluate the performance of the ceramic heater 11 of the present embodiment will be described.

[0039] First, measurement samples were prepared as follows. A ceramic heater was prepared which includes a ceramic sheet having a line width of each outer wiring portion being 0.60 mm, a line width of each inner wiring portion being 0.60 mm, and a value of a ratio of the line width of the outer wiring portion to the line width of the inner wiring portion being 1.0. In other words, a ceramic heater in which the line width of each outer wiring portion was equal to the line width of each inner wiring portion was prepared. This ceramic heater was regarded as a sample 1A. Further, a ceramic heater having a line width of each outer wiring portion being 0.64 mm, a line width of each inner wiring portion being 0.60 mm, and a value of the ratio being 1.07 was prepared as a sample 1B. A ceramic heater having a line width of each outer wiring portion being 0.60 mm, a line width of each inner wiring portion being 0.55 mm, and a value of the ratio being 1.09 was prepared as a sample 1C. A ceramic heater having a line width of each outer wiring portion being 0.66 mm, a line width of each inner wiring portion being 0.60 mm, and a value of the ratio being 1.1, that is, a ceramic heater identical to the ceramic heater 11 of the present embodiment, was prepared as a sample 1D. A ceramic heater having a line width of each outer wiring portion being 0.69 mm, a line width of each inner wiring portion being 0.60 mm, and a value of the ratio being 1.15 was prepared as a sample 1E. A ceramic heater having a line width of each outer wiring portion being 1.20 mm, a line width of each inner wiring portion being 0.60 mm, and a value of the ratio being 2.0 was prepared as a sample 1F. A ceramic heater having a line width of each outer wiring portion being 1.44 mm, a line width of each inner wiring portion being 0.60 mm, and a value of the ratio being 2.4 was prepared as a sample 1G. As for each of the samples 1A to 1G, five samples were prepared.

[0040] Next, a nichrome wire was soldered to a pair of internal terminals (heater wire) included in the ceramic sheet of each of the measurement samples (samples 1A to 1G), and each measurement sample, in its dry state, was placed on a base. Then, a voltage (AC 240V) was applied across the pair of internal terminals for 6 minutes, and the surface temperature of the ceramic sheet was measured by a thermocamera. In addition, it was observed whether local heat generation occurred at the outer wiring portions and whether dielectric breakdown occurred between the pair of outer wiring portions. If dielectric breakdown occurred, the occurrence time was measured and recorded. The results are shown on Table 1.

[Table 1]

Sample	Line width			Test result	
	Outer wiring portion (W1)	Inner wiring portion (W2)	Ratio (W1/W2)	Local heat generation	Dielectric breakdown
1A	0.60 mm	0.60 mm	1.0	5/5	5/5
1B	0.64 mm	0.60 mm	1.07	5/5	2/5
1C	0.60 mm	0.55 mm	1.09	0/5	0/5
1D	0.66 mm	0.60 mm	1.1	0/5	0/5
1E	0.69 mm	0.60 mm	1.15	0/5	0/5

(continued)

Sample	Line width			Test result	
	Outer wiring portion (W1)	Inner wiring portion (W2)	Ratio (W1/W2)	Local heat generation	Dielectric breakdown
1F	1.20 mm	0.60 mm	2.0	0/5	0/5
1G	1.44 mm	0.60 mm	2.4	0/5	0/5

[0041] According to the results, as for the sample 1A, it was found that, in all the five samples, local heat generation occurred, and dielectric breakdown occurred with a spark after 1 min and 50 sec had passed. As for the sample 1B, it was found that local heat generation occurred in all the five samples, and dielectric breakdown occurred in two samples among the five samples. Meanwhile, as for samples 1C to 1G, neither local heat generation nor dielectric breakdown was found in any of the five samples throughout observation for 6 minutes. However, as for the sample 1G, it was found that the temperature at the wrapping-ends meeting portion of the ceramic sheet was reduced, leading to reduction in thermal uniformity.

[0042] From the above, it was verified that local heat generation and dielectric breakdown are not likely to occur and thermal uniformity is not likely to be reduced if the line width of each of the pair of outer wiring portions positioned on opposite sides from each other with the wrapping-ends meeting portion therebetween is set to be not smaller than 1.09 times and not larger than 2.0 times the line width of each inner wiring portion disposed between the pair of outer wiring portions.

[0043] Therefore, the following effects can be achieved according to the present embodiment.

(1) In the ceramic heater 11 of the present embodiment, when the line width W1 of each outer wiring portion 46 is larger than the line width W2 of each inner wiring portion 47, electric resistance of the outer wiring portion 46 becomes smaller than that of the inner wiring portion 47. Therefore, at the wrapping-ends meeting portion 20 where the outer wiring portions 46 are positioned, local heat generation of the heater wire 41 can be suppressed. As a result, melting of the glass component present in the ceramic sheet 19 near the outer wiring portions 46 is suppressed, thereby inhibiting dielectric breakdown between the pair of outer wiring portions 46, and inhibiting breakage of the ceramic heater 11. Thus, reliability of the ceramic heater 11 can be improved.

(2) In the present embodiment, the pair of internal terminals 42 formed in the ceramic sheet 19 are disposed inward of the pair of outer wiring portions 46 also formed in the ceramic sheet 19 (refer to FIG. 4). Therefore, when the ceramic sheet 19 is wrapped around the outer periphery of the support member 17, the internal terminals 42 are positioned on opposite sides from each other in the radial direction of the support member 17. As a result, the distance between the internal terminals 42 is increased, whereby occurrence of discharge between the internal terminals 42 can be suppressed.

[Second embodiment] Hereinafter, a second embodiment of the present disclosure will be described with reference to the drawings. The following description focuses on a difference from the first embodiment. In the present embodiment, the structure of the heater wire is different from that of the first embodiment.

[0044] Specifically, as shown in a ceramic sheet 61 of FIG. 6, each of outer wiring portions 63 as components of a heater wire 62 has: a line width W4, at a center portion 64, set to 0.66 mm; a line width W5, at a portion 65 other than the center portion 64, set to 0.60 mm; and a thickness set to 15 μ m. The "center portion 64 of the outer wiring portion 63" is a region, of a center portion of the outer wiring portion 63, which occupies not larger than one-third of the length of the outer wiring portion 63. Further, each of inner wiring portions 66 as components of the heater wire 62 has a line width W6 set to 0.60 mm, and a thickness set to 15 μ m. Further, each of connection portions 67 as components of the heater wire 62 also has a line width W7 set to 0.60 mm, and a thickness set to 15 μ m. That is, the line width W4 of the center portion 64 of the outer wiring portion 63 is larger than the line width W5 of the other portion 65 of the outer wiring portion 63, the line width W6 of the inner wiring portion 66, and the line width W7 of the connection portion 67. Specifically, the line width W4 of the center portion 64 is set to be 1.1 times the line width W5 of the other portion 65, the line width W6 of the inner wiring portion 66, and the line width W7 of the connection portion 67. Since the thickness of the center portion 64 is equal to the thickness of the other portion 65, the thickness of the inner wiring portion 66, and the thickness of the connection portion 67, the cross-sectional area of the center portion 64 is larger than the cross-sectional area of the other portion 65, the cross-sectional area of the inner wiring portion 66, and the cross-sectional area of the connection portion 67. In a connection portion between the center portion 64 and the other portion 65, the line width of the outer wiring portion 63 gradually increases from the other portion 65 to the center portion 64.

<Experimental example>

[0045] Hereinafter, an example of an experiment performed to evaluate the performance of the ceramic heater of the present embodiment will be described.

[0046] First, measurement samples were prepared as follows. A ceramic heater was prepared which includes a ceramic sheet having a line width of the center portion of each outer wiring portion being 0.60 mm, a line width of each inner wiring portion being 0.55 mm, and a value of a ratio of the line width of the center portion to the line width of the inner wiring portion being 1.09. This ceramic heater was regarded as a sample 1C'. Further, a ceramic heater having a line width of the center portion being 0.66 mm, a line width of each inner wiring portion being 0.60 mm, and a value of the ratio being 1.1, that is, a ceramic heater identical to the ceramic heater of the present embodiment, was prepared as a sample 1D'. A ceramic heater having a line width of the center portion being 0.69 mm, a line width of each inner wiring portion being 0.60 mm, and a value of the ratio being 1.15 was prepared as a sample 1E'. A ceramic heater having a line width of the center portion being 1.20 mm, a line width of each inner wiring portion being 0.60 mm, and a value of the ratio being 2.0 was prepared as a sample 1F'. As for each of the samples 1C' to 1F', five samples were prepared.

[0047] Next, a voltage (AC 240V) was applied across a pair of internal terminals included in each of the measurement samples (samples 1C' to 1F') for 6 minutes, and the surface temperature of the ceramic sheet was measured by a thermocamera. In addition, it was observed whether local heat generation occurred at the outer wiring portions and whether dielectric breakdown occurred between the pair of outer wiring portions. The results are shown on Table 2.

[Table 2]

Sample	Line width			Examination result	
	Center portion (W4)	Inner wiring portion (W6)	Ratio (W4/W6)	Local heat generation	Dielectric breakdown
1C'	0.60 mm	0.55 mm	1.09	0/5	0/5
1D'	0.66 mm	0.60 mm	1.1	0/5	0/5
1E'	0.69 mm	0.60 mm	1.15	0/5	0/5
1F'	1.20 mm	0.60 mm	2.0	0/5	0/5

[0048] According to the results, as for the samples 1C' to 1F', neither local heat generation nor dielectric breakdown was found in any of the five samples throughout observation for 6 minutes. As for the samples 1D' and 1E', the temperature of the center portion of each outer wiring portion was reduced a little, but it was found that this reduction in temperature did not adversely affect thermal uniformity of the ceramic sheet.

[0049] From the above, it was verified that local heat generation and dielectric breakdown are not likely to occur and thermal uniformity is not likely to be reduced if the line width of the center portion of each of the pair of outer wiring portions positioned on opposite sides from each other with the wrapping-ends meeting portion therebetween is set to be not smaller than 1.09 times and not larger than 2.0 times the line width of each inner wiring portion disposed between the pair of outer wiring portions.

[0050] According to the present embodiment, when the line width W4 of the center portion 64 of each outer wiring portion 63 is larger than the line width W6 of each inner wiring portion 66, electric resistance of the center portion 64 becomes smaller than that of the inner wiring portion 66. Therefore, at the wrapping-ends meeting portion of the ceramic sheet 61 where the outer wiring portions 63 are positioned, local heat generation of the heater wire 62 can be suppressed. As a result, melting of the glass component present in the ceramic sheet 61 near the center portions 64 of the outer wiring portions 63 is suppressed, thereby inhibiting dielectric breakdown between the pair of outer wiring portions 63, and inhibiting breakage of the ceramic heater. Therefore, reliability of the ceramic heater can be improved.

