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(71) Applicants:
- **DAIHATSU MOTOR COMPANY, LTD.**
  Ikeda-shi,
  Osaka-fu 563-8651 (JP)
- **RESEARCH INSTITUTE OF INNOVATIVE TECHNOLOGY FOR THE EARTH**
  Soraku-gun,
  Kyoto 619-0292 (JP)

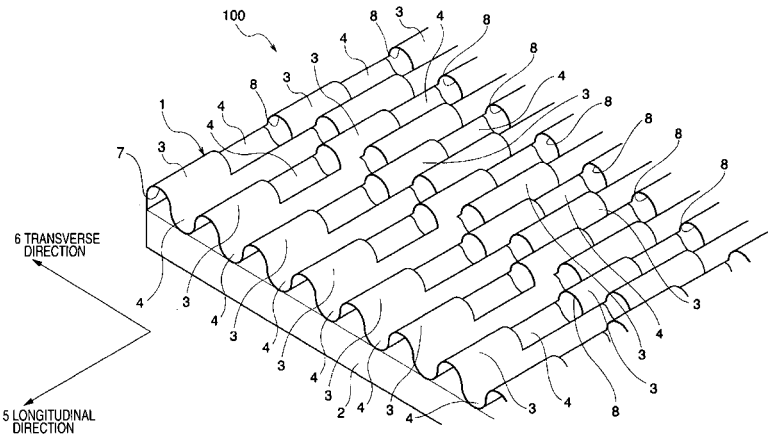
(72) Inventors:
- **NAITO, Kazuya**
  Shiga 520-2593 (JP)
- **KIM., Yoonho**
  Shiga 520-2593 (JP)
- **OGAWA, Takashi**
  Shiga 520-2593 (JP)
- **IWASAKI, Ryouhei**
  Shiga 520-2593 (JP)
- **TAN, Isao**
  Shiga 520-2593 (JP)
- **WAKUDA, Mitsuhiro**
  Shiga 520-2593 (JP)
- **TANAKA, Hirohisa**
  Shiga 520-2593 (JP)
- **YAO, Shui-Liang**
  Kyoto 619-0292 (JP)

(74) Representative: **Kramer - Barske - Schmidtchen**
European Patent Attorneys
Landsberger Strasse 300
80687 München (DE)

(54) ELECTRODE FOR PLASMA REACTOR

(57) Provided is an electrode for a plasma reactor including a plurality of charge concentrating portions that are formed on at least one surface of a metal plate so as to protrude from the surface, or an electrode for a plasma reactor including a metal plate a part of which protrudes to form a through-hole having a first opening and a second opening, and a dielectric material that is formed on one surface of the metal plate.

FIG. 2



EP 1 933 606 A1

Description

Technical Field

[0001] The present invention relates to an electrode for a plasma reactor used in an apparatus for removing components that are included in exhaust gas discharged from a factory, a plant, an internal-combustion engine, and the like and have an adverse effect on environment.

Background Art

[0002] Generally, there has been used a catalytic agent and a DPF (a diesel particulate filter) in order to decrease emission amount of CO (carbon monoxide), HC (hydrocarbon), NOx (nitrogen oxide), and PM (particulate material) that are included in exhaust gas discharged from, for example, a car engine, and particularly a diesel engine. However, in the case of the DPF, when PM of the inside thereof increases by collecting PM, ventilation of exhaust gas deteriorates, and exhaust resistance of the diesel engine increases. As a result, fuel efficiency and generating power decrease.

[0003] Considering this situation, recently it has been tried to remove the collected PM by oxidizing and vaporizing (CO_2) the PM, and reduce emission amount of the PM and the like by reforming exhaust gas. As for one of such trials, it has been known to use a plasma reactor, in an exhaust gas purification apparatus including a catalytic agent. For example, in Patent Document 1, there are provided two electrodes disposed to face each other, and a dielectric material laminated on any one of the two electrodes. In addition, grooves or pores are provided at predetermined periodic intervals on the surface of at least one of the electrode and the dielectric material. With such a configuration, plasma is generated between the electrodes disposed to face each other, exhaust gas is made to contact with the plasma, and thus it is possible to reduce emission amount of PM and the like in the exhaust gas.

