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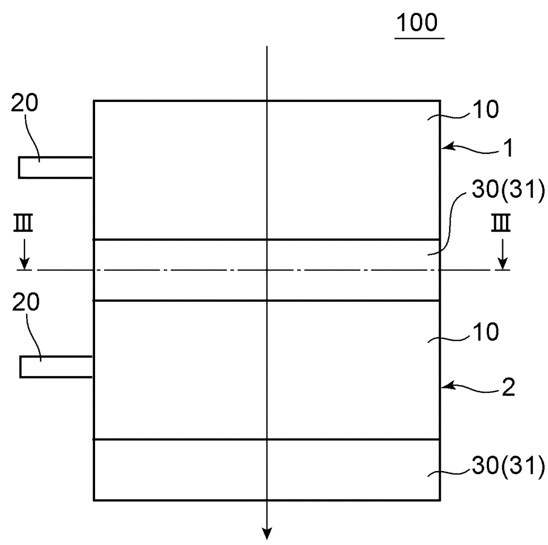
(54) **HEATING ELEMENT**

(57) Provided is a heat generating element, which has excellent heat generation characteristics, and has a shape that can be easily adjusted. A heat generating element according to an embodiment of the present invention includes a plurality of honeycomb structure units each including a honeycomb structure portion that includes partition walls, and is configured to generate heat by energization, the partition walls defining and forming a plurality of cells that extend from a first end surface to a second end surface of the honeycomb structure portion, and serve as fluid flow passages. The plurality of honeycomb structure units include a first honeycomb structure unit and a second honeycomb structure unit, and a fluid having passed through the first honeycomb structure unit passes through an insulating portion that is formed between the first honeycomb structure unit and the second honeycomb structure unit, and then passes through the second honeycomb structure unit.

FIG. 1



Description

Technical Field

[0001] The present invention relates to a heat generating element.

Background Art

[0002] There has been proposed a configuration in which a honeycomb structural body that is used as a catalyst carrier or the like is energized to generate heat. For example, as disclosed in Patent Literature 1, at the time of treatment of a harmful substance in an exhaust gas emitted from a vehicle engine, when a temperature of a catalyst is low, the temperature of the catalyst is prevented from being increased up to a predetermined temperature, and hence there is a problem in that the exhaust gas is not sufficiently purified. In order to solve such a problem, there has been proposed a honeycomb structural body that can be used as a catalyst carrier, and can also function as a heat generating element.

Citation List

Patent Literature

[0003] [PTL 1] JP 6438939 B2

Summary of Invention

Technical Problem

[0004] Incidentally, it may be desired to utilize a heat generating element also in applications other than purification of an exhaust gas emitted from an internal combustion engine. For example, it has been desired that a shape of the heat generating element can be easily adjusted in accordance with the application.

[0005] In view of the above, the present invention provides a heat generating element, which has excellent heat generation characteristics, and has a shape that can be easily adjusted.

Solution to Problem

[0006]

1. According to an embodiment of the present invention, there is provided a heat generating element, including a plurality of honeycomb structure units each including a honeycomb structure portion that includes partition walls, and is configured to generate heat by energization, the partition walls defining and forming a plurality of cells that extend from a first end surface to a second end surface of the honeycomb structure portion, and serve as fluid flow passages, wherein the plurality of honeycomb structure units include a first honeycomb structure unit and a second honeycomb structure unit, and wherein a fluid having passed through the first honeycomb structure unit passes through an insulating portion that is formed between the first honeycomb structure unit and the second honeycomb structure unit, and then passes through the second honeycomb structure unit.

2. In the heat generating element according to the above-mentioned item 1, the plurality of honeycomb structure units may each include a pair of electrode portions configured to energize and heat the honeycomb structure portion.

3. In the heat generating element according to the above-mentioned item 2, the honeycomb structure portion may include an outer peripheral wall that surrounds the partition walls. The pair of electrode portions may be provided on the outer peripheral wall, and when the honeycomb structure portion is viewed from an extending direction of the cells, the pair of electrode portions may be arranged on one side from a center of the honeycomb structure portion.

4. In the heat generating element according to any of the above-mentioned items 1 to 3, an extending direction of the cells in the first honeycomb structure unit and an extending direction of the cells in the second honeycomb structure unit may be aligned with each other.

5. In the heat generating element according to any of the above-mentioned items 1 to 4, the insulating portion may include an insulating member made of an insulating material.

6. In the heat generating element according to the above-mentioned item 5, the insulating member may be arranged in contact with the first honeycomb structure unit and the second honeycomb structure unit.

7. In the heat generating element according to the above-mentioned item 5 or 6, the insulating member may be joined to the first honeycomb structure unit and the second honeycomb structure unit.

8. In the heat generating element according to any of the above-mentioned items 5 to 7, the insulating member may include partition walls that define and form a plurality of cells serving as fluid flow passages.

9. In the heat generating element according to the above-mentioned item 8, an open area ratio per unit area of a plane orthogonal to the extending direction

of the cells in the honeycomb structure portion may be smaller than an open area ratio per unit area of a plane orthogonal to an extending direction of the cells in the insulating member.

10. In the heat generating element according to the above-mentioned item 8 or 9, a hydraulic diameter of each of the cells in the honeycomb structure portion may be smaller than a hydraulic diameter of each of the cells in the insulating member.

11. In the heat generating element according to any of the above-mentioned items 5 to 10, when the first honeycomb structure unit is viewed from an extending direction of the cells, a region in which the honeycomb structure portion of the first honeycomb structure unit and the insulating member do not overlap each other may be defined.

12. In the heat generating element according to the above-mentioned item 11, when the first honeycomb structure unit is viewed from the extending direction of the cells, a region without the insulating member may be defined in a center part of the honeycomb structure portion of the first honeycomb structure unit.

13. In the heat generating element according to any of the above-mentioned items 5 to 12, the insulating member may be made of ceramics.

14. In the heat generating element according to any of the above-mentioned items 5 to 13, the insulating member may include a catalyst.

15. In the heat generating element according to any of the above-mentioned items 1 to 14, the honeycomb structure portion may be made of ceramics.

16. In the heat generating element according to any of the above-mentioned items 1 to 15, the honeycomb structure portion may include a catalyst.

Advantageous Effects of Invention

[0007] According to an embodiment of the present invention, a heat generating element, which has excellent heat generation characteristics, and has a shape that can be easily adjusted can be provided.

Brief Description of Drawings

[0008]

FIG. **1** is a schematic view for illustrating a schematic configuration of a heat generating element according to a first embodiment of the present invention, as viewed from above.