[Third embodiment] Hereinafter, a ceramic heater and a production method therefor according to a third embodiment of the present disclosure will be described with reference to the drawings.

[0051] A ceramic heater 111 according to the present embodiment is used in, for example, a heat exchanger of a heat exchange unit of a warm water washing toilet seat, for the purpose of warming washing water.

[0052] As shown in FIGS. 7 and 8, the ceramic heater 111 includes: a cylindrical ceramic heater body 113 made of ceramic; and an annular flange 115 made of metal, externally fitted to the heater body 113. The flange 115 is an annular member formed by bending a metal plate such as a stainless-steel plate. The flange 115 has a recessed (cup-shaped) center portion.

[0053] In the present embodiment, as shown in FIG. 8, in the recessed portion of the flange 115, a space surrounded by an outer peripheral surface 114 of the heater body 113 and an inner surface of the flange 115 serves as a glass

reservoir 135. The glass reservoir 135 is filled with glass 133, and the heater body 113 and the flange 115 are welded and fixed via the glass 133. In FIG. 8, the glass 133 is shown by hatching.

[0054] As shown in FIGS. 7 to 9, the heater body 113 is composed of: a cylindrical support member 117 made of ceramic; and a ceramic sheet 119 wrapped around the outer periphery of the support member 117. In the present embodiment, the support member 117 and the ceramic sheet 119 are formed by using ceramic such as alumina (Al_2O_3). The thermal expansion coefficient of alumina is within a range of $50 \times 10^{-7}/\text{K}$ to $90 \times 10^{-7}/\text{K}$, and is $70 \times 10^{-7}/\text{K}$ (30°C to 380°C) in the present embodiment. In the present embodiment, the support member 117 has an outer diameter set to 12 mm, an inner diameter set to 8 mm, and a length set to 65 mm. The ceramic sheet 119 has a thickness set to 0.5 mm, and a length set to 60 mm. The ceramic sheet 119 does not completely cover the outer periphery of the support member 117. Therefore, a slit 121 is formed at a wrapping-ends meeting portion 120 of the ceramic sheet 119. The slit 121 extends along an axial direction of the support member 117, and exposes an outer peripheral surface of the support member 117. The slit 121 of the present embodiment has a width set to 1 mm, and a depth set to 0.5 mm.

[0055] As shown in FIGS. 9 and 10, inside the ceramic sheet 119, a heater wire 141 having a meandering pattern and a pair of internal terminals 142 are formed. In the present embodiment, the heater wire 141 and the internal terminals 142 contain tungsten (W) as a main component. The internal terminals 142 are electrically connected to external terminals 143 (refer to FIG. 7) formed on an outer peripheral surface of the ceramic sheet 119, through via conductors (not shown) or the like.

[0056] The heater wire 141 includes: a plurality of wiring portions 144 extending along the axial direction of the support member 117; and connection portions 145 each connecting adjacent wiring portions 144 to each other. The wiring portions 144 include a pair of outer wiring portions 146, and a plurality of inner wiring portions 147. The outer wiring portions 146 are disposed on opposite sides from each other with a wrapping-ends meeting portion 120 (refer to FIG. 9) of the ceramic sheet 119 therebetween. A first end (upper end in FIG. 10) of each outer wiring portion 146 is connected to an internal terminal 142, and a second end (lower end in FIG. 10) of each outer wiring portion 146 is connected to an inner wiring portion 147 via a connection portion 145. The internal terminals 142 are disposed between the pair of outer wiring portions 146 when the ceramic sheet 119 is viewed in the thickness direction.

[0057] As shown in FIGS. 9 and 10, in the ceramic sheet 119, the inner wiring portions 147 are disposed between the pair of outer wiring portions 146. A first end (upper end in FIG. 10) of each inner wiring portion 147 is connected to a first end of an adjacent inner wiring portion 147 via a connection portion 145. A second end (lower end in FIG. 10) of each inner wiring portion 147 is connected to a second end of an adjacent inner wiring portion 147 or to a second end of an adjacent outer wiring portion 146, via a connection portion 145.

[0058] Each outer wiring portion 146 of the present embodiment has a thickness T_1 set to $20\text{ }\mu\text{m}$, and a line width set to 0.60 mm. Each inner wiring portion 147 of the present embodiment has a thickness T_2 set to $15\text{ }\mu\text{m}$, and a line width set to 0.60 mm. Likewise, each connection portion 145 of the present embodiment has a thickness set to $15\text{ }\mu\text{m}$, and a line width set to 0.60 mm. That is, the thickness T_1 of the outer wiring portion 146 is larger than the thickness T_2 of the inner wiring portion 147 and the thickness of the connection portion 145. Specifically, the thickness T_1 of the outer wiring portion 146 is set to be 1.33 times the thickness T_2 of the inner wiring portion 147 and the thickness of the connection portion 145. The thickness T_2 of the inner wiring portion 147 is equal to the thickness of the connection portion 145. Since the line width of the outer wiring portion 146 is equal to the line width of the inner wiring portion 147 and to the line width of the connection portion 145, the cross-sectional area of the outer wiring portion 146 is larger than the cross-sectional area of the inner wiring portion 147 and the cross-sectional area of the connection portion 145.

[0059] Next, a method of producing the ceramic heater 111 of the present embodiment will be described.

[0060] First, a clayey slurry containing alumina as a main component is put in a conventionally known extruder (not shown), and the slurry is molded into a tubular member. Then, the molded tubular member is dried, and thereafter is subjected to pre-firing in which the cylindrical member is heated to a predetermined temperature (e. g., about 1000°C), thereby obtaining the support member 117 (refer to FIG. 11A).

[0061] Using a ceramic material containing alumina powder as a main component, first and second ceramic green sheets 151 and 152, which will become the ceramic sheet 119, are formed. As for a method of forming the ceramic green sheets, a known formation method such as a doctor blade method can be adopted.

[0062] Then, a printing process is performed by using a conventionally known paste printing apparatus (not shown), to print a conductive paste (tungsten paste in the present embodiment) on the surface of the first ceramic green sheet 151. In the present embodiment, the conductive paste is printed dividedly in two times to make the thickness T_1 of the outer wiring portion 146 larger than the thickness T_2 of the inner wiring portion 147. Specifically, first, the conductive paste is printed on the surface of the first ceramic green sheet 151, thereby forming a first electrode 153 as an unfired electrode which forms the heater wire 141 and the internal terminals 142 (refer to FIG. 11B). The line width of the first electrode 153 is adjusted to be, for example, a width obtained by adding an amount of shrinkage at firing to the line width of the heater wire 141. Next, the conductive paste is printed on portions, of the first electrode 153, which will become the outer wiring portions 146, thereby forming a second electrode 154 which forms portions of the outer wiring portions 146 (refer to FIG. 11B). Although not shown, the line width of the second electrode 154 is adjusted to be narrower

than that of the first electrode 153, for example.

[0063] After drying of the conductive paste, a second ceramic green sheet 152 is stacked on the printed surface (surface on which the first electrode 153 and the second electrode 154 are formed) of the first ceramic green sheet 151, and a pressing force is applied in the sheet stacking direction. As a result, the ceramic green sheets 151 and 152 are unified, thereby forming a green-sheet stacked body 155 (refer to FIG. 11C). Further, using the paste printing apparatus, the conductive paste is printed on the surface of the second ceramic green sheet 152. As a result, an unfired electrode 156, which will become the external terminals 143, is formed on the surface of the second ceramic green sheet 152.

[0064] Next, a wrapping process is performed in which a ceramic paste (alumina paste) is applied to one side of the green-sheet stacked body 155, and the green-sheet stacked body 155 is wrapped around the outer peripheral surface of the support member 117 so as to be adhered to the support member 117 (refer to FIG. 11D). At this time, the size of the green-sheet stacked body 155 is adjusted so that the opposing ends of the green-sheet stacked body 155 do not overlap each other. Next, a drying process, a degreasing process, etc. are performed according to conventionally known techniques, and thereafter, co-firing is performed in which the green-sheet stacked body 155 (the ceramic green sheets 151 and 152, the first electrode 153, the second electrode 154, and the unfired electrode 156) is heated to a predetermined temperature (e.g., about 1400°C to 1600°C) at which alumina and tungsten in the green-sheet stacked body 155 can be sintered. As a result, alumina in the ceramic green sheets 151 and 152 and tungsten in the conductive paste are simultaneously sintered, whereby the green-sheet stacked body 155 becomes the ceramic sheet 119, the electrodes 153 and 154 become the heater wire 141 and the internal terminal 142, respectively, and the unfired electrode 156 becomes the external terminals 143. Thereafter, the external terminals 143 are plated with nickel to obtain the heater body 113.

[0065] Next, a plate member made of stainless steel is press-formed using a die, thereby forming the cup-shaped flange 115. Then, the flange 115 is externally fitted to the heater body 113 at a predetermined position. Thereafter, the heater body 113 and the flange 115 are welded and fixed via the glass 133 to complete the ceramic heater 111.

<Experimental example>

[0066] Hereinafter, an example of an experiment performed to evaluate the performance of the ceramic heater 111 of the present embodiment will be described.

[0067] First, measurement samples were prepared as follows. A ceramic heater was prepared which includes a ceramic sheet having a thickness of each outer wiring portion being 15 μm , a thickness of each inner wiring portion being 15 μm , and a value of a ratio of the thickness of the outer wiring portion to the thickness of the inner wiring portion being 1.0. In other words, a ceramic heater in which the thickness of each outer wiring portion is equal to the thickness of each inner wiring portion was prepared. This ceramic heater was regarded as a sample 2A. Further, a ceramic heater having a thickness of each outer wiring portion being 18 μm , a thickness of each inner wiring portion being 15 μm , and a value of the ratio being 1.2 was prepared as a sample 2B. A ceramic heater having a thickness of each outer wiring portion being 15 μm , a thickness of each inner wiring portion being 12 μm , and a value of the ratio being 1.25 was prepared as a sample 2C. A ceramic heater having a thickness of each outer wiring portion being 19 μm , a thickness of each inner wiring portion being 15 μm , and a value of the ratio being 1.27 was prepared as a sample 2D. A ceramic heater having a thickness of each outer wiring portion being 20 μm , a thickness of each inner wiring portion being 15 μm , and a value of the ratio being 1.33, that is, a ceramic heater identical to the ceramic heater 111 of the present embodiment, was prepared as a sample 2E. A ceramic heater having a thickness of the outer wiring portion being 25 μm , a thickness of the inner wiring portion being 15 μm , and a value of the ratio being 1.67 was prepared as a sample 2F. A ceramic heater having a thickness of each outer wiring portion being 30 μm , a thickness of each inner wiring portion being 15 μm , and a value of the ratio being 2.0 was prepared as a sample 2G. A ceramic heater having a thickness of each outer wiring portion being 36 μm , a thickness of each inner wiring portion being 15 μm , and a value of the ratio being 2.4 was prepared as a sample 2H. As for each of the samples 2A to 2H, five samples were prepared.

