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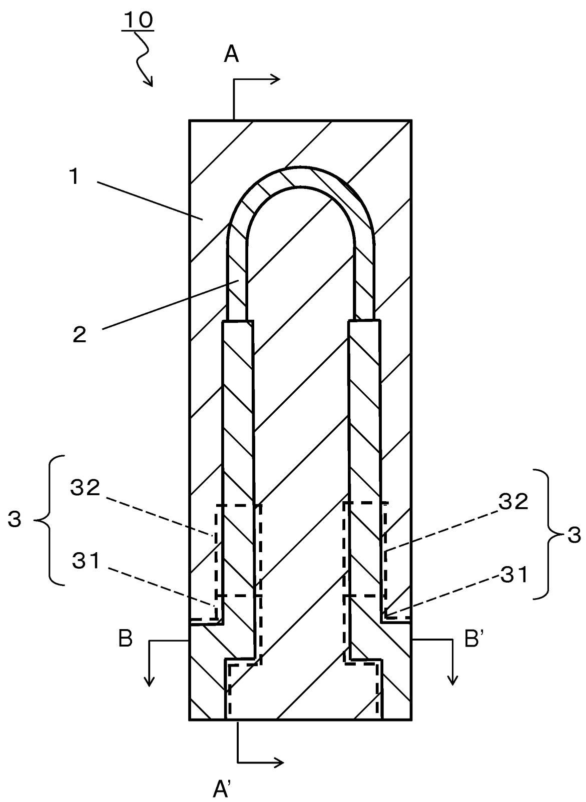
(54) HEATER AND IGNITION DEVICE

(57) A heater includes a ceramic multilayer body including a plurality of ceramic layers that are stacked together; a heat-generating resistor having a belt shape, the heat-generating resistor being disposed between the ceramic layers and arranged, and including both ends that are at a side surface of the ceramic multilayer body; and conductive layers having a belt shape, disposed between the ceramic layers and stacked on both end portions of the heat-generating resistor in such a manner that one end of each conductive layer is at the side surface. Each conductive layer includes a first conductive layer that extends to the side surface and a second conductive layer that is adjacent to the first conductive layer, each of the first conductive layer and the second conductive layer being formed of a plurality of grains, the grains of the first conductive layer having an average grain diameter smaller than an average grain diameter of the grains of the second conductive layer.

Fig. 1



EP 3 136 819 A1

Description

Technical Field

[0001] The present invention relates to a heater and an ignition device.

Background Art

[0002] A heater (ceramic heater) in which a heat-generating body is disposed in a ceramic body is known as an example of a heater for use in a gas stove, an on-vehicle heating device, a kerosene fan heater, a glow plug of an automobile engine, or the like. Patent Document 1 discloses an example of a ceramic heater.

[0003] Japanese Unexamined Patent Application Publication No. 2000-156275 (hereinafter referred to as Patent Document 1) discloses a ceramic heater including a ceramic structure, a heat-generating resistor embedded in the ceramic structure, and feeder lines that are connected to the heat-generating resistor and extend to a surface of the ceramic structure.

[0004] The ceramic heater described in Patent Document 1 has a risk that cracks will be formed in the feeder lines when the ceramic heater is repeatedly used in a high-temperature environment. When, in particular, cracks are formed in portions of the feeder lines exposed at the surface of the ceramic structure, the outside air may flow into the feeder lines. Therefore, the resistance of the feeder lines may change due to a reaction between the feeder lines and the outside air, and abnormal local heat generation may occur. Thus, it is difficult to increase the long-term reliability when the ceramic heater is repeatedly used in a high-temperature environment.

Summary of Invention

[0005] A heater includes a ceramic multilayer body including a plurality of ceramic layers that are stacked together; a heat-generating resistor having a belt shape, the heat-generating resistor being disposed between the ceramic layers and arranged, and including both ends that are at a side surface of the ceramic multilayer body; and conductive layers having a belt shape, disposed between the ceramic layers and stacked on both end portions of the heat-generating resistor in such a manner that one end of each conductive layer is at the side surface. Each conductive layer includes a first conductive layer that extends to the side surface and a second conductive layer that is adjacent to the first conductive layer, each of the first conductive layer and the second conductive layer being formed of a plurality of grains, the grains of the first conductive layer having an average grain diameter smaller than an average grain diameter of the grains of the second conductive layer.

Brief Description of Drawings

[0006]

Fig. 1 is a longitudinal sectional view of a heater.
Fig. 2 is a cross-sectional view of the heater illustrated in Fig. 1 taken along line A-A'.
Fig. 3 is a cross-sectional view of the heater illustrated in Fig. 1 taken along line B-B'.
Fig. 4 is a cross-sectional view of a modification of the heater.
Fig. 5 is a perspective view of an ignition device including the heater illustrated in Fig. 1.

Description of Embodiments

[0007] A heater 10 will be described with reference to the drawings.

[0008] As illustrated in Figs. 1 to 3, the heater 10 includes a ceramic multilayer body 1 including a plurality of ceramic layers 11 that are stacked together, a heat-generating resistor 2 provided between the adjacent ceramic layers 11, and conductive layers 3 stacked on the heat-generating resistor 2. The heater 10 may be used in, for example, a glow plug of an automobile engine or a gas stove.