FIG. **2** is a perspective view for illustrating a schematic configuration of a first honeycomb structure unit forming the heat generating element illustrated in FIG. **1.**

FIG. **3** is a view for illustrating an example of a cross section taken along the line III-III of FIG. **1.**

FIG. **4** is a view for illustrating an example of a cross section of the heat generating element illustrated in FIG. **1.**

FIG. **5** is a sectional view for illustrating a schematic configuration of a honeycomb structure unit in a modification example.

FIG. **6** is a sectional view for schematically illustrating a schematic configuration of a heat generating element according to a second embodiment of the present invention.

Description of Embodiments

[0009] Embodiments of the present invention are described below with reference to the drawings. However, the present invention is not limited to these embodiments. For clearer illustration, some widths, thicknesses, shapes, and the like of respective portions may be schematically illustrated in the drawings in comparison to the embodiments. However, the widths, the thicknesses, the shapes, and the like are each merely an example, and do not limit the understanding of the present invention. In addition, in the drawings, the same or similar components are denoted by the same reference symbols, and repetitive description thereof may be omitted.

[0010] A heat generating element according to the embodiments of the present invention includes a plurality of honeycomb structure units. FIG. **1** is a schematic view for illustrating a schematic configuration of a heat generating element according to a first embodiment of the present invention, as viewed from above. FIG. **2** is a perspective view for illustrating a schematic configuration of a first honeycomb structure unit forming the heat generating element illustrated in FIG. **1.** FIG. **3** is a view for illustrating an example of a cross section taken along the line III-III of FIG. **1.** FIG. **4** is a view for illustrating an example of a cross section of the heat generating element illustrated in FIG. **1.**

[0011] A heat generating element **100** includes a first honeycomb structure unit **1** and a second honeycomb structure unit **2.** The first honeycomb structure unit **1** and the second honeycomb structure unit **2** each include: a honeycomb structure portion **10** that can generate heat by energization; and a pair of electrode portions **20** and **20** that energize and heat the honeycomb structure portion **10.**

[0012] As illustrated in FIG. **2,** the first honeycomb structure unit **1** includes the honeycomb structure portion

10 and the pair of electrode portions **20** and **20.** The honeycomb structure portion **10** includes partition walls **14** and an outer peripheral wall **16.** The partition walls **14** define and form a plurality of cells **12,** which extend from a first end surface **10a** to a second end surface **10b** of the honeycomb structure portion **10** (in a lengthwise direction), and can serve as fluid flow passages. The outer peripheral wall **16** is located on an outer periphery of the honeycomb structure portion **10,** and surrounds the partition walls **14.** Although FIG. **2** shows the first honeycomb structure unit **1** illustrated in FIG. **1** as a representative, the second honeycomb structure unit **2** also has the same configuration.

[0013] As illustrated in FIG. **4,** in the heat generating element **100,** the first honeycomb structure unit **1** and the second honeycomb structure unit **2** are arranged so that extending directions of the cells **12** (lengthwise directions) in the respective honeycomb structure portions **10** are aligned with each other. The arrow of FIG. **1** indicates a flowing direction of a fluid. The fluid having passed through the first honeycomb structure unit **1** may pass through the second honeycomb structure unit **2.** In the heat generating element **100,** the first honeycomb structure unit **1** and the second honeycomb structure unit **2** are arranged away from each other. The heat generating element **100** includes an insulating portion **30** formed between the first honeycomb structure unit **1** and the second honeycomb structure unit **2.** The fluid having passed through the first honeycomb structure unit **1** passes through the insulating portion **30** formed between the first honeycomb structure unit **1** and the second honeycomb structure unit **2,** and then passes through the second honeycomb structure unit **2.**

[0014] In the illustrated example, the heat generating element includes two honeycomb structure units, but may include three or more honeycomb structure units. For example, an insulating portion **30** is provided in advance on an end surface of the second honeycomb structure unit **2** on a side on which no first honeycomb structure unit **1** is arranged, and another honeycomb structure unit may be further provided through intermediation of this insulating portion **30.** The three or more honeycomb structure units may be arranged so that extending directions of the respective cells in the three or more honeycomb structure units are aligned with each other. The three or more honeycomb structure units may be arranged away from each other.

[0015] When the plurality of honeycomb structure portions that can generate heat by energization are arranged through intermediation of the insulating portion, the heat generating element can have extremely excellent heat generation characteristics. Specifically, energy applied in each of the honeycomb structure units can be efficiently utilized for increasing a temperature of the honeycomb structure portion serving as fluid flow passages. Generally, a difference in temperature of the honeycomb structure portion may occur between an upstream side and a downstream side of the fluid flow passages (for example, the temperature on the downstream side may be higher than that on the upstream side), but in each of the honeycomb structure units, the temperature of the fluid flow passages can be satisfactorily controlled. In addition, a short circuit between the honeycomb structure portions can be prevented, and for example, a failure such as damage on a device or a circuit that supplies electric power to the heat generating element can be prevented. Further, when the plurality of honeycomb structure portions are arranged through intermediation of the insulating portion, a shape of the heat generating element to be obtained can be adjusted in accordance with the application.

[0016] The outer peripheral wall **16** of the honeycomb structure portion 10 extends in the lengthwise direction. The plurality of cells **12** are each defined as a space extending in the lengthwise direction. In the illustrated example, a cross section of each of the cells **12** that is perpendicular to the lengthwise direction has a quadrangular shape, but may have any other polygonal shape, or may have any other shape such as a circular shape. A thickness of the partition wall **14** is, for example, from 70 μm to 500 μm. The number of the cells **12** per unit area in a plane orthogonal to the extending direction of the cells **12** is, for example, from 15 cells/cm^2 to 150 cells/cm^2. The thickness of the partition wall **14** and the number of cells **12** can be measured with, for example, a digital microscope.

[0017] An open area ratio of the honeycomb structure portion **10** is, for example, from 65% to 90%. Herein, the open area ratio of the honeycomb structure portion 10 refers to an open area ratio per unit area in the plane orthogonal to the extending direction of cells **12** in the honeycomb structure portion **10.** Specifically, the open area ratio of the honeycomb structure portion **10** is a ratio of the sum of areas of void portions of the cells **12** to a total area of the plane orthogonal to the extending direction of the cells **12** in the honeycomb structure portion **10.** The open area ratio of the honeycomb structure portion **10** can be measured with, for example, a digital microscope.