[0068] Next, a nichrome wire was soldered to a pair of internal terminals (heater wire) included in the ceramic sheet of each of the measurement samples (samples 2A to 2H), and each measurement sample, in its dry state, was placed on a base. Then, a voltage (AC 240V) was applied across the pair of internal terminals for 6 minutes, and the surface temperature of the ceramic sheet was measured by a thermocamera. In addition, it was observed whether local heat generation occurred at the outer wiring portions and whether dielectric breakdown occurred between the pair of outer wiring portions. If dielectric breakdown occurred, the occurrence time was measured and recorded. The results are shown on Table 3.

[Table 3]

Sample	Thickness			Test result	
	Outer wiring portion (T1)	Inner wiring portion (T2)	Ratio (T1/T2)	Local heat generation	Dielectric breakdown
2A	15 μm	15 μm	1.0	5/5	5/5
2B	18 μm	15 μm	1.2	5/5	2/5
2C	15 μm	12 μm	1.25	1/5	0/5
2D	19 μm	15 μm	1.27	0/5	0/5
2E	20 μm	15 μm	1.33	0/5	0/5
2F	25 μm	15 μm	1.67	0/5	0/5
2G	30 μm	15 μm	2.0	0/5	0/5
2H	36 μm	15 μm	2.4	0/5	0/5

[0069] According to the results, as for the sample 2A, it was found that, in all the five samples, local heat generation occurred, and dielectric breakdown occurred with a spark after 1 min and 50 sec had passed. As for the sample 2B, it was found that local heat generation occurred in all the five samples, and dielectric breakdown occurred in two samples among the five samples. As for the sample 2C, occurrence of dielectric breakdown was not found, but local heat generation was found in one sample among the five samples. Meanwhile, as for the samples 2D to 2H, neither local heat generation nor dielectric breakdown was found in any of the five samples throughout observation for 6 minutes. However, in the sample 2H, it was found that the temperature at the wrapping-ends meeting portion of the ceramic sheet was reduced, leading to reduction in thermal uniformity.

[0070] From the above, it was verified that local heat generation and dielectric breakdown are not likely to occur and thermal uniformity is not likely to be reduced if the thickness of each of the pair of outer wiring portions positioned on opposite sides from each other with the wrapping-ends meeting portion therebetween is set to be not smaller than 1.27 times and not larger than 2.0 times the thickness of each inner wiring portion disposed between the pair of outer wiring portions.

[0071] Therefore, the following effects can be achieved according to the present embodiment.

(1) In the ceramic heater 111 of the present embodiment, since the thickness T1 of each outer wiring portion 146 is larger than the thickness T2 of each inner wiring portion 147, electric resistance of the outer wiring portion 146 becomes smaller than that of the inner wiring portion 147. Therefore, at the wrapping-ends meeting portion 120 where the outer wiring portions 146 are positioned, local heat generation of the heater wire 141 can be suppressed. As a result, melting of the glass component present in the ceramic sheet 119 near the outer wiring portions 146 is suppressed, thereby inhibiting dielectric breakdown between the pair of outer wiring portions 146, and inhibiting breakage of the ceramic heater 111. Thus, reliability of the ceramic heater 111 can be improved.

(2) In the present embodiment, the pair of internal terminals 142 formed in the ceramic sheet 119 are disposed inward of the pair of outer wiring portions 146 also formed in the ceramic sheet 119 (refer to FIG. 10). Therefore, when the ceramic sheet 119 is wrapped around the outer periphery of the support member 117, the internal terminals 142 are positioned on opposite sides from each other in the radial direction of the support member 117. As a result, the distance between the internal terminals 142 is increased, whereby occurrence of discharge between the internal terminals 142 can be suppressed.

(3) In the present embodiment, since the electric resistance of each outer wiring portion 146 is reduced without increasing the width of the outer wiring portion 146. Therefore, it is easy to ensure the distance between the pair of outer wiring portions 146 disposed on opposite sides from each other with the wrapping-ends meeting portion 120 therebetween. Accordingly, occurrence of partial discharge between the outer wiring portions 146 can be suppressed more reliably.

[Fourth embodiment] Hereinafter, a fourth embodiment of the present disclosure will be described with reference to the drawings. The following description focuses on a difference from the third embodiment. In the present embodiment, the structure of the heater wire is different from that of the third embodiment.

[0072] Specifically, as shown in FIGS. 12 and 13, each of outer wiring portions 163 as components of a heater wire

162 included in a ceramic sheet 161, has: a thickness T3, of a center portion 164, set to 20 μm ; a thickness, of a portion 165 other than the center portion 164, set to 15 μm ; and a line width set to 0.60 mm. The "center portion 164 of the outer wiring portion 163" is a region, of a center portion of the outer wiring portion 163, which occupies not larger than one-third of the length of the outer wiring portion 163. Each of inner wiring portions 166 as components of the heater wire 162 has a thickness T4 set to 15 μm , and a line width set to 0.60 mm. Further, each of connection portions 167 as components of the heater wire 162 also has a thickness set to 15 μm , and a line width set to 0.60 mm. That is, the thickness T3 of the center portion 164 of the outer wiring portion 163 is larger than the thickness of the other portion 165 of the outer wiring portion 163, the thickness T4 of the inner wiring portion 166, and the thickness of the connection portion 167. Specifically, the thickness T3 of the center portion 164 is set to be 1.33 times the thickness of the other portion 165, the thickness T4 of the inner wiring portion 166, and the thickness of the connection portion 167. Since the line width of the center portion 164 is equal to the line width of the other portion 165, the line width of the inner wiring portion 166, and the line width of the connection portion 167, the cross-sectional area of the center portion 164 is larger than the cross-sectional area of the other portion 165, the cross-sectional area of the inner wiring portion 166, and the cross-sectional area of the connection portion 167.

[0073] In the present embodiment, the conductive paste is printed dividedly in two times, to make the thickness T3 of the center portion 164 larger than the thickness T4 of the inner wiring portion 166. Specifically, first, the conductive paste is printed on the surface of a ceramic green sheet which will become the ceramic sheet 161, thereby forming a first electrode as an unfired electrode which forms the heater wire 162. Next, the conductive paste is printed on portions, of the first electrode, which will become the center portions 164, thereby forming a second electrode which form portions of the center portions 164. Although not shown, the line width of the second electrode is adjusted so as to be narrower than that of the first electrode, for example. Thereafter, a firing process is performed, whereby the ceramic green sheet becomes the ceramic sheet 161, portions of the region where the first electrode is formed become the inner wiring portions 166, and the regions where the first and second electrodes are formed become the center portions 164 thicker than the inner wiring portions 166.

<Experimental example>

[0074] Hereinafter, an example of an experiment performed to evaluate the performance of the ceramic heater of the present embodiment will be described.

[0075] First, measurement samples were prepared as follows. A ceramic heater was prepared which includes a ceramic sheet having a thickness of the center portion of each outer wiring portion being 15 μm , a thickness of each inner wiring portion being 12 μm , and a value of a ratio of the thickness of the center portion to the thickness of the inner wiring portion being 1.25. This ceramic heater was regarded as a sample 2C'. Further, a ceramic heater having a thickness of the center portion being 20 μm , a thickness of each inner wiring portion being 15 μm , and a value of the ratio being 1.33, that is, a ceramic heater identical to the ceramic heater of the present embodiment, was prepared as a sample 2E'. A ceramic heater having a thickness of the center portion being 25 μm , a thickness of each inner wiring portion being 15 μm , and a value of the ratio being 1.67 was prepared as a sample 2F'. A ceramic heater having a thickness of the center portion being 30 μm , a thickness of each inner wiring portion being 15 μm , and a value of the ratio being 2.0 was prepared as a sample 2G'. As for each of the samples 2C', 2E' to 2G', five samples were prepared.

[0076] Next, a voltage (AC 240V) was applied across a pair of internal terminals included in each of the measurement samples (samples 2C', 2E' to 2G') for 6 minutes, and the surface temperature of the ceramic sheet was measured by a thermocamera. In addition, it was observed whether local heat generation occurred at the outer wiring portions and whether dielectric breakdown occurred between the pair of outer wiring portions. The results are shown on Table 4.

[Table 4]

Sample	Thickness			Test result	
	Center portion (T3)	Inner wiring portion (T4)	Ratio (T3/T4)	Local heat generation	Dielectric breakdown
2C'	15 μm	12 μm	1.25	0/5	0/5
2E'	20 μm	15 μm	1.33	0/5	0/5
2F'	25 μm	15 μm	1.67	0/5	0/5
2G'	30 μm	15 μm	2.0	0/5	0/5

[0077] According to the results, as for the samples 2C' and 2E' to 2G', neither local heat generation nor dielectric breakdown was found in any of the five samples throughout observation for 6 minutes. As for the samples 2E' to 2G',

the temperature of the center portion of each outer wiring portion was reduced a little, but it was found that this reduction in temperature did not adversely affect thermal uniformity of the ceramic sheet.

[0078] From the above, it was verified that local heat generation and dielectric breakdown are not likely to occur and thermal uniformity is not likely to be reduced if the thickness of the center portion of each of the pair of outer wiring portions positioned at opposite sides from each other with the wrapping-ends meeting portion therebetween is set to be not smaller than 1.25 times and not larger than 2.0 times the thickness of each inner wiring portion disposed between the pair of outer wiring portions.

[0079] According to the present embodiment, when the thickness T3 of the center portion 164 of each outer wiring portion 163 is larger than the thickness T4 of each inner wiring portion 166, electric resistance of the center portion 164 becomes smaller than that of the inner wiring portion 166. Therefore, at the wrapping-ends meeting portion 168 of the ceramic sheet 161, where the outer wiring portions 163 are positioned, local heat generation of the heater wire 162 can be suppressed. As a result, melting of the glass component present in the ceramic sheet 161 near the center portions 164 of the outer wiring portions 163 is suppressed, thereby inhibiting dielectric breakdown between the pair of outer wiring portions 163, and inhibiting breakage of the ceramic heater. Therefore, reliability of the ceramic heater can be improved.

[Other embodiments] The above-described embodiments may be modified as follows.

[0080] In the first embodiment, the line width W3 of the connection portion 45 may be larger than the line width W1 of the outer wiring portion 46 and the line width W2 of the inner wiring portion 47. Likewise, in the second embodiment, the line width W7 of the connection portion 67 may be larger than the line width W4 of the center portion 64 of the outer wiring portion 63, the line width W5 of the other portion 65 of the outer wiring portion 63, and the line width W6 of the inner wiring portion 66.