[0009] The ceramic multilayer body 1 is a member in which the heat-generating resistor 2 and the conductive layers 3 are embedded. The durabilities of the heat-generating resistor 2 and the conductive layers 3 can be increased by placing the heat-generating resistor 2 and the conductive layers 3 in the ceramic multilayer body 1. The ceramic multilayer body 1 is, for example, a rod-shaped or plate-shaped member.

[0010] The ceramic multilayer body 1 is made of an electrically insulative ceramic, such as an insulating ceramic, a nitride ceramic, or a carbide ceramic. More specifically, the ceramic multilayer body 1 is made of, for example, an alumina ceramic, a silicon nitride ceramic, an aluminum nitride ceramic, or a silicon carbide ceramic.

[0011] The ceramic multilayer body 1 made of a silicon nitride ceramic may be obtained by the following method. For example, silicon nitride, which is the main component, is mixed with 5 to 15 mass% of rare earth oxide, such as Y_2O_3, Yb_2O_3, or Er_2O_3, which functions as a sintering additive; 0.5 to 5 mass% of Al_2O_3; and SiO_2, the amount of which is adjusted so that the amount of SiO_2 in the sintered body is 1.5 to 5 mass%. The thus-obtained material is formed in a predetermined shape, and is then fired at a temperature of 1650°C to 1780°C. Thus, the ceramic multilayer body 1 made of a silicon nitride ceramic is obtained. Hot press firing, for example, may be performed in the firing process.

[0012] When the ceramic multilayer body 1 is rod-shaped, more specifically, rectangular-prism-shaped, the length of the ceramic multilayer body 1 is set to, for example, 20 to 100 mm. The cross-sectional shape of the ceramic multilayer body 1 is set to, for example, a rectangle having a thickness of 1 to 6 mm and a width of 2 to 40 mm.

[0013] The heat-generating resistor 2 is a layer-shaped member that generates heat when a voltage is applied thereto. The heat-generating resistor 2 is disposed between the adjacent ceramic layers 11. When a voltage is applied to the heat-generating resistor 2, a current flows through the heat-generating resistor 2, and the heat-generating resistor 2 generates heat. The generated heat is transferred through the ceramic multilayer body 1, so that the temperature of the surface of the ceramic multilayer body 1 increases. The heat is transferred from the surface of the ceramic multilayer body 1 to an object to be heated, thereby providing the function of the heater 10. The object to be heated that receives the heat from the surface of the ceramic multilayer body 1 is, for example, diesel oil to be supplied to an automobile diesel engine.

[0014] The heat-generating resistor 2 is arranged in such a manner that both ends thereof are at a side surface of the ceramic multilayer body 1 near the rear end of the ceramic multilayer body 1. The heat-generating resistor 2 has, for example, a bent shape in longitudinal cross section (cross section parallel to the length direction of the heat-generating resistor 2). More specifically, the heat-generating resistor 2 includes two linear portions that are arranged next to each other and a connecting portion that has substantially semicircular or substantially semielliptical inner and outer peripheries and that is bent so as to connect the two linear portions. The heat-generating resistor 2 is bent at a location near the front end of the ceramic multilayer body 1. The total length of the heat-generating resistor 2 is, for example, 35 to 100 mm.

[0015] The heat-generating resistor 2 is designed so as to generate a large amount of heat in a region near the front end of the ceramic multilayer body 1. More specifically, the conductive layers 3 are stacked on both end portions of the heat-generating resistor 2 in a region near the rear end of the ceramic multilayer body 1. Accordingly, a current flows through both the heat-generating resistor 2 and the conductive layers 3 in the region near the rear end of the ceramic multilayer body 1. As a result, the amount of heat generated by the heat-generating resistor 2 is small in the region near the rear end of the ceramic multilayer body 1. In contrast, the current flows only through the heat-generating resistor 2 in the region near the front end of the ceramic multilayer body 1. As a result, the amount of heat generated by the heat-generating resistor 2 is large in the region near the front end of the ceramic multilayer body 1.

[0016] The heat-generating resistor 2 is made of, for example, a material having a carbide, nitride, silicide, etc., of tungsten (W), molybdenum (Mo), titanium (Ti), etc., as the main component. When the ceramic multilayer body 1 is made of a silicon nitride ceramic, the heat-generating resistor 2 is preferably made of a material having tungsten carbide as the main component. In this case, the coefficient of thermal expansion of the ceramic multilayer body 1 and that of the heat-generating resistor 2 can be made close to each other.