[0018] A hydraulic diameter of the cell 12 in the honeycomb structure portion **10** is, for example, from 0.7 mm to 1.8 mm. Herein, the hydraulic diameter of the cell **12** in the honeycomb structure portion **10** is calculated, based on a peripheral length (unit: mm) surrounded by the partition walls **14** and a sectional area (unit: mm^2) of the cell **12,** by the expression of 4× (sectional area)/(peripheral length). Further, the peripheral length surrounded by the partition walls **14,** and the sectional area of the cell **12** can be measured with, for example, a digital microscope.

[0019] In the illustrated example, a cross section of the outer peripheral wall **16** that is perpendicular to the lengthwise direction has a quadrangular shape, but may have any other polygonal shape, or may have any other shape such as a circular shape. A thickness of the outer peripheral wall **16** is, for example, from 0.5 mm to 5 mm. In the example illustrated in FIG. **1,** the honeycomb structure portions of the two honeycomb structure units forming the heat generating element have the same shape and size, but the heat generating element may include a plurality of honeycomb structure unit portions having different shapes and sizes. The thickness of the outer peripheral wall **16** can be measured with, for example, a digital microscope.

[0020] The pair of electrode portions 20 and 20 are provided on the outer peripheral wall **16** of the honeycomb structure portion **10.** The pair of electrode portions **20** and **20** may be formed of electrode terminals, respectively. One of the electrode terminals may be connected to a positive pole of a power source, and another one of the electrode terminals may be connected to a negative pole of the power source. When the honeycomb structure portion **10** is viewed from the extending direction of the cells **12,** the pair of electrode portions **20** and **20** are arranged on one side from a center of the honeycomb structure portion **10.** With such arrangement, extremely excellent assemblability of the heat generating element can be achieved. Further, such arrangement can also contribute to space saving at the time of installing the heat generating element. The arrangement of the pair of electrode portions **20** and **20** is not particularly limited as long as the honeycomb structure portion **10** can be energized and heated. For example, when the honeycomb structure portion **10** is viewed from the extending direction of the cells **12,** the pair of electrode portions **20** and **20** may be arranged with the center of the honeycomb structure portion **10** located therebetween.

[0021] In the illustrated example, the electrode terminal having a columnar shape is provided as each of the electrode portions **20,** but a shape and a size of the electrode terminal are not particularly limited. For example, the shape of the electrode terminal may be a prismatic shape or a comb shape. Although not shown, the electrode portion **20** may be configured by forming an electrode layer (not shown) on the outer peripheral wall **16** of the honeycomb structure portion **10** and providing an electrode terminal through intermediation of this electrode layer. A thickness of the electrode layer is, for example, from 100 μm to 5 mm.

[0022] An insulating member **31** made of an insulating material may be arranged in the insulating portion **30.** For example, from the viewpoint of space saving, the insulating member **31** is arranged in contact with the first honeycomb structure unit **1** and the second honeycomb structure unit **2.** For example, from the viewpoint of assemblability, it is preferred that the insulating member **31** be joined to the first honeycomb structure unit **1** and the second honeycomb structure unit **2.** A method of joining the insulating member **31** is not particularly limited. For example, the insulating member **31** may be joined to the honeycomb structure unit with use of an adhesive material or a joining component. Further, for example, at the time of manufacturing the honeycomb structure unit (honeycomb structure portion **10),** the insulating member **31** may be formed integrally therewith.

[0023] When the first honeycomb structure unit **1** is viewed from the extending direction of the cells **12,** a region **40** in which the honeycomb structure portion **10** of the first honeycomb structure unit **1** and the insulating member **31** do not overlap each other may be defined in the insulating portion **30.** In the illustrated example, when the first honeycomb structure unit **1** is viewed from the extending direction of the cells **12,** the region **40** without the insulating member **31** is defined in a center part of the honeycomb structure portion **10** of the first honeycomb structure unit **1.** As illustrated in FIG. **4,** a space portion **42** surrounded by an inner peripheral wall **38** of the insulating member **31** is defined in the insulating portion **30.** With the space portion **42** being defined in the insulating portion **30,** a pressure loss caused by a fluid passing through the insulating portion **30** can be reduced.

[0024] The insulating member **31** includes partition walls **34** and an outer peripheral wall **36.** The partition walls **34** define and form a plurality of cells **32,** which extend from a first end surface **31a** to a second end surface **31b** of the insulating member **31** (in the lengthwise direction), and can serve as fluid flow passages. The outer peripheral wall **36** is located on an outer periphery of the insulating member **31,** and surrounds the partition walls **34.** The insulating member **31** is arranged so that an extending direction of the cells **32** in the insulating member **31** is aligned with the extending direction of the cells **12** in the first honeycomb structure unit **1** and the extending direction of the cells **12** in the second honeycomb structure unit **2.** With the insulating member **31** having a honeycomb structure, a pressure loss caused by a fluid passing through the insulating portion **30** can be reduced. Regarding details of the honeycomb structure of the insulating member **31,** the same description as that given with regard to the honeycomb structure portion **10** as described above can be applied.

[0025] When the insulating member **31** has a honeycomb structure, the open area ratio of the honeycomb structure portion **10** as described above may be designed to be smaller than an open area ratio of the insulating member **31.** Specifically, from the viewpoint of ensuring an area of contact with a fluid, the open area ratio of the honeycomb structure portion **10** may be designed to be smaller. Meanwhile, from the viewpoint of reducing a pressure loss caused by a fluid passing through the insulating portion **30,** the open area ratio of the insulating member **31** may be designed to be larger. The open area ratio of the insulating member **31** is preferably from 70% to 92%. Herein, the open area ratio of the insulating member **31** refers to an open area ratio per unit area in a plane orthogonal to the extending direction of the cells **32** in the insulating member **31.** Specifically, the open area ratio of the insulating member **31** is a ratio of the sum of areas of void portions of the cells **32** to a total area of the plane orthogonal to the extending direction of the cells **32** in the insulating member **31.** In the illustrated example, the open area ratio of the insulating member **31** is a ratio of the sum of the areas of the void portions of the cells **32**

to an area of a region surrounded by the outer peripheral wall **36** excluding the space portion **42,** in the plane orthogonal to the extending direction of the cells **32** in the insulating member **31.**

[0026] When the insulating member **31** has a honeycomb structure, the hydraulic diameter of the cell **12** in the honeycomb structure portion **10** as described above may be designed to be smaller than a hydraulic diameter of the cell **32** in the insulating member **31.** Specifically, from the viewpoint of ensuring an area of contact with a fluid, the hydraulic diameter of the cell **12** in the honeycomb structure portion **10** may be designed to be smaller. Meanwhile, from the viewpoint of reducing a pressure loss caused by a fluid passing through the insulating portion **30,** the hydraulic diameter of the cell **32** in the insulating member **31** may be designed to be larger. The hydraulic diameter of the cell **32** in the insulating member **31** is preferably from 0.9 mm to 2 mm. Herein, the hydraulic diameter of the cell **32** in the insulating member **31** is calculated, based on a peripheral length (unit: mm) surrounded by the partition walls **34** and a sectional area (unit: mm^2) of the cell **32,** by the expression of 4×(sectional area)/(peripheral length).