[0081] In the second embodiment, one center portion 64 is formed in one outer wiring portion 63. However, two or more wide portions each having the same line width as the center portion 64 may be formed in one outer wiring portion. When two or more wide portions are formed in one outer wiring portion, the respective wide portions may be disposed apart from each other along the direction in which the outer wiring portion extends, or may be disposed in contact with each other along the direction in which the outer wiring portion extends.

[0082] In the above embodiments, the support member 17 of the ceramic heater 11 and the support member 117 of the ceramic heater 111 are tubular in shape. However, these support members each may have a rod shape. That is, the ceramic heaters may be used in equipment (e. g., a fan heater) other than a warm water washing toilet seat. In the above embodiments, the flange made of stainless steel is used. However, a flange made of alumina may be used, for example.

[0083] In the above embodiments, the ceramic heater 11 and the ceramic heater 111 are configured such that an AC voltage is applied across the pair of internal terminals 42 and across the pair of internal terminals 142, respectively. However, a DC voltage may be applied across the pair of internal terminals 42 and across the pair of internal terminals 142.

[0084] In the third embodiment, the conductive paste is printed dividedly in two times to make the thickness T1 of the outer wiring portion 146 larger than the thickness T2 of the inner wiring portion 147. However, the conductive paste may be printed dividedly in three or more times to make the thickness T1 of the outer wiring portion 146 larger than the thickness T2 of the inner wiring portion 147. Likewise, in the fourth embodiment, the conductive paste is printed dividedly in two times to make the thickness T3 of the center portion 164 larger than the thickness T4 of the inner wiring portion 166. However, the conductive paste may be printed dividedly in three or more times to make the thickness T3 of the center portion 164 larger than the thickness T4 of the inner wiring portion 166.

[0085] In the third embodiment, the conductive paste is printed on the surface of the first ceramic green sheet 151 to form the unfired electrode (first electrode 153) which forms almost the entirety of the heater wire 141 (region excluding upper-layer portions of the outer wiring portions 146). Thereafter, the conductive paste is printed on portions, of the first electrode 153, which will become the outer wiring portions 146, to form the unfired electrode (second electrode 154) which forms the upper-layer portions of the outer wiring portions 146. However, the conductive paste may be printed on portions, of the surface of the first ceramic green sheet 151, which will become the outer wiring portions 146, to form the unfired electrode which forms lower-layer portions of the outer wiring portions 146. Thereafter, the conductive paste may be printed on the unfired electrode and the surface of the first ceramic green sheet 151 to form the unfired electrode which forms almost the entirety of the heater wire 141 (region excluding the lower-layer portions of the outer wiring portions 146). Alternatively, the entirety of the heater wire 141 may be formed by performing printing of the conductive paste only one time by using an ink-jet apparatus or the like.

[0086] In the fourth embodiment, the conductive paste is printed on the surface of the ceramic green sheet to form the unfired electrode (first electrode) which forms almost the entirety of the heater wire 162 (region excluding upper-layer portions of the center portions 164). Thereafter, the conductive paste is printed on portions, of the first electrode, which will become the center portions 164, to form the unfired electrode (second electrode) which forms the upper-layer portions of the center portions 164. However, the conductive paste may be printed on portions, of the surface of the ceramic green sheet, which will become the center portions 164 to form the unfired electrode which forms lower-layer

portions of the center portions 164. Thereafter, the conductive paste may be printed on the unfired electrode and the surface of the ceramic green sheet to form the unfired electrode which forms almost the entirety of the heater wire 162 (region excluding the lower-layer portions of the center portions 164). Alternatively, the entirety of the heater wire 162 may be formed by performing printing of the conductive paste only one time by using an ink-jet apparatus or the like.

[0087] In the third embodiment, the line width of the second electrode 154 which will become the outer wiring portions 146 is adjusted to be narrower than that of the first electrode 153 which also will become the outer wiring portions 146. However, the line width of the second electrode 154 may be equal to that of the first electrode 153, or may be larger than that of the first electrode 153. Likewise, in the fourth embodiment, the line width of the second electrode which will become the center portions 164 is adjusted to be narrower than the first electrode which also will become the center portions 164. However, the line width of the second electrode may be equal to that of the first electrode, or may be larger than that of the first electrode.

[0088] Hereinafter, the correspondence relationship of wordings will be described.

[0089] In the above embodiments, the ceramic heaters 11 and 111 each correspond to an example of a ceramic heater, the support members 17 and 117 each correspond to an example of a support member, and the ceramic sheets 19, 61, 119, and 161 each correspond to an example of a ceramic sheet.

[0090] The wrapping-ends meeting portions 20, 120, and 168 each correspond to an example of a wrapping-ends meeting portion, the heater wires 41, 62, 141, and 162 each correspond to an example of a heater wire, the wiring portions 44 and 144 each correspond to an example of a wiring portion, and the connection portions 45, 67, 145, and 167 each correspond to an example of a connection portion.

[0091] The outer wiring portions 46, 63, 146, and 163 each correspond to an example of an outer wiring portion, the inner wiring portions 47, 66, 147, and 166 each correspond to an example of an inner wiring portion, and the center portions 64 and 164 of the outer wiring portions each correspond to an example of a center portion of an outer wiring portion. [Other technical ideas] Next, a description will be given of technical ideas that can be understood from the above-described embodiments, other than the technical ideas described in claims.

(1) A ceramic heater configured such that an outer wiring portion has a line width larger than that of an inner wiring portion or configured such that a center portion of an outer wiring portion has a line width larger than that of an inner wiring portion, wherein the line width of the outer wiring portion is set to be not smaller than 1.09 times and not larger than 2.0 times the line width of the inner wiring portion, preferably, not smaller than 1.1 times and not larger than 2.0 times the line width of the inner wiring portion.

(2) A ceramic heater configured such that a center portion of an outer wiring portion has a line width larger than that of an inner wiring portion, wherein the line width of the center portion is larger than that of a portion, of the outer wiring portion, other than the center portion.

(3) A ceramic heater configured such as a center portion of an outer wiring portion has a thickness larger than that of an inner wiring portion, wherein the thickness of the center portion is larger than that of a portion, of the outer wiring portion, other than the center portion.

(4) A method of producing a ceramic heater configured such that an outer wiring portion has a thickness larger than that of an inner wiring portion, the method including: a printing step of printing a conductive paste on a ceramic sheet to form a heater wire; and a wrapping step of wrapping, around a support member, the ceramic sheet on which the heater wire is printed, wherein, in the printing step, the conductive paste is printed dividedly in multiple times to make the thickness of the outer wiring portion larger than that of the inner wiring portion.

(5) The method of producing a ceramic heater according to the technical idea (4), wherein the printing step includes: forming, on the ceramic sheet, a first electrode which forms the heater wire; and forming a second electrode narrower than the first electrode, on a portion, of the first electrode, which will become the outer wiring portion.

(6) A method of producing a ceramic heater configured such that a center portion of an outer wiring portion has a thickness larger than that of the inner wiring portion, the method including: a printing step of printing a conductive paste on a ceramic sheet to form a heater wire; and a wrapping step of wrapping, around a support member, the ceramic sheet on which the heater wire is printed, wherein, in the printing step, the conductive paste is printed dividedly in multiple times to make the thickness of the center portion larger than that of the inner wiring portion.

(7) The method of producing a ceramic heater according to the technical idea (6), wherein the printing step includes: forming, on the ceramic sheet, a first electrode which forms the heater wire; and forming a second electrode narrower than the first electrode, on a portion, of the first electrode, which will become the center portion.

Claims

1. A ceramic heater comprising a support member made of ceramic, and a ceramic sheet which is wrapped around an outer periphery of the support member, and includes a heater wire, wherein
the heater wire includes: a plurality of wiring portions extending along an axial direction of the support member; and
a connection portion connecting adjacent wiring portions to each other,
the plurality of wiring portions include: a pair of outer wiring portions disposed on opposite sides from each other with a wrapping-ends meeting portion of the ceramic sheet therebetween; and an inner wiring portion disposed, in the ceramic sheet, between the pair of outer wiring portions, and
each outer wiring portion has a cross-sectional area larger than that of the inner wiring portion.
2. The ceramic heater according to claim 1, wherein each outer wiring portion has a line width larger than that of the inner wiring portion.
3. The ceramic heater according to claim 2, wherein the line width of the outer wiring portion is set to be larger than 1.07 times and smaller than 2.4 times the line width of the inner wiring portion.
4. The ceramic heater according to claim 1, wherein each outer wiring portion has a thickness larger than that of the inner wiring portion.
5. The ceramic heater according to claim 4, wherein the thickness of the outer wiring portion is set to be larger than 1.25 times and smaller than 2.4 times the thickness of the inner wiring portion.
6. A ceramic heater comprising a support member made of ceramic, and a ceramic sheet which is wrapped around an outer periphery of the support member, and includes a heater wire, wherein
the heater wire includes: a plurality of wiring portions extending along an axial direction of the support member; and
a connection portion connecting adjacent wiring portions to each other,
the plurality of wiring portions include: a pair of outer wiring portions disposed on opposite sides from each other with a wrapping-ends meeting portion of the ceramic sheet therebetween; and an inner wiring portion disposed, in the ceramic sheet, between the pair of outer wiring portions, and
a center portion of each outer wiring portion has a cross-sectional area larger than that of the inner wiring portion.
7. The ceramic heater according to claim 6, wherein the center portion of each outer wiring portion has a line width larger than that of the inner wiring portion.
8. The ceramic heater according to claim 7, wherein the line width of the center portion is set to be larger than 1.07 times and not larger than 2.0 times the line width of the inner wiring portion.
9. The ceramic heater according to claim 6, wherein the center portion of each outer wiring portion has a thickness larger than that of the inner wiring portion.
10. The ceramic heater according to claim 9, wherein the thickness of the center portion is set to be not smaller than 1.25 times and not larger than 2.0 times the thickness of the inner wiring portion.
11. The ceramic heater according to any one of claims 1 to 10, wherein the support member and the ceramic sheet contain alumina.
12. The ceramic heater according to any one of claims 1 to 11, wherein the heater wire contains, as a main component, at least one of tungsten and molybdenum.