[0017] The conductive layers 3 are members for adjusting the amount of heat generated by the heat-generating resistor 2 in the region near the rear end of the ceramic multilayer body 1, that is, in the region around the portions of the side surface of the ceramic multilayer body 1 to which the heat-generating resistor 2 extends. In Fig. 1, the conductive layers 3 are shown by the broken lines. In Fig. 1, the broken lines that show the conductive layers 3 and the solid lines that show the heat-generating resistor 2 are shifted from each other to improve visibility. However, in practice, the conductive layers 3 and the heat-generating resistor 2 have substantially the same width, and are stacked together so as to be aligned with each other in the width direction. As illustrated in Figs. 2 and 3, the conductive layers 3 are stacked on both end portions of the heat-generating resistor 2 in the space between the ceramic layers 11, and are arranged such that one end of each conductive layer 3 is at the side surface of the ceramic multilayer body 1. By covering both end portions of the heat-generating resistor 2, which are to be connected to an external circuit, with the conductive layers 3, the amount of heat generated in the region near the rear end of the ceramic multilayer body 1 can be reduced. Accordingly, the connection reliability between the external circuit and the heater 10 can be increased.

[0018] Each conductive layer 3 includes a first conductive layer 31 that extends to the side surface of the ceramic multilayer body 1 and a second conductive layer 32 that is adjacent to the first conductive layer 31. The first conductive layer 31 and the second conductive layer 32 are each formed of a plurality of grains. The average grain diameter of the grains of the first conductive layer 31 is smaller than that of the grains of the second conductive layer 32. Since the first conductive layer 31, which is located closer to the outside, is formed of grains having a small average grain diameter, the density of the first conductive layer 31 can be increased. As a result, the voidage of the first conductive layer 31 is reduced, and the risk that the outside air will flow into each conductive layer 3 can be reduced.

[0019] Since not only the conductive layers 3 but also the heat-generating resistor 2 extends to the side surface of the ceramic multilayer body 1, portions that extend to the side surface have a two-layer structure. Therefore, even when cracks are formed either in the conductive layers 3 or in the heat-generating resistor 2, the risk that the cracks will extend into the other of the conductive layers 3 and the heat-generating resistor 2 can be reduced.

[0020] Since the second conductive layer 32 is formed of grains having a large average grain diameter, the number of grain boundaries of the grains of the second conductive layers 32 can be reduced. Therefore, the resistance of the second conductive layer 32 can be reduced. Accordingly, unnecessary heat generation by each conductive layer 3 can be suppressed.

[0021] As a result, the long-term reliability of the heater 10 when used in a heat cycle is increased.

[0022] More specifically, for example, in the case where conductive layers having a constant average grain diameter in each portion thereof are provided, unlike the above-described heater 10, the following problem arises. That is, when the average grain diameter of the conductive layers is simply reduced, even though the risk that the outside air will flow into the conductive layers can be reduced, since the resistance of the conductive layers increases, unnecessary heat generation by the conductive layers occurs. Conversely, when the average grain diameter of the conductive layers is simply increased, even though unnecessarily heat generation by the conductive layers can be suppressed, the outside air easily flows into the conductive layers. In contrast, by making the average grain diameter of the grains of the first conductive layer 31 smaller than that of the grains of the second conductive layer 32 as in the above-described heater 10, the risk that the outside air will enter each conductive layer 3 can be reduced and unnecessary heat generation by each conductive layer 3 can be suppressed.

[0023] In addition, as illustrated in Fig. 2, the first conductive layer 31 and the second conductive layer 32 preferably partially overlap. In such a case, unlike the case in which the first conductive layer 31 and the second conductive layer 32 do not overlap, each conductive layer 3 can be formed so as to have a coefficient of thermal expansion that changes gradually in the length direction thereof. As a result, the possibility that cracks will be formed in the conductive layers 3 in a heat cycle can be reduced.

[0024] Preferably, the first conductive layer 31 is located between the second conductive layer 32 and the heat-generating resistor 2, and, in a region in which the first conductive layer 31 is located between the second conductive layer 32 and the heat-generating resistor 2, the first conductive layer 31 has a thickness that decreases toward the other end thereof. In such a case, each conductive layer 3 can be formed so as to have a coefficient of thermal expansion that changes smoothly. As a result, the possibility that cracks will be formed in the conductive layers 3 in a heat cycle can be further reduced.

[0025] In the above-described heater 10, each conductive layer 3 includes only the first conductive layer 31 and the second conductive layer 32. However, each conductive layer 3 is not limited to this, and may further include a portion other than the first conductive layer 31 and the second conductive layer 32. For example, as illustrated in Fig. 4, each conductive layer 3 may include, in addition to the first conductive layer 31 and the second conductive layer 32, a third conductive layer 33. The third conductive layer 33 is adjacent to the second conductive layer 32 at a side opposite to the side adjacent to the first conductive layer 31.

[0026] There is no particular limitation regarding the layer used as the third conductive layer 33. For example, the third conductive layer 33 may be formed of grains having an average grain diameter smaller than that of the grains of the second conductive layer 32. In such a case, the number of crystal grain boundaries of the grains of the third conductive layer 33 can be increased. Accordingly, the resistance of the third conductive layer 33 can be set to a value higher than that of the second conductive layer 32. Therefore, the amount of heat generated by the heat-generating resistor 2 can be changed gradually. Accordingly, the surface of the heater 10 can be heated in such a manner that the temperature thereof changes gradually. As a result, the risk that a large local thermal stress will be generated in the ceramic multilayer body 1 can be reduced.