[0027] FIG. **5** is a sectional view for illustrating a schematic configuration of a honeycomb structure unit in a modification example. In this modification example, the honeycomb structure portion **10** has a first slit **17** and a second slit **18.** Specifically, the first slit **17** extends from a first portion **P1** toward a second portion **P2,** which face each other, of the outer peripheral wall **16** (side surfaces of the honeycomb structure portion **10).** The second slit **18** extends from the second portion **P2** toward the first portion **P1,** which face each other, of the outer peripheral wall **16.** Such slits can function as electrical insulating portions. When the first slit **17** is defined so as to extend from the first portion **P1** located between the pair of electrode portions **20** and **20,** a short circuit between the pair of electrode portions **20** and **20** can be effectively prevented, and hence the honeycomb structure portion **10** can be caused to stably generate heat. Further, when the second slit **18** is defined so as to be located between first slits **17** and **17** that are arranged adjacent to each other, the entire honeycomb structure portion **10** can be caused to more uniformly generate heat.

[0028] A volume resistivity of the honeycomb structure portion **10** is, for example, 0.001 Ω·cm or more, preferably 0.01 Ω·cm or more, more preferably 0.1 Ω·cm or more. With such a volume resistivity, a failure such as an excessive electric current flowing, which may be caused depending on the applied voltage, can be prevented. Meanwhile, a volume resistivity of the honeycomb structure portion **10** is, for example, 200 Ω·cm or less, preferably 100 Ω·cm or less. With such a volume resistivity, the honeycomb structure portion **10** can sufficiently generate heat by energization. The volume resistivity may be a value measured at a temperature of 25°C using a four-terminal method.

[0029] The honeycomb structure portion **10** is preferably made of ceramics. With the adoption of ceramics, the above-mentioned volume resistivity can be satisfactorily satisfied. Further, ceramics has a low thermal expansion coefficient, and hence can have excellent shape stability as well.

[0030] The honeycomb structure portion **10** is made of, for example, a material containing silicon carbide. The honeycomb structure portion **10** is preferably made of a material containing a silicon carbide material or a silicon-silicon carbide composite material as a main component. Herein, the expression "containing as a main component" means that the content of the component in the material is, for example, 80 mass% or more, preferably 90 mass% or more.

[0031] The above-mentioned silicon carbide material may be a material impregnated with silicon (silicon-impregnated silicon carbide). The silicon-silicon carbide composite material may be a material in which a plurality of silicon carbide particles are bonded to each other by metal silicon. In the silicon-silicon carbide composite material, silicon carbide particles may function as aggregate, and silicon may function as a binding material. With the use of the material as described above, the above-mentioned volume resistivity can be satisfactorily achieved. The volume resistivity of the honeycomb structure portion **10** may also be controlled by adjusting a porosity thereof.

[0032] Typically, the honeycomb structure portion **10** can be obtained by drying and firing a molded body obtained by molding of a molding material containing a ceramic raw material. When the honeycomb structure portion **10** is made of the above-mentioned silicon-silicon carbide composite material, the above-mentioned molding material may contain silicon carbide (for example, silicon carbide powder) and metal silicon (for example, metal silicon powder). Examples of other raw material that may be contained in the molding material include a binder, a dispersant, and an additive.

[0033] Typically, the honeycomb structure portion **10** may be used as a catalyst carrier, and a catalyst may be supported on the partition walls **14** of the honeycomb structure portion **10.** For example, CO, NO_x, and a hydrocarbon in a fluid (e.g., gas) passing through the cell **12** can be changed to a harmless substance by a catalytic reaction. The catalyst may preferably contain a precious metal (e.g., platinum, rhodium, palladium, ruthenium, indium, silver, or gold), aluminum, nickel, zirconium, titanium, cerium, cobalt, manganese, zinc, copper, tin, iron, niobium, magnesium, lanthanum, samarium, bismuth, barium, and combinations thereof.

[0034] The volume resistivity of the electrode portion **20** varies depending on a configuration and a constituent material of the electrode portion **20,** but is typically from 1×10^{-6} Ω·cm to 10 Ω·cm, preferably from 0.01 Ω·cm to 10 Ω·cm.

[0035] The electrode portion **20** may include any appropriate material. For example, a metal, conductive ceramics, or a composite material (cermet) of a metal and conductive ceramics may be used as a constituent material of the electrode portion **20.** Examples of the metal include Cr, Fe, Co, Ni, Si, and Ti. Those materials may be used alone or in combination. When two or more kinds thereof are used in combination, an alloy of two or more kinds of metals may be used. Examples of the conductive ceramics include: silicon carbide (SiC); and metal compounds, for example, metal silicides, such as tantalum silicide ($TaSi_2$) and chromium silicide ($CrSi_2$). Specific examples of the composite material (cermet) of a metal and conductive ceramics include a composite material of a metal silicon and silicon carbide, and a composite material of the metal silicide, a metal silicon, and silicon carbide. In addition, specific examples of the composite material (cermet) of a metal and conductive ceramics include composite materials obtained by adding one kind or two or more kinds of insulating ceramics, such as alumina, mullite, zirconia, cordierite, silicon nitride, and aluminum nitride, to one kind or two or more kinds of the above-mentioned compounds or a metal from the viewpoint of reducing thermal expansion.

[0036] When a constituent material of the electrode terminal forming the electrode portion **20** is a metal, it is preferred that the shape of the electrode terminal be a comb shape. When the constituent material of the electrode terminal is conductive ceramics or a composite material (cermet) of a metal and conductive ceramics, it is preferred that the shape of the electrode terminal be a circular shape or a prismatic shape. When the constituent material of the electrode terminal is conductive ceramics or a composite material (cermet) of a metal and conductive ceramics, metal portions may be joined to both end parts of the electrode terminal, respectively. The electrode terminal made of ceramics and the metal portions may be joined to each other by employing, for example, swaging, welding, or a conductive adhesive. An example of a material of the metal portion may be a conductive metal, such as an iron alloy or a nickel alloy.