FIG.1

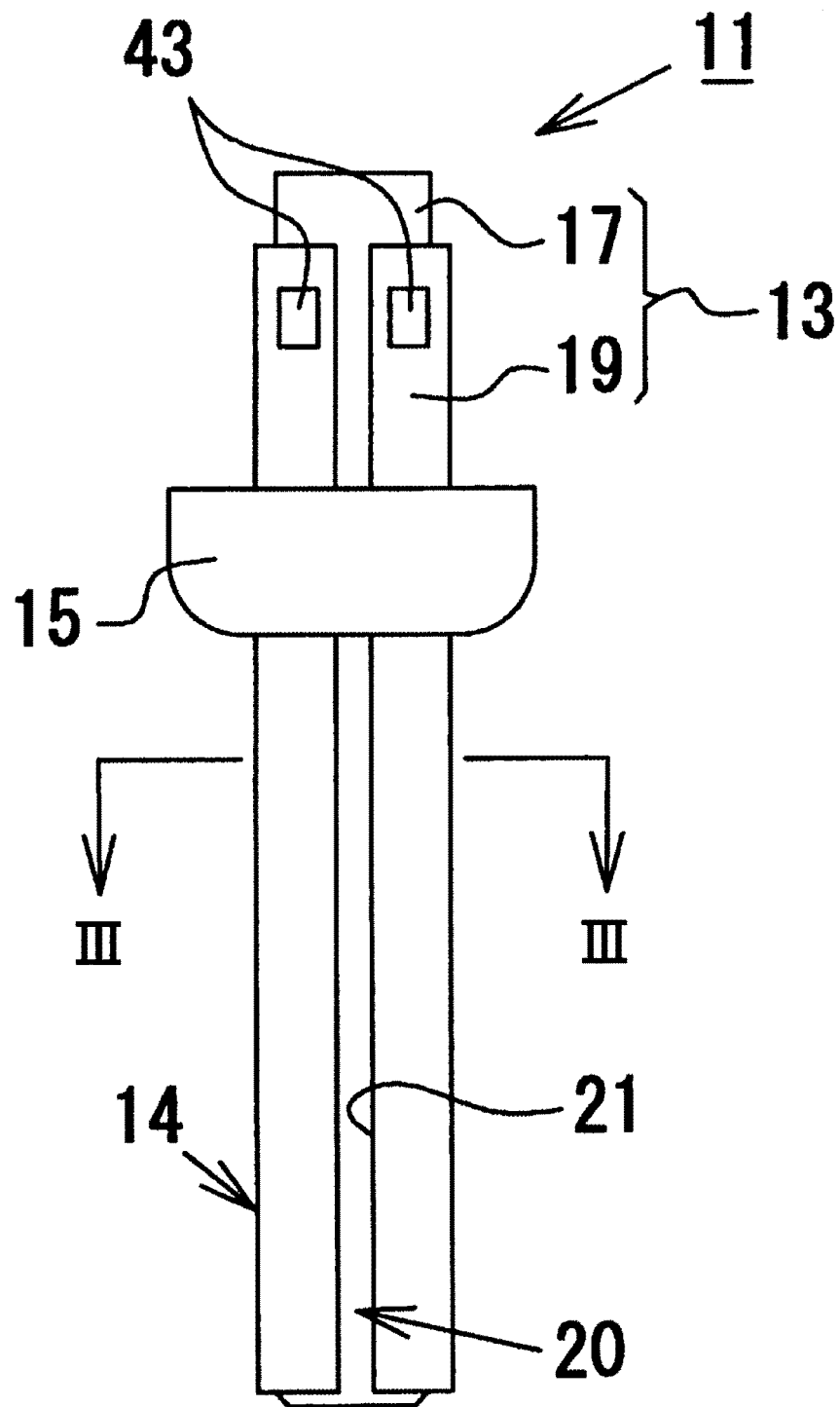


FIG.2

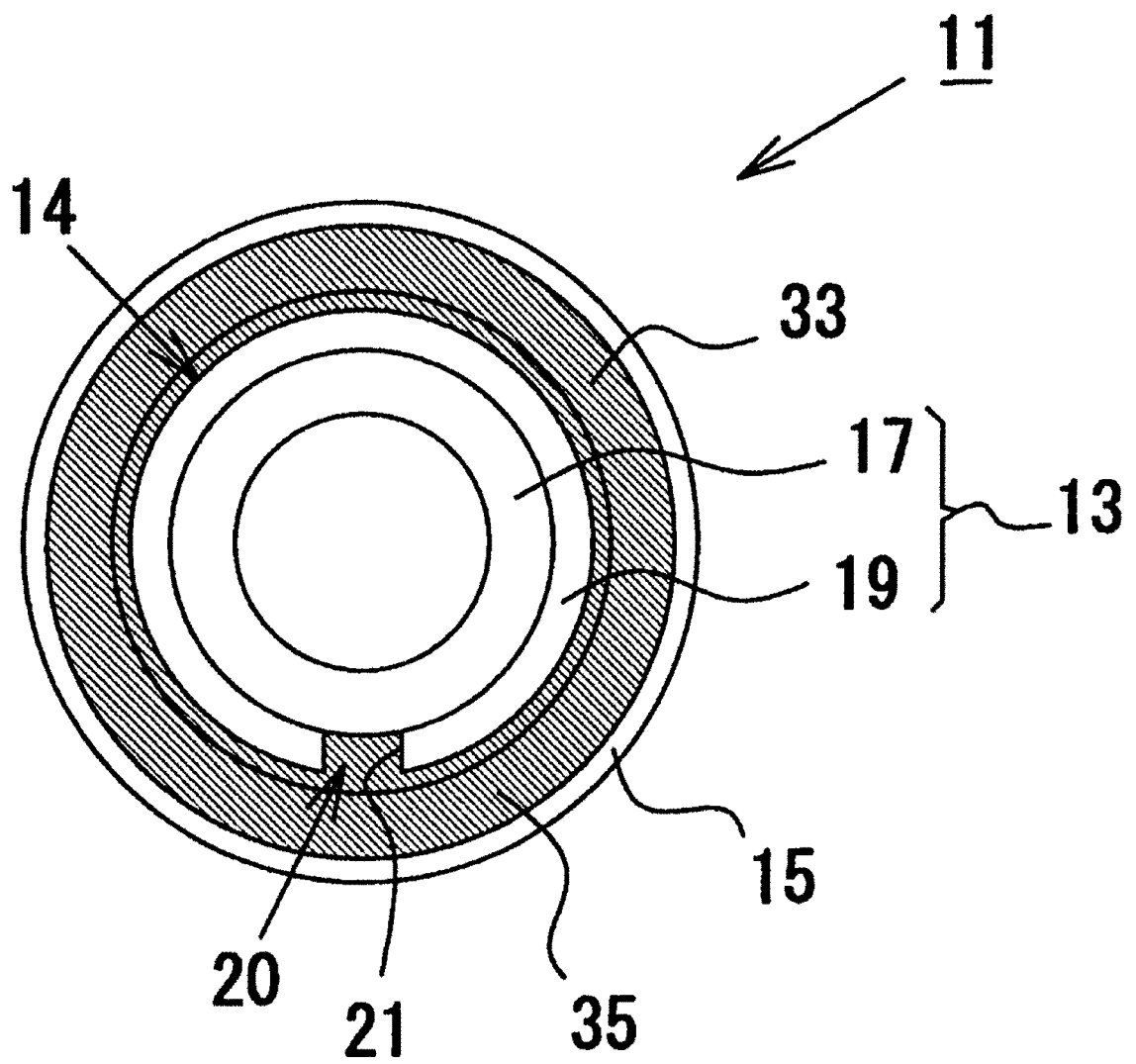


FIG.3

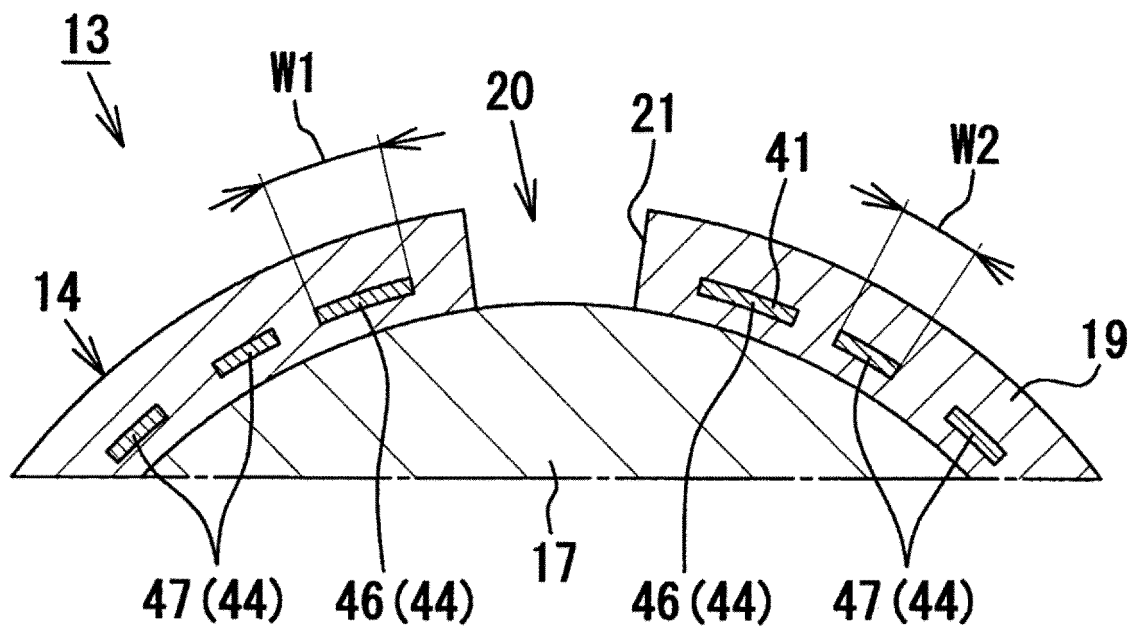


FIG.4

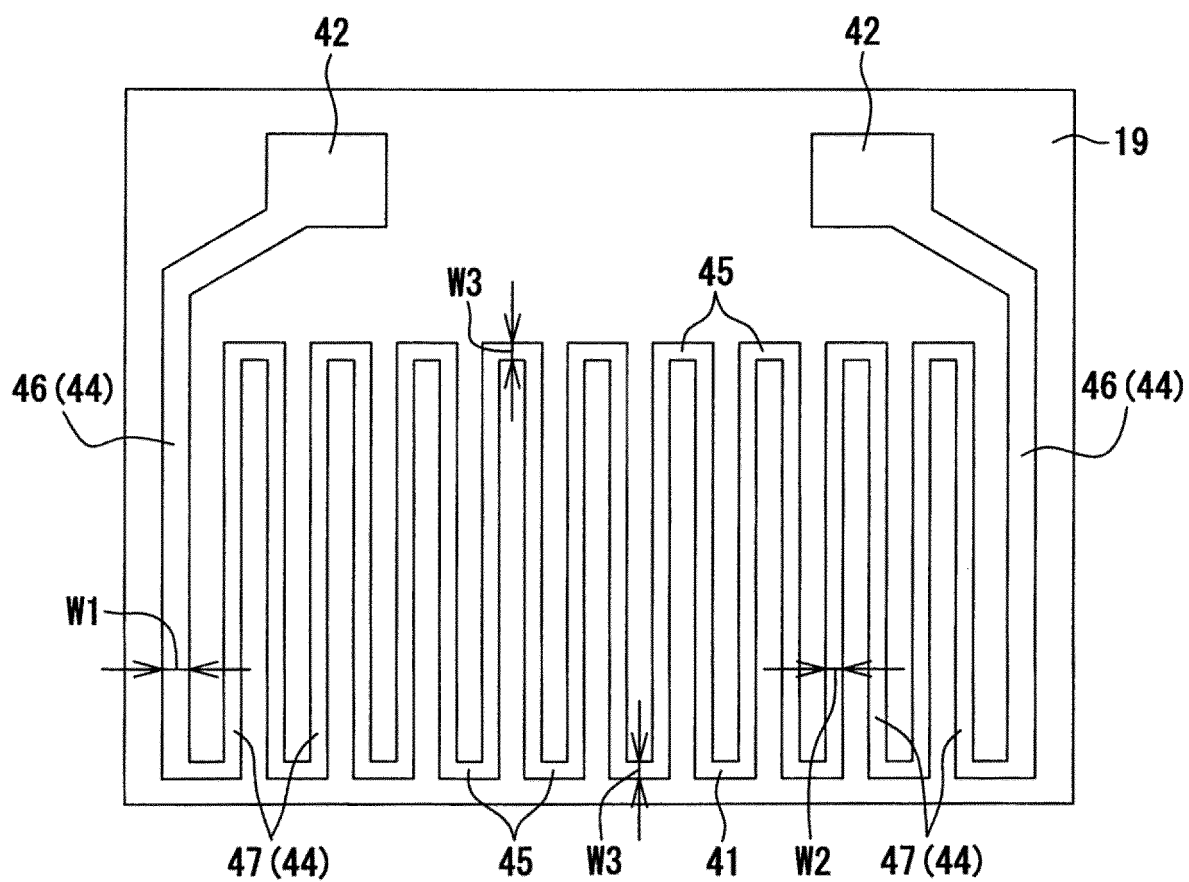


FIG.5A



FIG.5B

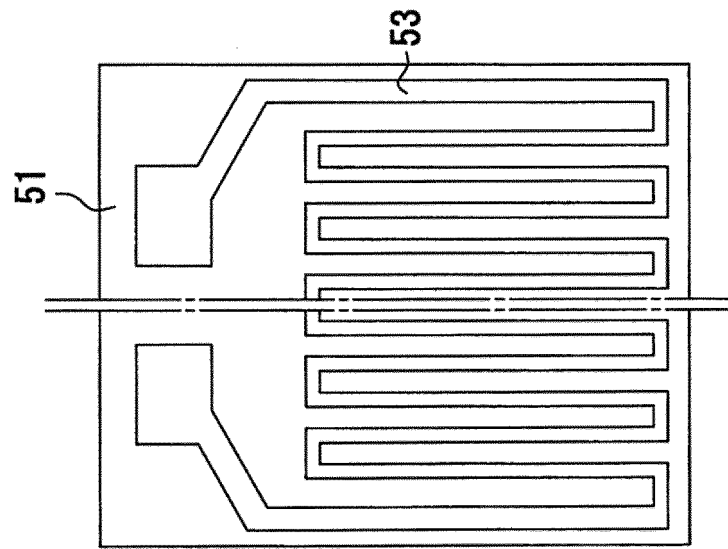


FIG.5C

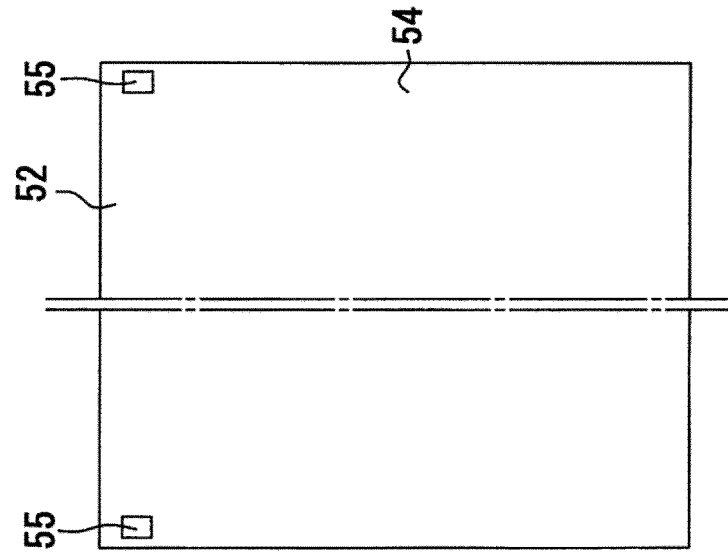


FIG.5D

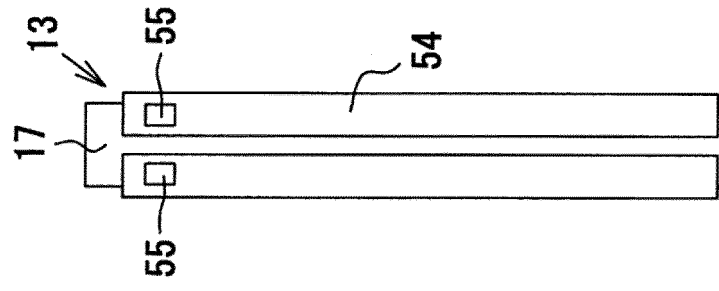


FIG.6

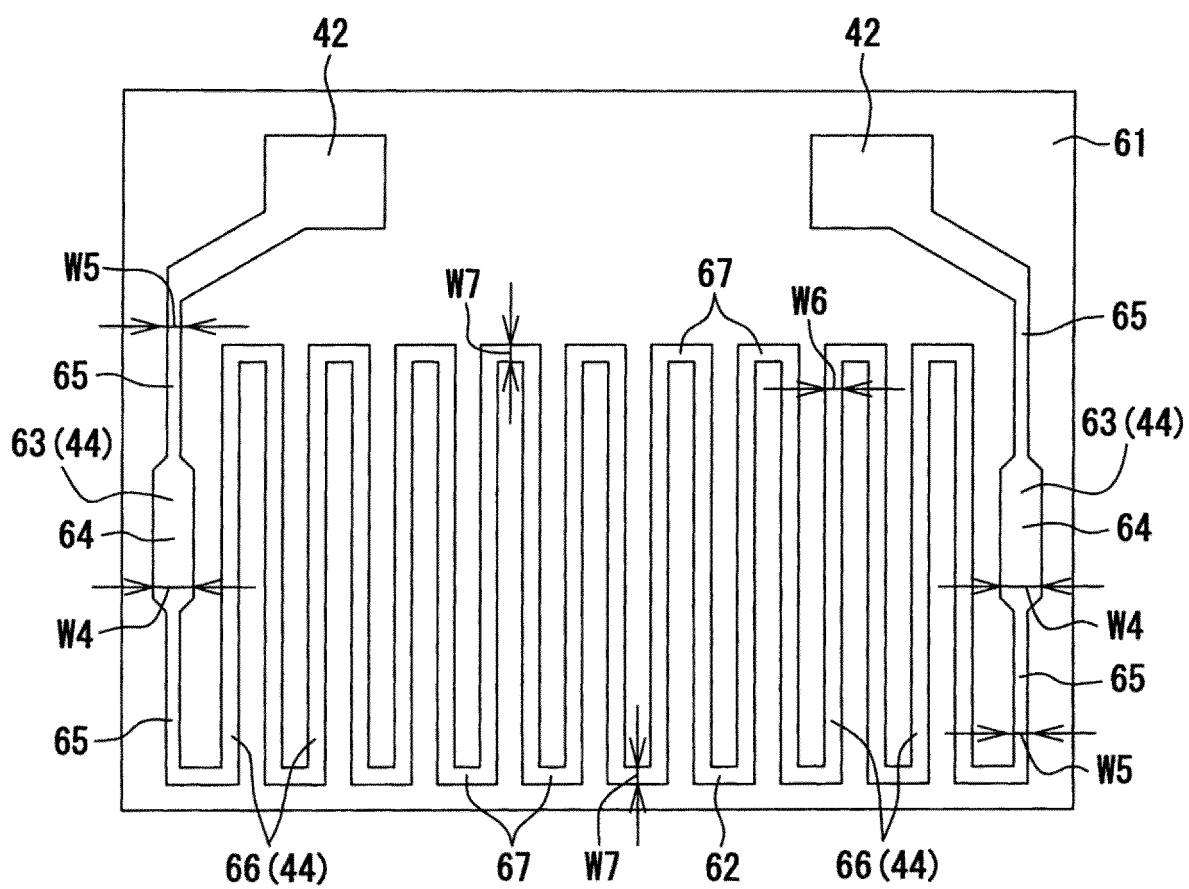


FIG.7

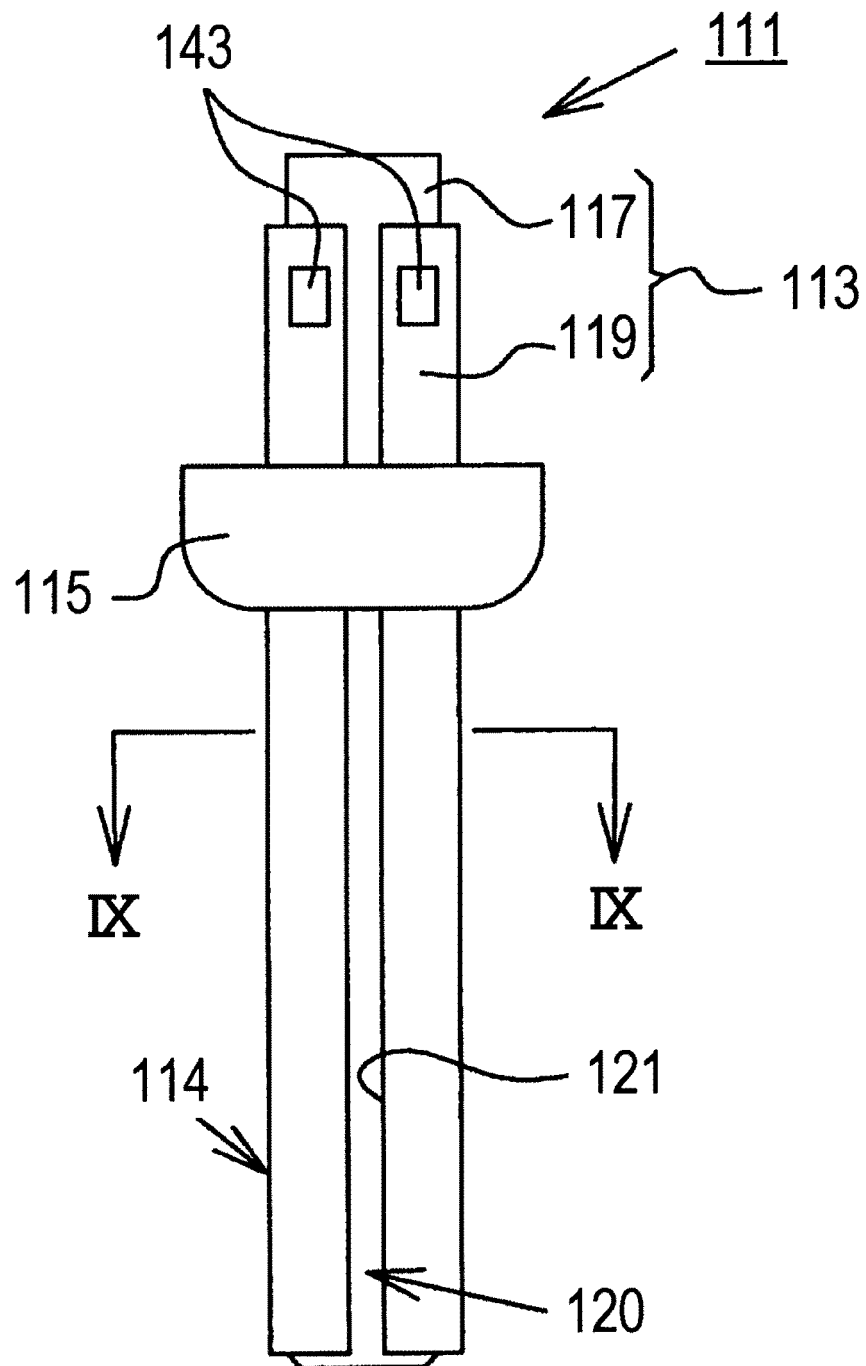


FIG.8

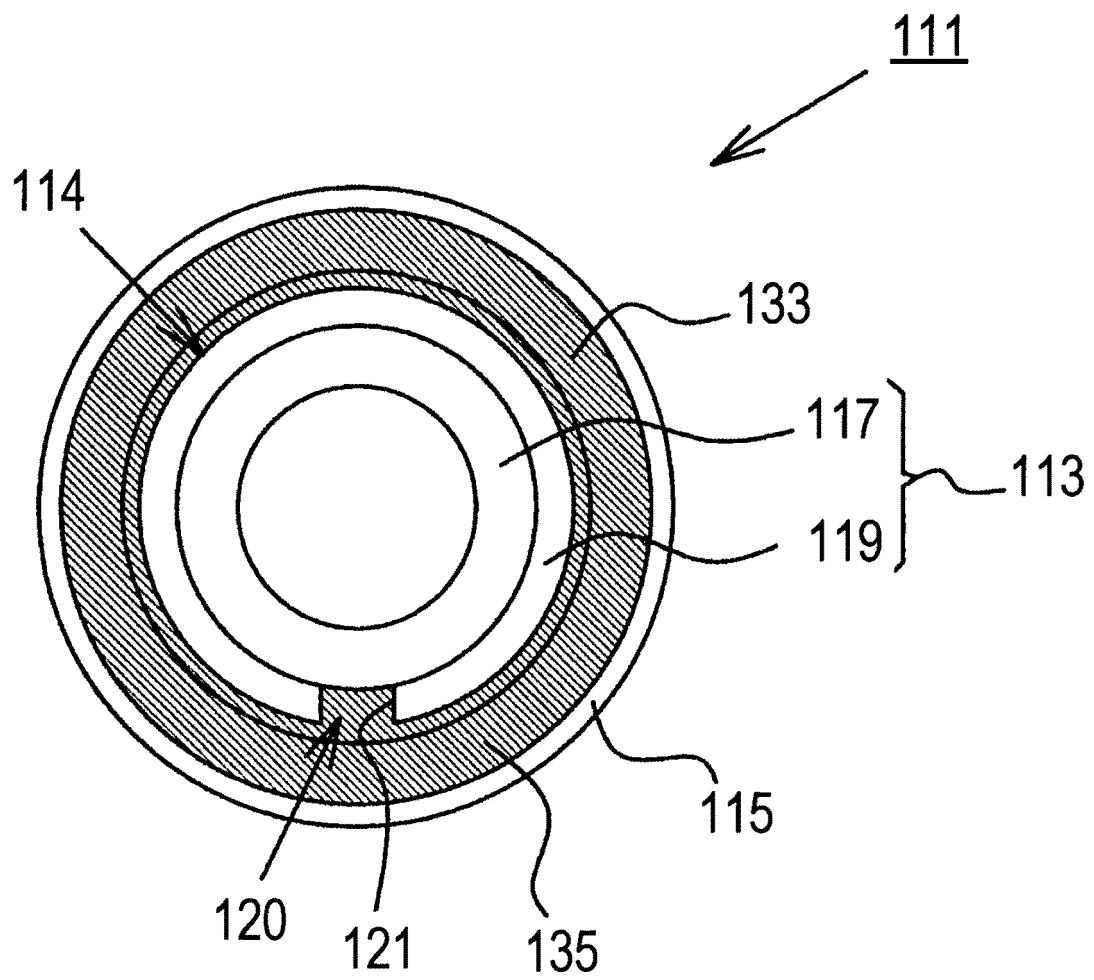


FIG.9

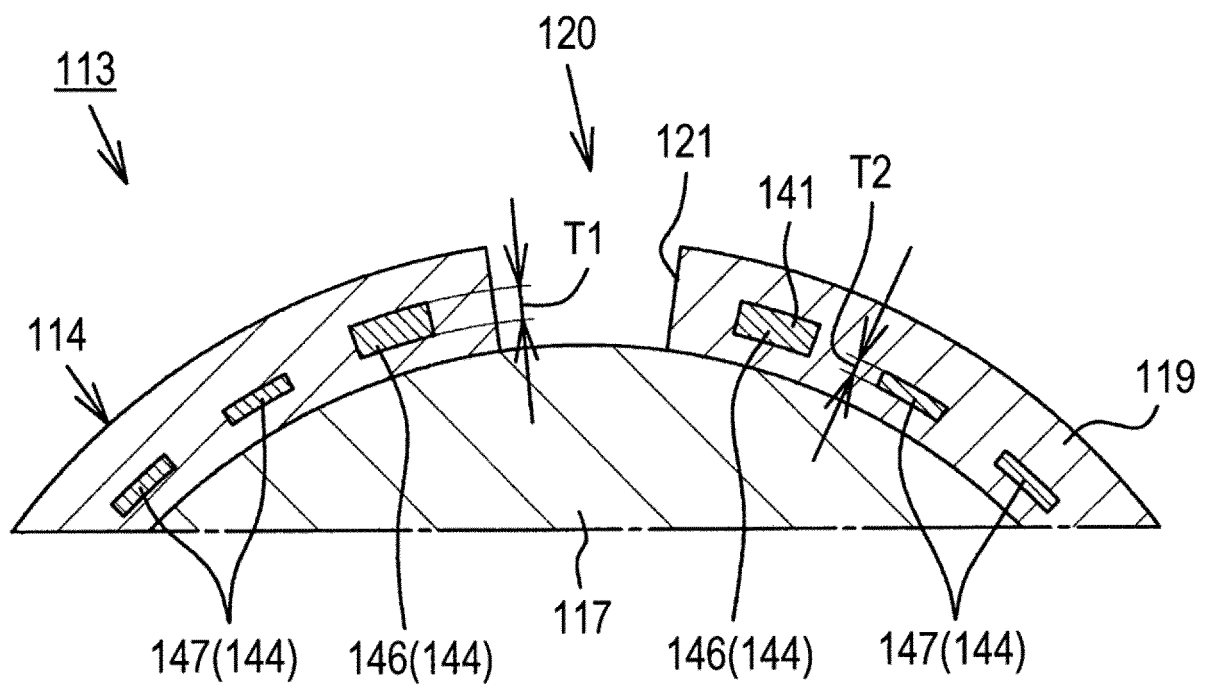