[0027] The first to third conductive layers 31 to 33 are made of, for example, a highly heat-resistant metal material, such as molybdenum (Mo), tungsten (W), or rhenium (Re). $MoSi_2$, WSi_2, etc., are preferably mixed in the material to make the coefficient of thermal expansion close to that of the ceramic multilayer body 1. The length of a portion of the first conductive layer 31 that extends in the length direction of the heat-generating resistor 2 is set to about 2 to 10 mm. The thickness of the first conductive layer 31 is set to about 5 to 30 μm. The length of a portion of the second conductive layer 32 that extends in the length direction of the heat-generating resistor 2 is set to about 5 to 20 mm. The thickness of the second conductive layer 32 is set to about 25 to 75 μm. In the case where the first conductive layer 31 and the second conductive layer 32 overlap, the length of the overlapping region is set to, for example, about 500 μm.

[0028] The grain diameters of the first conductive layer 31 and the second conductive layer 32 can be adjusted as follows. In the case where the first conductive layer 31 and the second conductive layer 32 are both made of W, the grain diameters of the first conductive layer 31 and the second conductive layer 32 can be adjusted by changing the particle diameter of W powder, which is the starting material. For example, the average grain diameter of the W powder used to form the first conductive layer 31 may be set to 0.2 μm, and the average grain diameter of the W powder used to form the second conductive layer 32 may be set to 1.2 μm. In this case, the average grain diameter of the first conductive layer 31 can be set to 0.2 to 2 μm, and the average grain diameter of the second conductive layer 32 can be set to 1.2 to 12 μm.

[0029] In particular, the average grain diameter of the first conductive layer 31 is preferably less than 1 μm. In such a case, entrance of the outside air into the first conductive layer 31 through the spaces between the grains can be suppressed, and therefore the risk that the outside air will flow into the first conductive layer 31 can be reduced. The voidage of the first conductive layer is preferably less than 20%. In such a case, entrance of the outside air into the first conductive layer 31 can be suppressed.

[0030] The average grain diameter of each conductive layer 3 can be determined by, for example, the following method. That is, the heater 10 is cut along a plane that passes through the conductive layer 3 and that is perpendicular to the conductive layer 3 by using a diamond cutter. Then, the cut surface is ground by using diamond powder. After that, the first conductive layer 31 and the second conductive layer 32 are observed by using a scanning electron microscope or metallographic microscope. More specifically, five arbitrary straight lines are drawn on the image obtained by the scanning electron microscope or metallographic microscope. Then, the average of the lengths of portions of the five straight lines, each portion passing through ten grains, is determined. The average grain diameter is determined by dividing the average by ten, which is the number of grains. The average grain diameter may instead be calculated by using an image analyzing device (LUZEX-FS produced by Nireco Corporation). This image analyzing device can also be used to measure the voidage of the first conductive layer 31.

[0031] The heater 10 is used in, for example, an ignition device 100 illustrated in Fig. 5. The ignition device 100 includes the heater 10 and a channel 20 through which fuel gas is supplied to the heater 10. The channel 20 includes, for example, a gas valve 21 and a gas flow pipe 22 having ejection holes 23. The gas valve 21 has a function of controlling the flow rate of the fuel gas. The fuel gas supplied from the gas valve 21 is, for example, natural gas or propane gas. The gas flow pipe 22 ejects the fuel gas, which is supplied from the gas valve 21, toward the heater 10 through the ejection holes 23. The ejected fuel gas can be ignited by heating the fuel gas with the heater 10. The ignition device 100, which includes the heater 10 having improved long-term reliability, has increased fuel-gas ignition stability.

Reference Signs List

[0032]

1 ceramic multilayer body

11	ceramic layer
2	heat-generating resistor
3	conductive layer
31	first conductive layer
32	second conductive layer
10	heater
20	channel
21	gas valve
22	gas flow pipe
23	ejection hole
100	ignition device

Claims

1. A heater comprising:

a ceramic multilayer body comprising a plurality of ceramic layers that are stacked together;
a heat-generating resistor having a belt shape, the heat-generating resistor being disposed between the ceramic layers and arranged, and comprising both ends that are at a side surface of the ceramic multilayer body; and
conductive layers having a belt shape, disposed between the ceramic layers and stacked on both end portions of the heat-generating resistor in such a manner that one end of each conductive layer is at the side surface;

wherein each conductive layer comprises a first conductive layer that extends to the side surface and a second conductive layer that is adjacent to the first conductive layer, each of the first conductive layer and the second conductive layer being formed of a plurality of grains, the grains of the first conductive layer having an average grain diameter smaller than an average grain diameter of the grains of the second conductive layer.

2. The heater according to Claim 1, wherein the first conductive layer and the second conductive layer partially overlap.

3. The heater according to Claim 2, wherein, in a region in which the first conductive layer and the second conductive layer overlap, the first conductive layer is located between the second conductive layer and the heat-generating resistor, and
wherein, in a region in which the first conductive layer is located between the second conductive layer and the heat-generating resistor, the first conductive layer has a thickness that decreases toward the other end of the first conductive layer.