[0037] It is preferred that at least a part of the electrode portion **20** be made of a material having the same quality as that of the material of the honeycomb structure portion **10.** With such a configuration, a difference in thermal expansion coefficient between the honeycomb structure portion **10** and the electrode portion **20** can be reduced, and hence joining strength therebetween can be increased. Further, the above-mentioned configuration can also contribute to an improvement in productivity. The volume resistivity of the electrode portion **20** may be controlled by adjusting a porosity thereof.

[0038] From the viewpoint of ensuring an excellent insulating property, a volume resistivity of the insulating member **31** is preferably 1×10^{10} $\Omega\cdot$cm or more, more preferably 1×10^{12} $\Omega\cdot$cm or more. Meanwhile, the volume resistivity insulating member **31** is, for example, 1×10^{16} $\Omega\cdot$cm or less.

[0039] The insulating member **31** may be made of any appropriate material that can satisfy the above-mentioned volume resistivity. The insulating member **31** is preferably made of ceramics. With the adoption of ceramics, the above-mentioned volume resistivity can be satisfactorily satisfied. Further, ceramics has a low thermal expansion coefficient, and hence can have excellent shape stability as well. In addition, with the adoption of ceramics, a difference in thermal expansion coefficient between the honeycomb structure portion **10** and the insulating member **31** can be reduced, and hence a thermal shock resistance can be improved. Examples of the ceramics include cordierite, mullite, alumina, spinel, silicon carbide, silicon nitride, and aluminum titanate. Those ceramics may be used alone or in combination.

[0040] A catalyst may be supported on the partition walls **34** of the insulating member **31.** For example, CO, NO_x, a hydrocarbon, or the like in a fluid (for example, gas) passing through the cells **32** can be changed to a harmless substance by a catalytic reaction. Specific examples of the catalyst are as described above.

[0041] FIG. **6** is a sectional view for schematically illustrating a schematic configuration of a heat generating element according to a second embodiment of the present invention. A heat generating element **200** is different from the heat generating element **100** of the first embodiment in that no space portion **42** is defined in the insulating portion **30** (no inner peripheral wall **38** is formed in the insulating member **31).** Specifically, the heat generating element **200** is different from the heat generating element **100** of the first embodiment in that, when the first honeycomb structure unit **1** is viewed from the extending direction of the cells **12,** no region **40** in which the honeycomb structure portion **10** of the first honeycomb structure unit **1** and the insulating member **31** do not overlap each other is defined in the insulating portion **30.** With no space portion **42** being defined in the insulating portion **30,** an excellent mechanical strength can be achieved. Further, a more excellent insulating property can be achieved in some cases.

[0042] The present invention is not limited to the above-mentioned embodiments, and various modifications may be made thereto. For example, the configurations described in the above-mentioned embodiments may each be replaced by substantially the same configuration, a configuration having the same action and effect, and a configuration that can achieve the same object.

Industrial Applicability

[0043] The heat generating element according to each of the embodiments of the present invention may be used as, for example, a catalyst carrier having a catalyst supported thereon.

Reference Signs List

[0044] **1** honeycomb structure unit, **2** honeycomb structure unit, **10** honeycomb structure portion, **12** cell, **14** partition wall, **16** outer peripheral wall, **17** first slit, **18**

second slit, **20** electrode portion, **30** insulating portion, **31** insulating member, **32** cell, **34** partition wall, **36** outer peripheral wall, **42** space portion, **100** heat generating element, **200** heat generating element

Claims

1. A heat generating element, comprising a plurality of honeycomb structure units each including a honeycomb structure portion that includes partition walls, and is configured to generate heat by energization, the partition walls defining and forming a plurality of cells that extend from a first end surface to a second end surface of the honeycomb structure portion, and serve as fluid flow passages,

   wherein the plurality of honeycomb structure units include a first honeycomb structure unit and a second honeycomb structure unit, and
   wherein a fluid having passed through the first honeycomb structure unit passes through an insulating portion that is formed between the first honeycomb structure unit and the second honeycomb structure unit, and then passes through the second honeycomb structure unit.

2. The heat generating element according to claim 1, wherein the plurality of honeycomb structure units each include a pair of electrode portions configured to energize and heat the honeycomb structure portion.

3. The heat generating element according to claim 2,

   wherein the honeycomb structure portion includes an outer peripheral wall that surrounds the partition walls, and the pair of electrode portions are provided on the outer peripheral wall, and
   wherein, when the honeycomb structure portion is viewed from an extending direction of the cells, the pair of electrode portions are arranged on one side from a center of the honeycomb structure portion.

4. The heat generating element according to claim 1 or 2, wherein an extending direction of the cells in the first honeycomb structure unit and an extending direction of the cells in the second honeycomb structure unit are aligned with each other.

5. The heat generating element according to claim 1, wherein the insulating portion includes an insulating member made of an insulating material.

6. The heat generating element according to claim 5, wherein the insulating member is arranged in contact with the first honeycomb structure unit and the second honeycomb structure unit.

7. The heat generating element according to claim 5, wherein the insulating member is joined to the first honeycomb structure unit and the second honeycomb structure unit.

8. The heat generating element according to claim 5, wherein the insulating member includes partition walls that define and form a plurality of cells serving as fluid flow passages.

9. The heat generating element according to claim 8, wherein an open area ratio per unit area of a plane orthogonal to the extending direction of the cells in the honeycomb structure portion is smaller than an open area ratio per unit area of a plane orthogonal to an extending direction of the cells in the insulating member.

10. The heat generating element according to claim 8, wherein a hydraulic diameter of each of the cells in the honeycomb structure portion is smaller than a hydraulic diameter of each of the cells in the insulating member.

11. The heat generating element according to claim 5, wherein, when the first honeycomb structure unit is viewed from an extending direction of the cells, a region in which the honeycomb structure portion of the first honeycomb structure unit and the insulating member do not overlap each other is defined.

12. The heat generating element according to claim 11, wherein, when the first honeycomb structure unit is viewed from the extending direction of the cells, a region without the insulating member is defined in a center part of the honeycomb structure portion of the first honeycomb structure unit.