FIG. 10

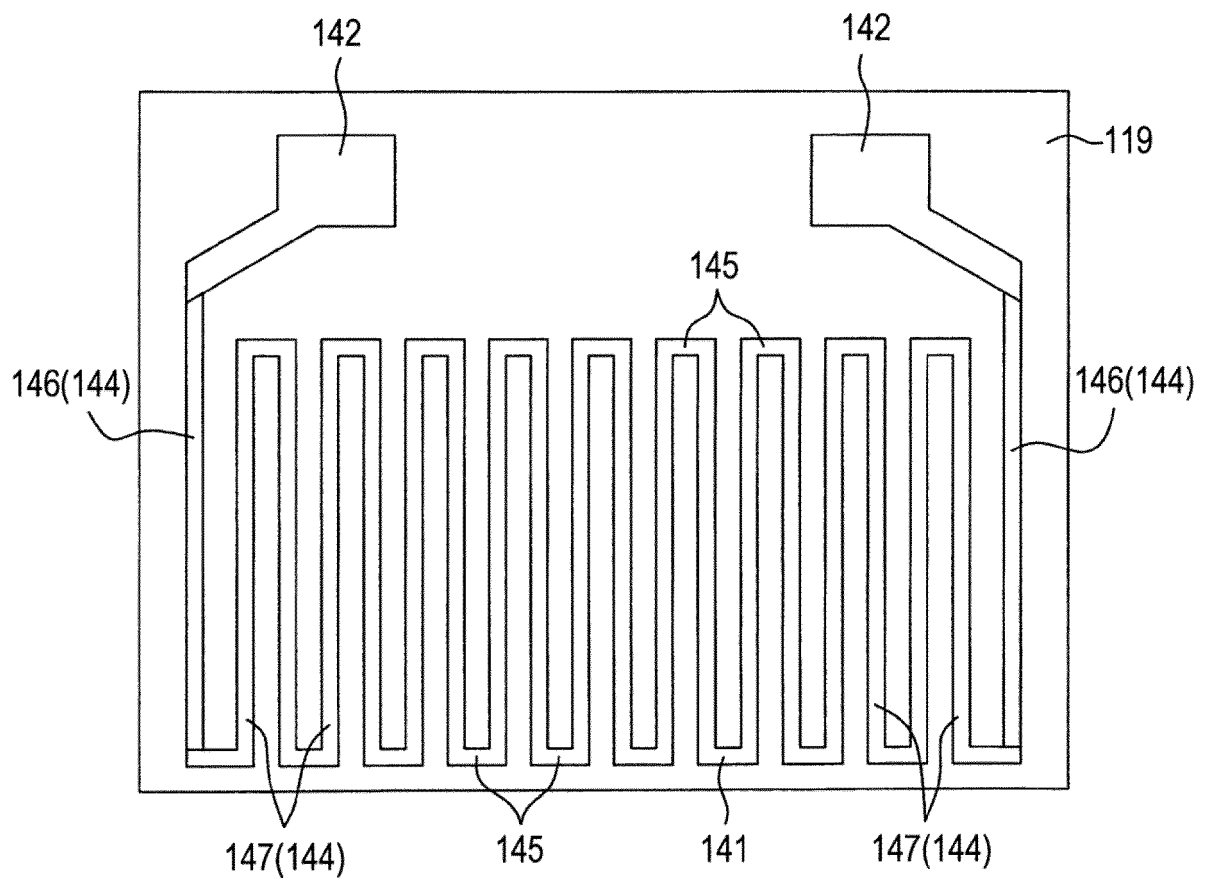


FIG.11A

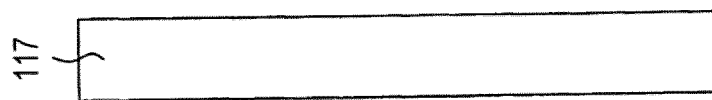


FIG.11B

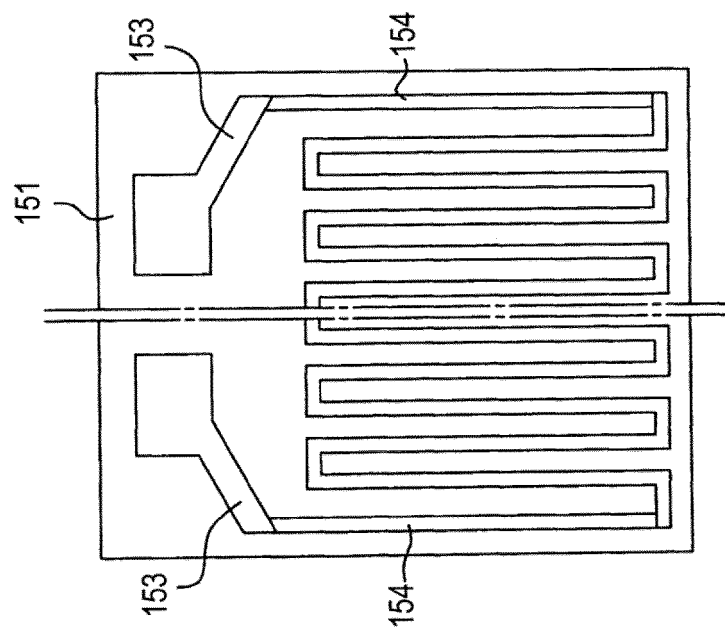


FIG.11C

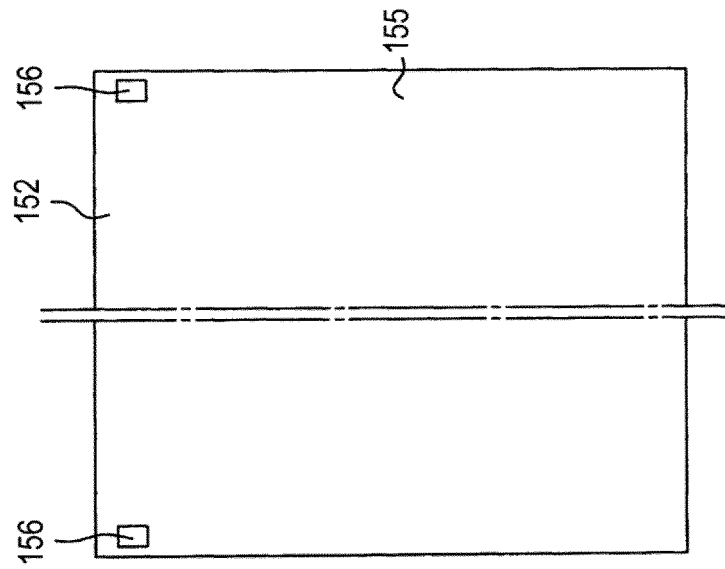


FIG.11D

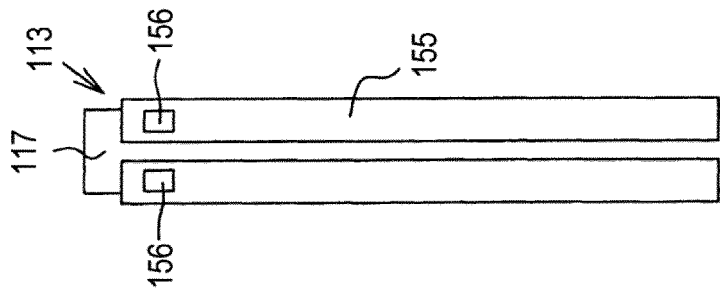


FIG.12

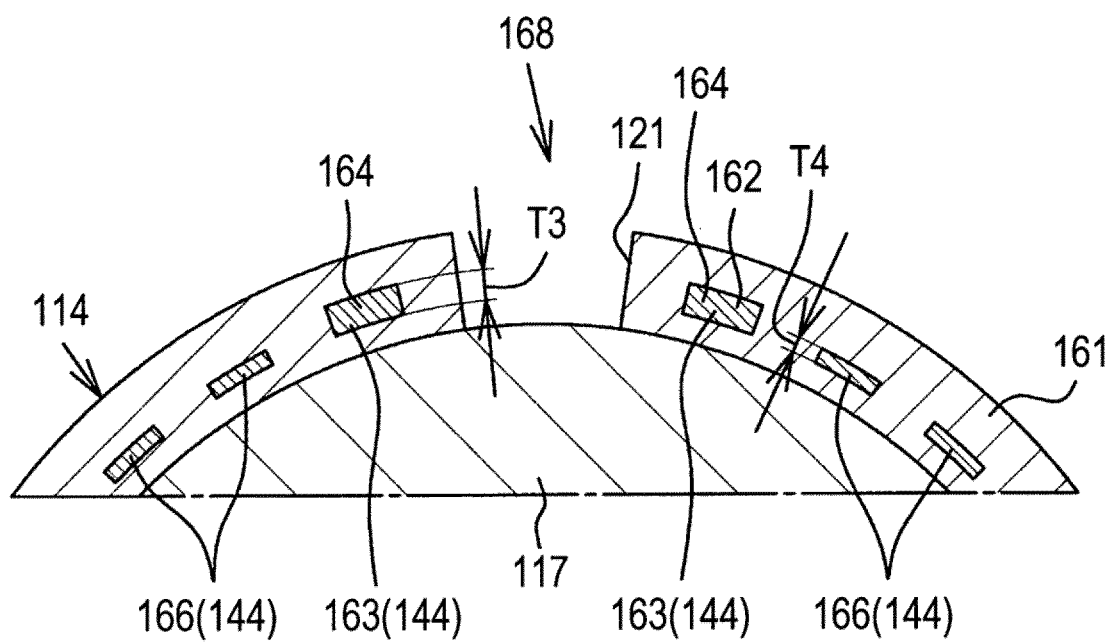
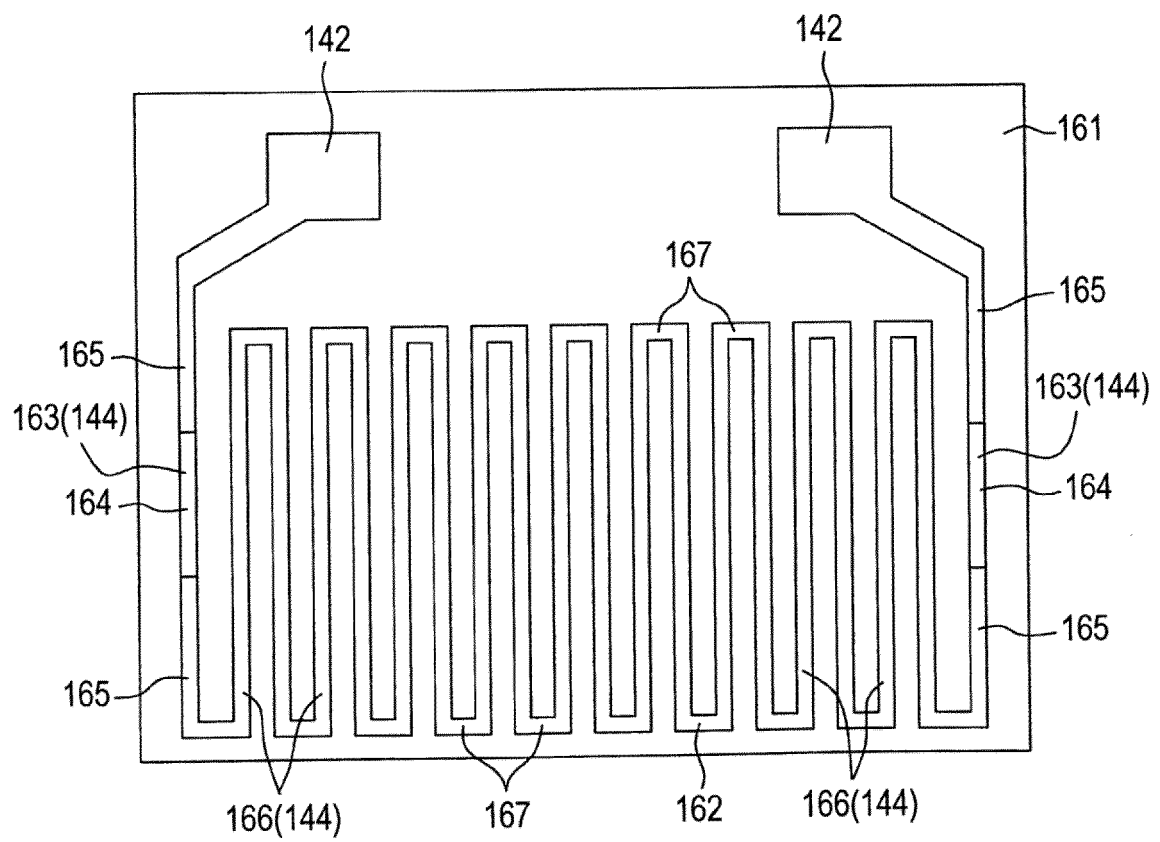


FIG.13



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/004800

A. CLASSIFICATION OF SUBJECT MATTER

H05B3/10(2006.01)i, H05B3/14(2006.01)i, H05B3/18(2006.01)i, H05B3/46(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)

H05B3/10, H05B3/14, H05B3/18, H05B3/46

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.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 029792/1986(Laid-open No. 142189/1987) (Kyocera Corp.), 08 September 1987 (08.09.1987), specification, page 4, lines 5 to 19; all drawings (Family: none)	1-12
Y	JP 2001-194942 A (Ricoh Co., Ltd.), 19 July 2001 (19.07.2001), paragraph [0015]; fig. 6 (Family: none)	1-12

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

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search
27 February 2017 (27.02.17)

Date of mailing of the international search report
07 March 2017 (07.03.17)

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

International application No.

PCT/JP2017/004800

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 054887/1986(Laid-open No. 167396/1987) (Kyocera Corp.), 23 October 1987 (23.10.1987), specification, page 7, lines 5 to 11; all drawings (Family: none)	4, 5, 9-12

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2016051823 A [0001]
- JP 2016051824 A [0001]
- JP 3038039 B [0005]