4. The heater according to any one of Claims 1 to 3, wherein the grains of the first conductive layer have an average grain diameter of 0.2 to 2 μm, and the grains of the second conductive layer have an average grain diameter of 1.2 to 12 μm.

5. The heater according to any one of Claims 1 to 4, wherein the first conductive layer has a voidage of less than 20%.

6. An ignition device comprising:

the heater according to any one of Claims 1 to 5; and
a channel through which fuel gas flows to the ceramic multilayer body included in the heater.

Fig. 1

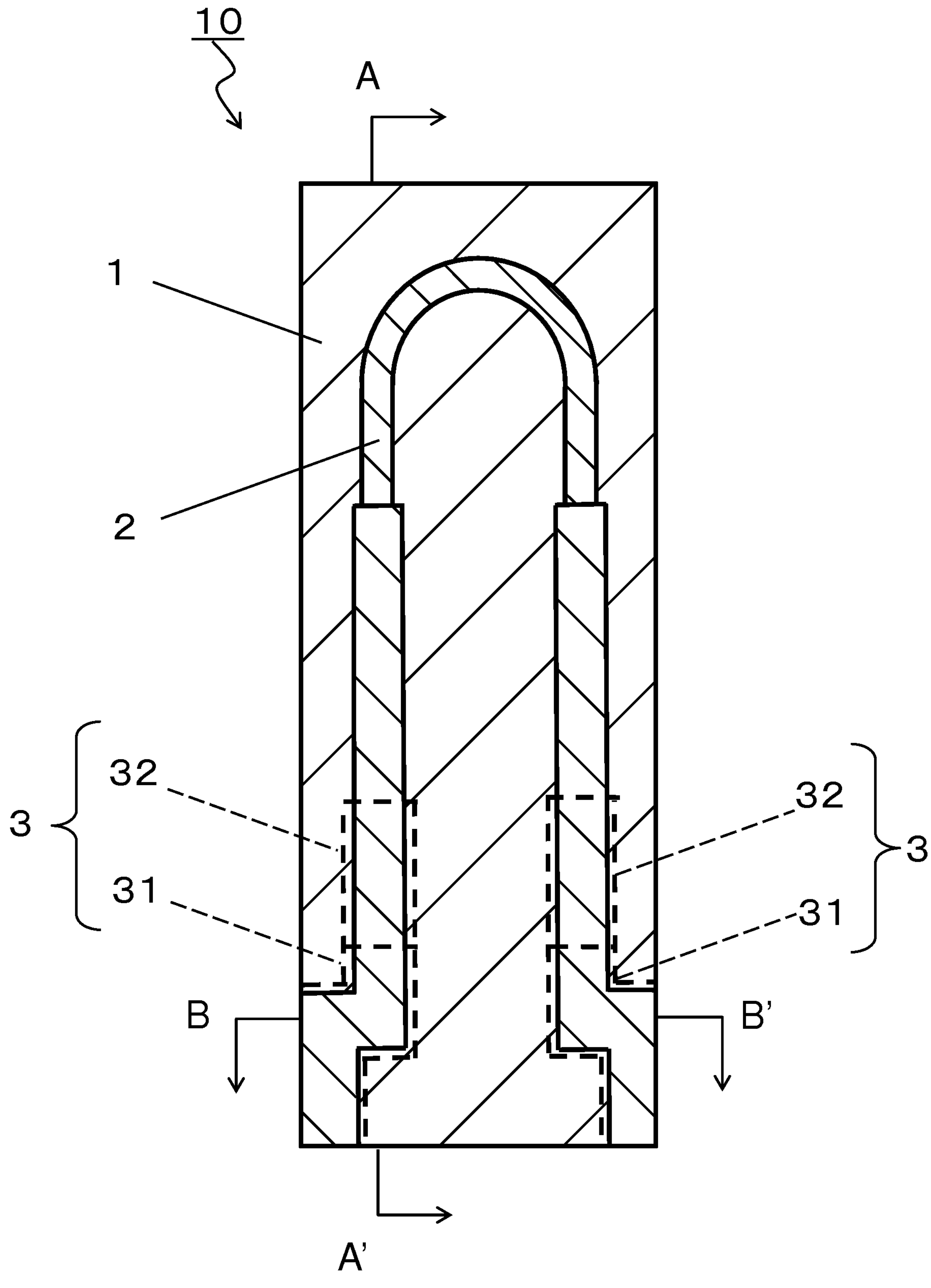


Fig. 2

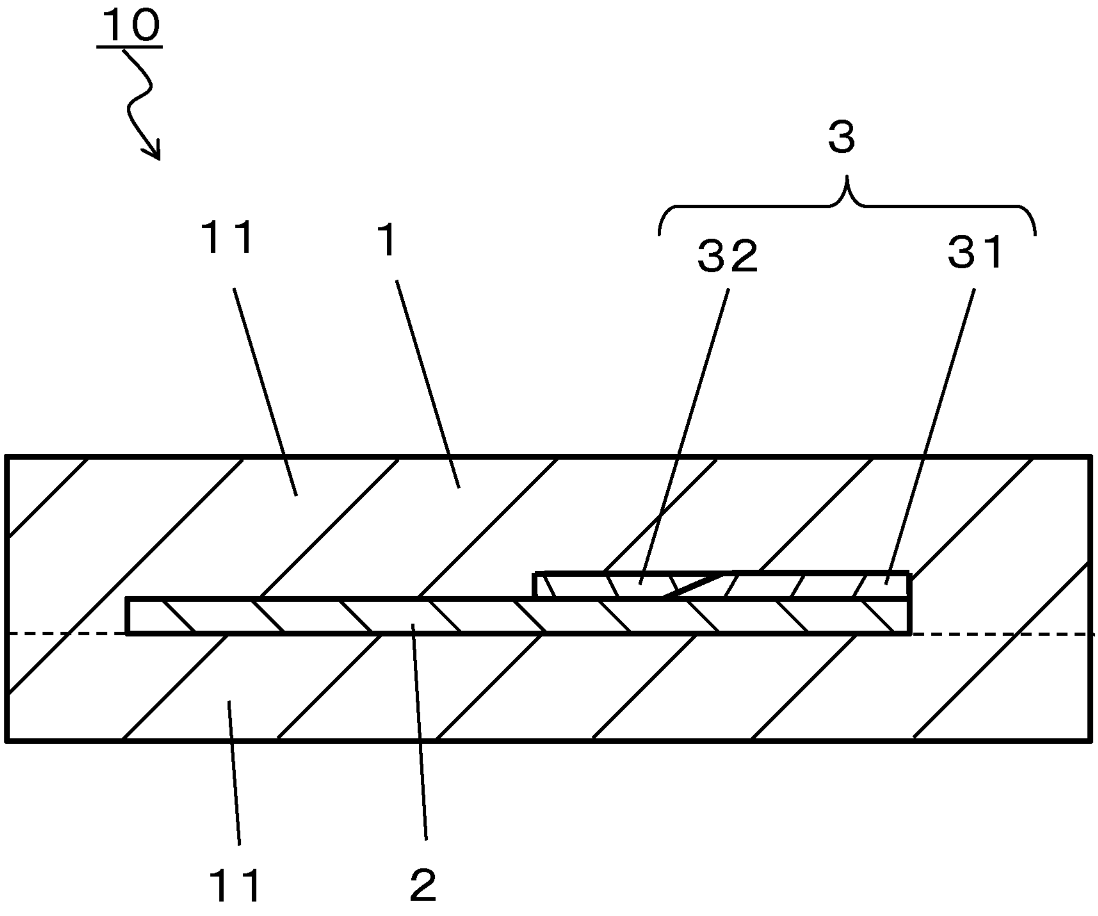


Fig. 3

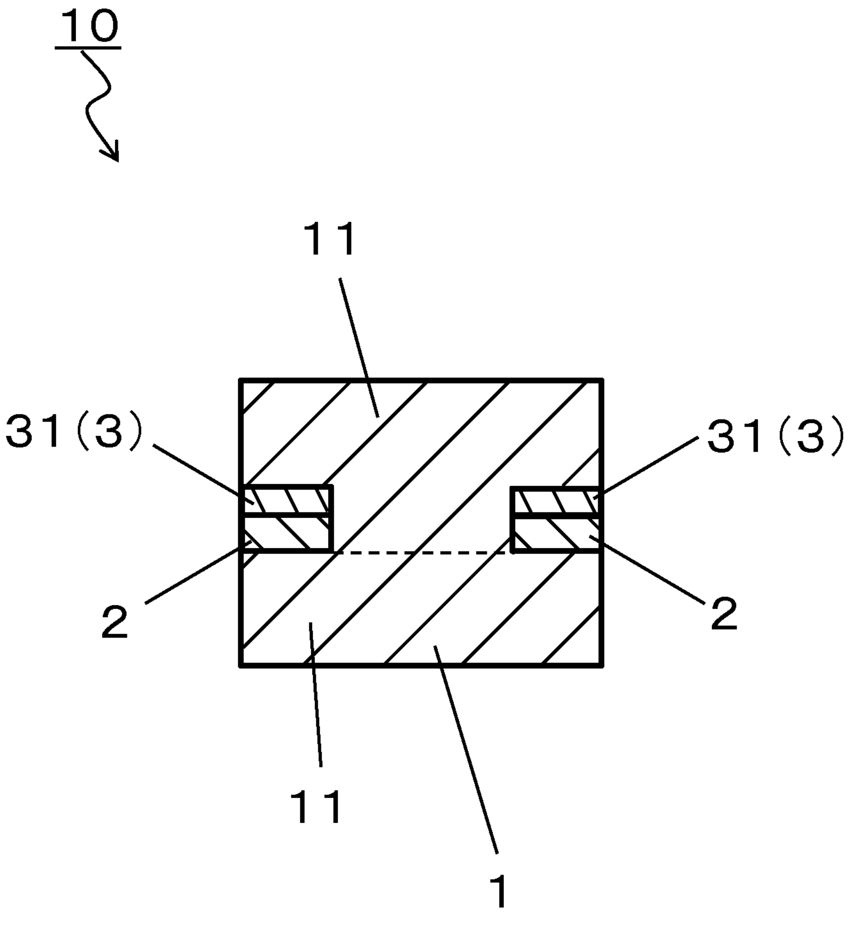


Fig. 4

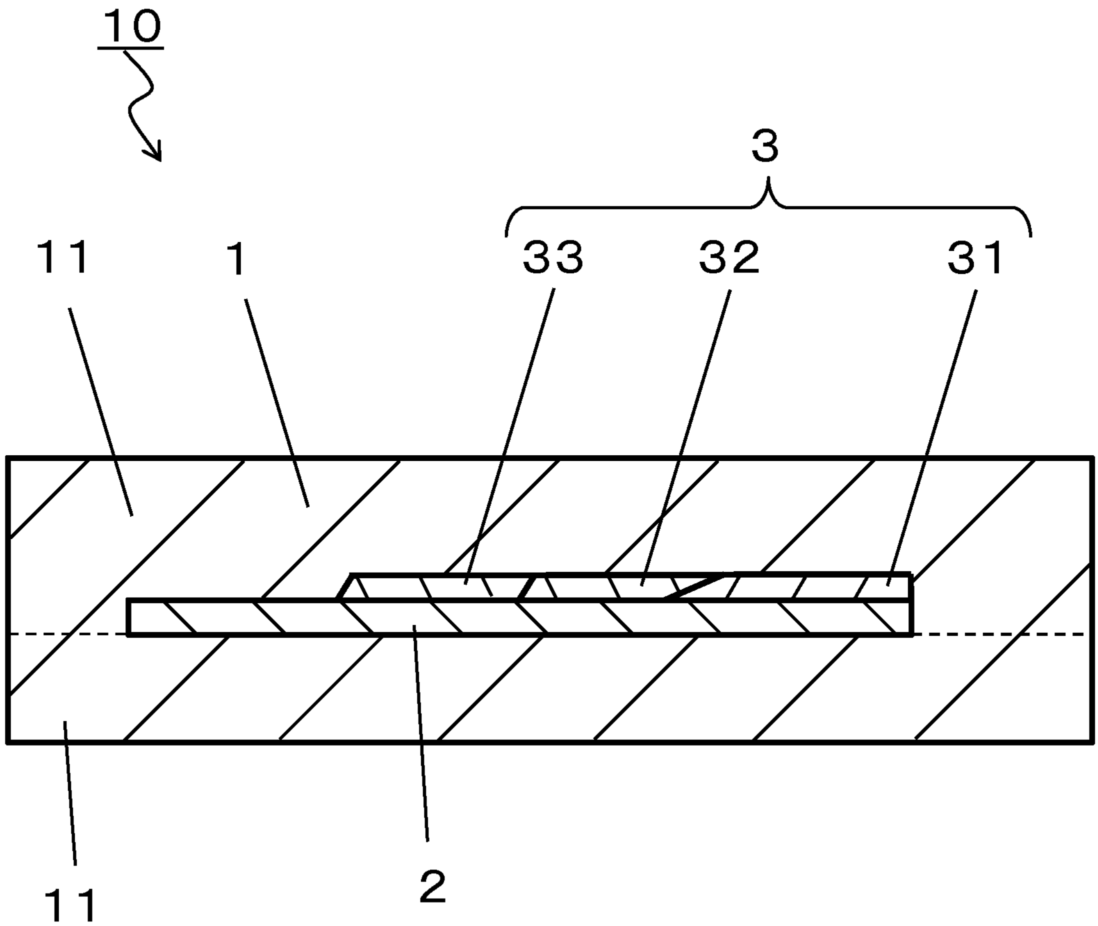
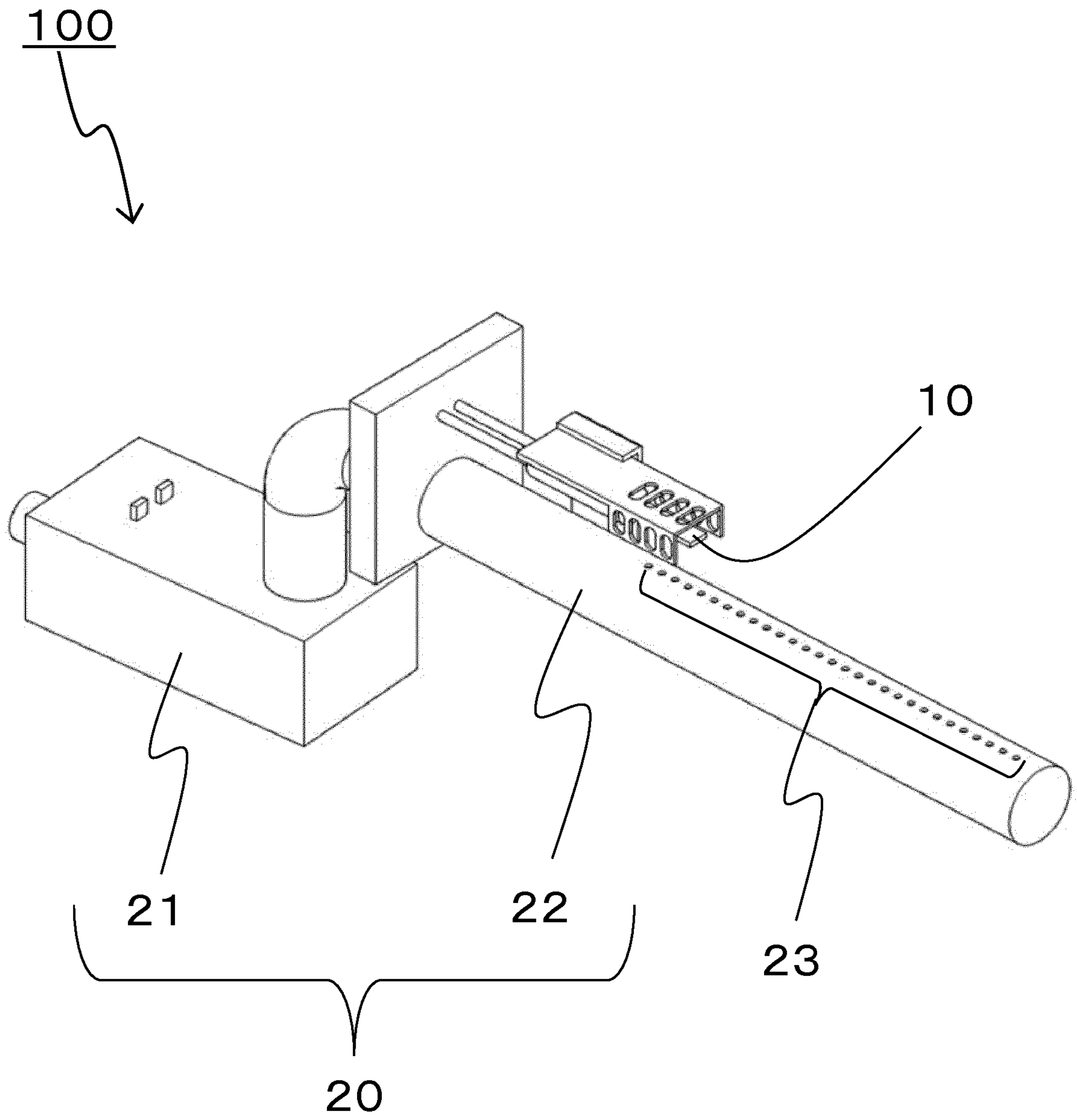