13. The heat generating element according to claim 5, wherein the insulating member is made of ceramics.

14. The heat generating element according to claim 5, wherein the insulating member includes a catalyst.

15. The heat generating element according to claim 1 or 5, wherein the honeycomb structure portion is made of ceramics.

16. The heat generating element according to claim 1 or 5, wherein the honeycomb structure portion includes a catalyst.

FIG. 1

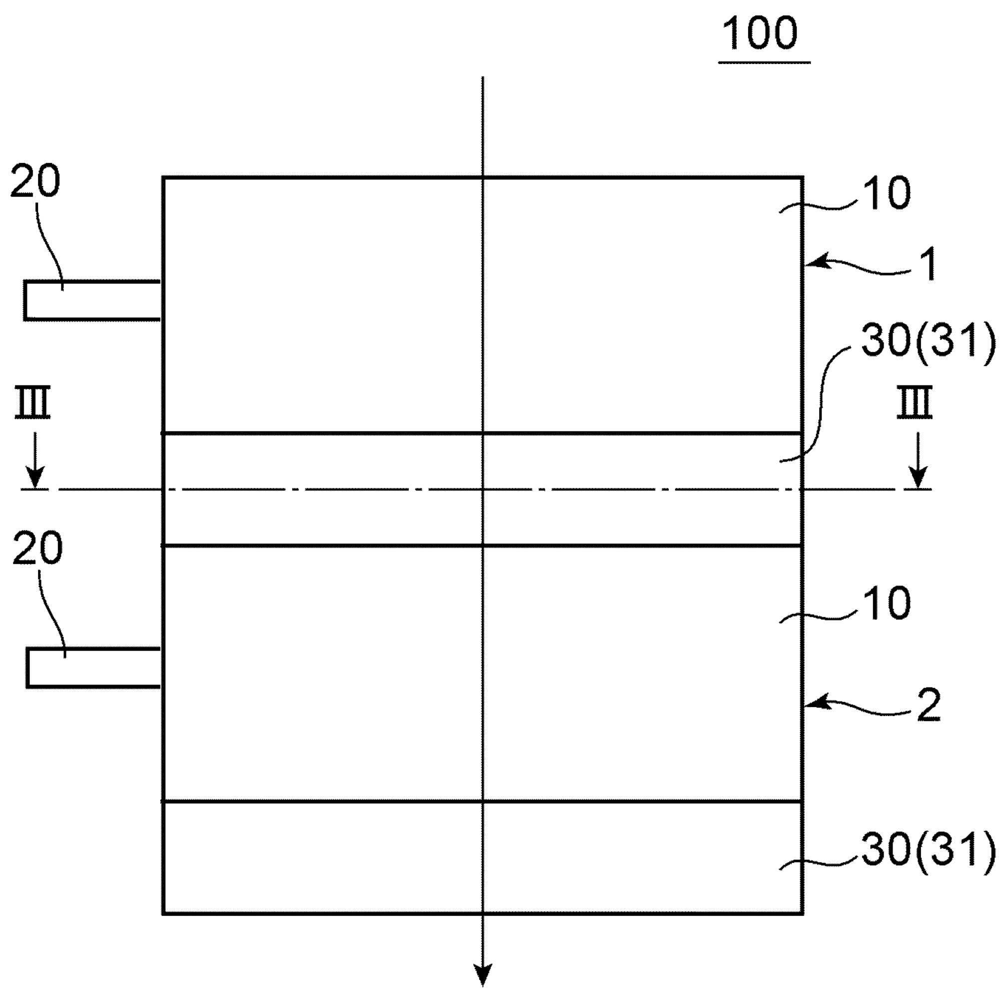


FIG. 2

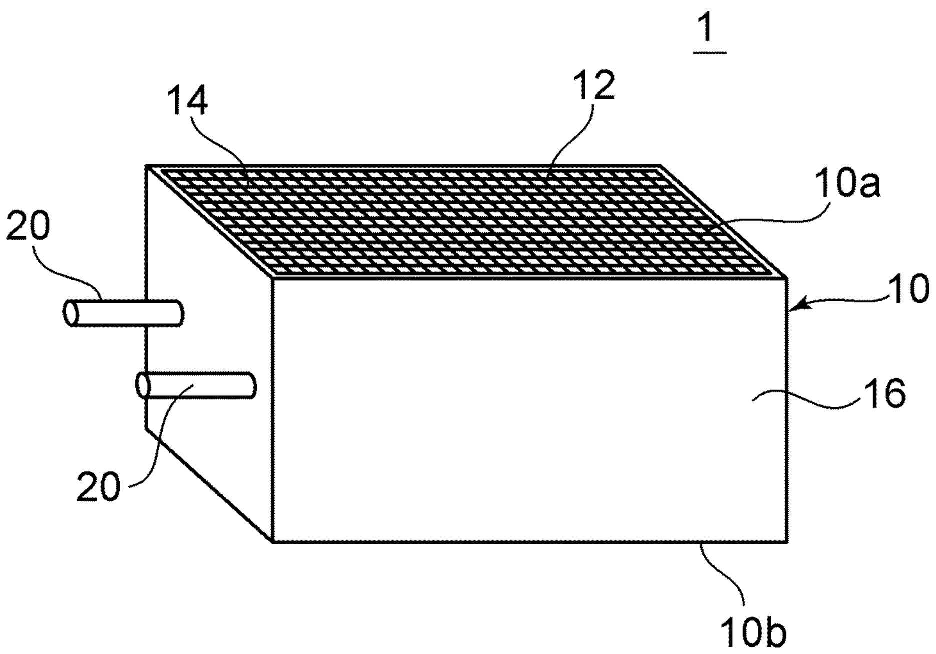


FIG. 3

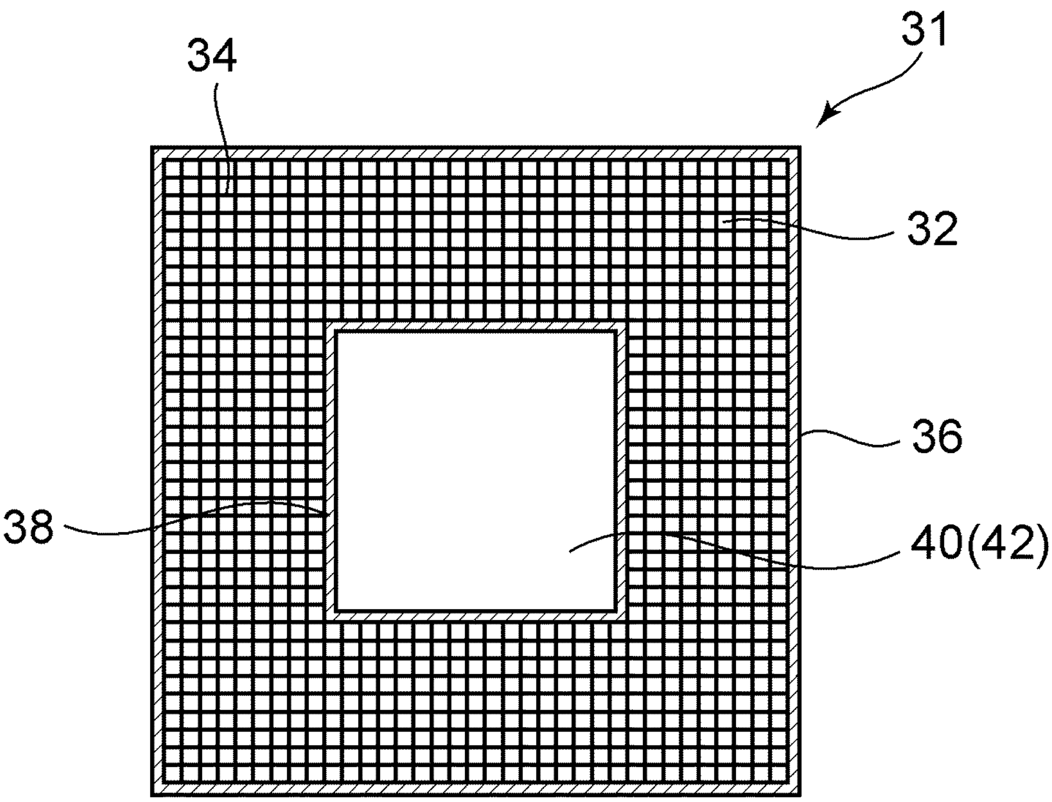


FIG. 4

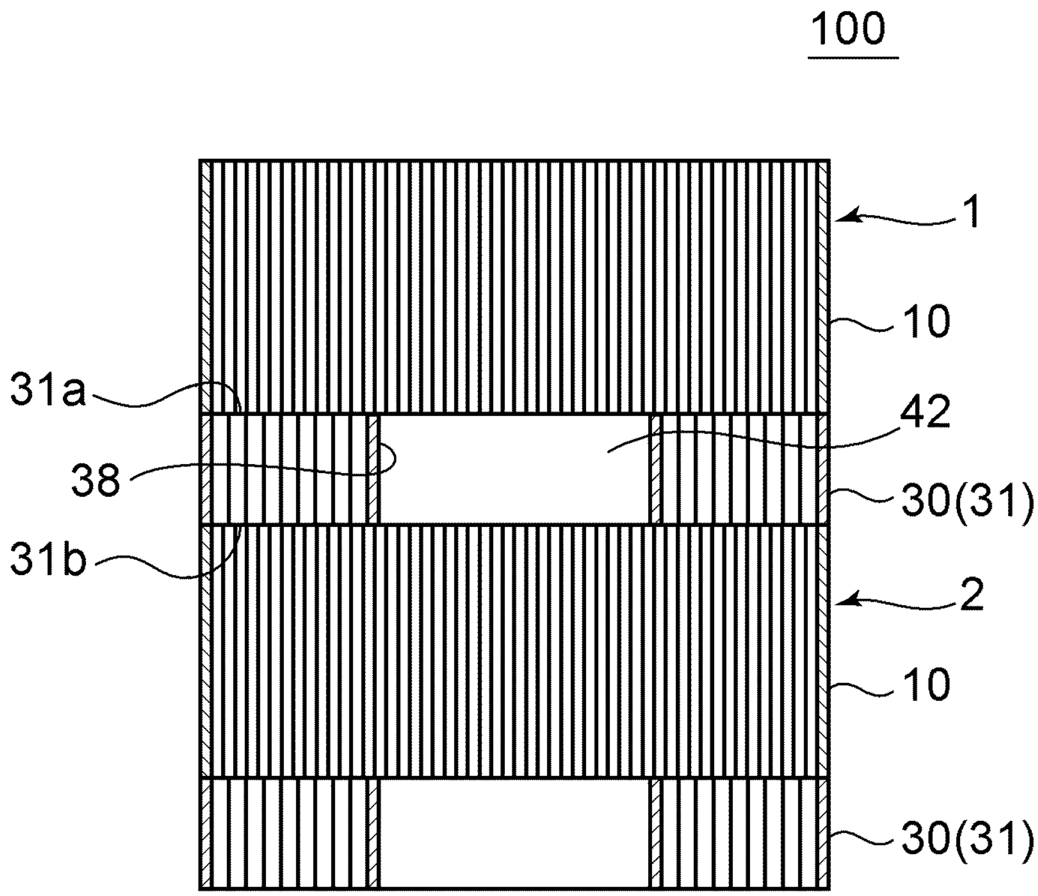


FIG. 5

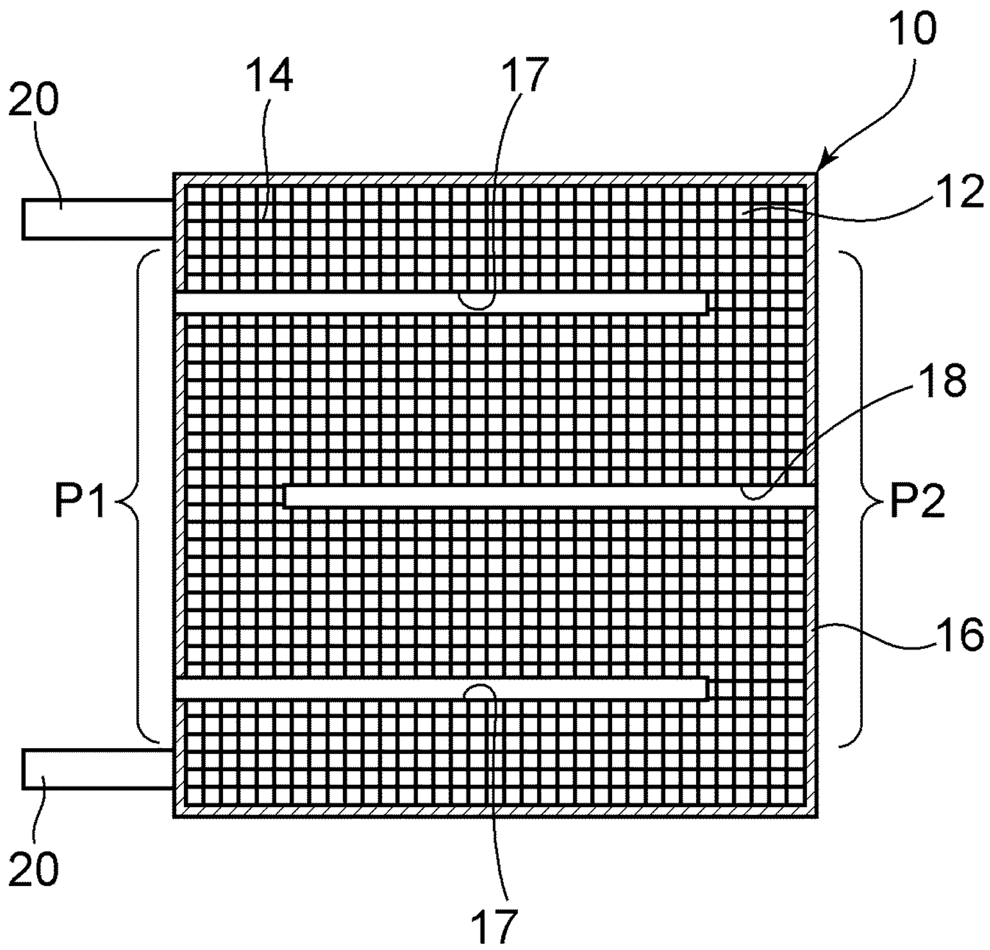
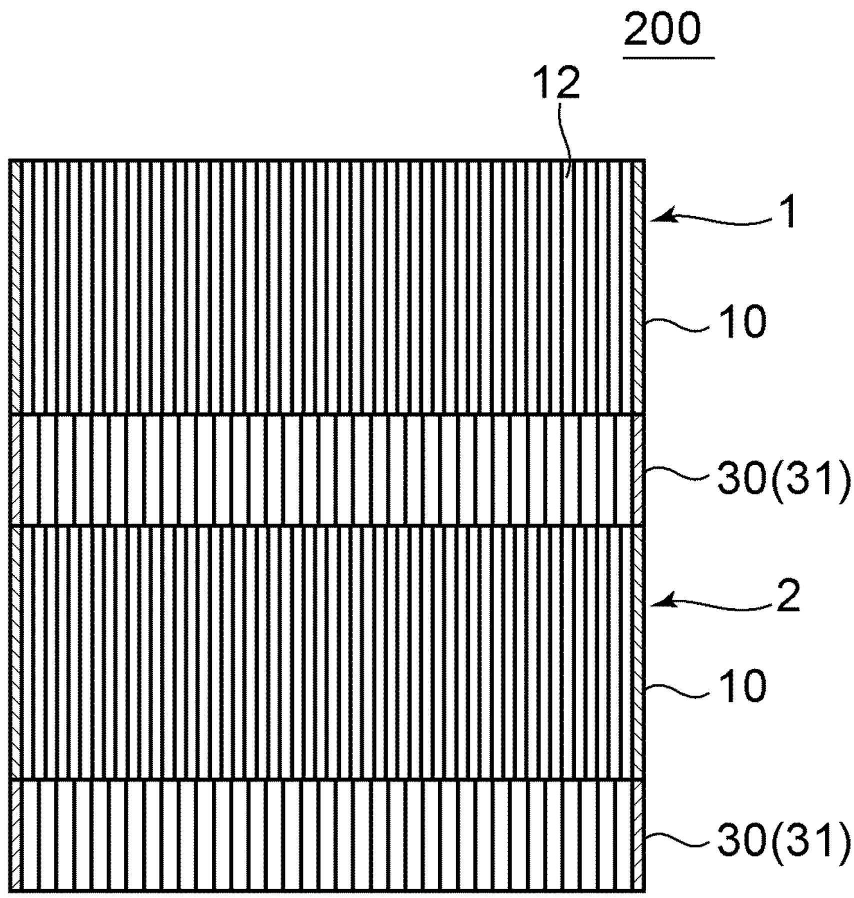


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/036367

A. CLASSIFICATION OF SUBJECT MATTER

B01J 35/57(2024.01)i; ***B01J 32/00***(2006.01)i; ***B01J 35/50***(2024.01)i; ***C04B 38/00***(2006.01)i; ***H05B 3/14***(2006.01)i
FI: B01J35/04 301J; B01J35/02 G; C04B38/00 303Z; H05B3/14 C; B01J32/00 ZAB

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)