Fig. 5



INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER
H05B3/02(2006.01)i, *H05B3/12*(2006.01)i, *H05B3/14*(2006.01)i, *H05B3/18*(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)
H05B3/02, H05B3/12, H05B3/14, H05B3/18

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	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 70436/1990(Laid-open No. 29192/1992) (NGK Spark Plug Co., Ltd.), 09 March 1992 (09.03.1992), entire text; all drawings (Family: none)	1-6
A	JP 2537271 B2 (NGK Spark Plug Co., Ltd.), 25 September 1996 (25.09.1996), column 3, lines 5 to 9; column 4, lines 23 to 30; fig. 1 to 2 & JP 2-75188 A	1-6

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

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 July 2015 (29.07.15)	11 August 2015 (11.08.15)

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

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2015/062651

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 11-126675 A (Heraeus Sensor-Nite International), 11 May 1999 (11.05.1999), paragraphs [0006] to [0009]; fig. 1 & EP 893688 A1 & DE 19731900 A & BR 9806334 A	1-6
A	JP 3121860 B2 (Kyocera Corp.), 09 January 2001 (09.01.2001), paragraph [0013]; fig. 3 & JP 4-359710 A	1-6
A	JP 2001-244053 A (TDK Corp.), 07 September 2001 (07.09.2001), paragraphs [0012], [0024], [0028]; fig. 1 (Family: none)	1-6
A	JP 2828575 B2 (Kyocera Corp.), 25 November 1998 (25.11.1998), paragraphs [0011], [0018]; fig. 1 & JP 7-135067 A & US 5998049 A & DE 4440005 A & DE 4440005 A1	1-6
A	JP 4183186 B2 (Kyocera Corp.), 19 November 2008 (19.11.2008), paragraphs [0037] to [0038]; fig. 1 to 5 & JP 2005-285521 A & US 2008/0210684 A1 & US 2011/0233190 A1 & WO 2005/069690 A1 & EP 1711034 A1 & KR 10-2006-0129234 A & KR 10-2008-0108372 A & KR 10-0908429 B1	1-6
A	JP 5357628 B2 (NGK Spark Plug Co., Ltd.), 04 December 2013 (04.12.2013), paragraph [0014] & JP 2010-277706 A	1-6
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A	JP 1-272078 A (Rinnai Corp.), 31 October 1989 (31.10.1989), page 2, upper left column, line 18 to page 2, lower right column, line 14; fig. 1 to 2 (Family: none)	6

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

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Patent documents cited in the description

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