B01J21/00-38/74;B01D39/00-39/20,46/00-46/90,53/86-53/90,53/94-53/96;C04B37/00-37/04,38/00; F01N3/00-3/38;H05B3/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 3-246315 A (NISSAN MOTOR CO., LTD.) 01 November 1991 (1991-11-01) claim 1, page 1, lower left column, lines 16-19, page 2, upper right column, line 16 to page 3, lower right column, line 5, fig. 1-4	1-2, 4-7, 11-13, 16
Y		3
A		8-10, 14-15
Y	JP 2001-293377 A (NIPPON YAKIN KOGYO CO., LTD.) 23 October 2001 (2001-10-23) claim 1, paragraph [0007], fig. 2-3, 5, 6	3
X	JP 2011-98306 A (GIFU UNIV.) 19 May 2011 (2011-05-19) claims, paragraphs [0031]-[0059], fig. 1-8	1-2, 4, 15
Y		3
A		5-14, 16
Y	JP 2022-109861 A (NGK INSULATORS LTD.) 28 July 2022 (2022-07-28) paragraphs [0044]-[0047], [0069]-[0071], fig. 3, 4, 7	3
A	JP 2005-194935 A (ISUZU MOTORS LTD.) 21 July 2005 (2005-07-21) claim 3, paragraphs [0049]-[0053], fig. 2	1-16

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

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- "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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Date of the actual completion of the international search	Date of mailing of the international search report
13 December 2023	**26 December 2023**

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

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/036367

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2016-1529 A (TOKAI KONETSU KOGYO CO., LTD.) 07 January 2016 (2016-01-07) claim 1, fig. 1	1-16
A	JP 2022-53219 A (IBIDEN CO., LTD.) 05 April 2022 (2022-04-05) claim 1, fig. 1	1-16

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/036367

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 3-246315 A	01 November 1991	(Family: none)	
JP 2001-293377 A	23 October 2001	(Family: none)	
JP 2011-98306 A	19 May 2011	(Family: none)	
JP 2022-109861 A	28 July 2022	US 2022/0227672 A1 paragraphs [0082]-[0086], [0125]-[0130], fig. 3, 4, 7 CN 114763308 A	
JP 2005-194935 A	21 July 2005	(Family: none)	
JP 2016-1529 A	07 January 2016	(Family: none)	
JP 2022-53219 A	05 April 2022	(Family: none)	

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- JP 6438939 B **[0003]**