[0004] In Patent Document 2, in the plasma generation electrode, at least one of the electrodes facing each other has a plate-like ceramic dielectric material, and a plurality of conductive films disposed in the ceramic dielectric material with a predetermined space therebetween in a film thickness direction. In addition, at least a sheet of the conductive films has a plurality of through-holes that are formed therethrough to be penetrated in the film thickness direction.

[0005] Patent Document 1: Japanese Unexamined Patent Application Publication No. 2005-138098

[0006] Patent Document 2: Japanese Unexamined Patent Application Publication No. 2005-203362

[0007] However, in the aforementioned configuration, there are provided the grooves, the pores, and the through-holes, but generally the electrodes are formed in a plate shape. Hence, plasma is not effectively generated between the electrodes (between the conductive films). Specifically, in the Patent Document 1, the grooves or pores are formed on a surface of the electrodes or the dielectric material. However, even when electric field is concentrated in portions of the grooves or the pores by a voltage applied to the electrodes, plasma discharge is generated in two dimensions, that is, a plane, in the grooves or pores. Hence, it is difficult to uniformly generate the plasma discharge in the space through which the exhaust gas passes, that is, in a space between the electrodes, then, it is not possible to efficiently generate plasma.

[0008] Likewise, in Patent Document 2, the conductive film having the through-hole is disposed in the ceramic dielectric material, but plasma has a tendency to be generated in two dimensions in the through-hole. Therefore, plasma may not be efficiently generated between the conductive films.

Disclosure of the invention

[0009] Accordingly, it is an object of the invention to solve the aforementioned problems.

[0010] Specifically, according to one aspect of the invention, an electrode for a plasma reactor includes a plurality of electric-potential concentrating portions (charge concentrating portions) that are formed on at least one surface of a metal plate so as to protrude from the surface.

[0011] With such a configuration, when a voltage is applied, electric potential is concentrated in the plurality of portions. By concentrating the electric potential, it is possible to increase plasma discharge efficiency in each portion. That is, in the plasma reactor, it is possible to substantially uniformly generate plasma in the substantially entire space between the electrodes disposed to face each other.

[0012] In the electric-potential concentrating portions according to the invention, if the tip of the portion has a sharp shape, whole shape of the portion is not limited. Specifically, convex portions and concave portions are alternately arranged to continue in a longitudinal direction and a transverse direction, and the electric-potential concentrating portions are cut surfaces formed at the boundaries between the convex portions and the concave portions in the longitudinal direction. In this case, exemplary shapes of the convex portion and the concave portion include a substantially semicircular shape, an equilateral triangle shape, and the like, and arrangement of the portions has a cross-sectional wave shape as a whole. Such a cross-sectional wave shape is obtained by, for example, performing a press processing on a metal

plate, and thus it is possible to increase productivity. In addition, in the configuration including the convex portions and the concave portions, it is preferred that the longitudinal direction corresponds to a flow direction of gas to be processed. With such a configuration, in the plasma reactor, it is possible to extend time period during which the gas to be processed is being in contact with plasma.

[0013] At the time of using the plasma reactor, it is preferred that the plasma reactor include a dielectric material formed on one surface in order to uniformly generate plasma discharge and stably generate plasma.

[0014] In addition, according to the other aspect of the invention, an electrode for a plasma reactor includes a metal plate a part of which protrudes to form a through-hole having a first opening and a second opening, and a dielectric material that is formed on one surface of the metal plate.

[0015] With such a configuration, when a voltage is applied, electric potential is concentrated in a part of the metal plate through which the through-hole is formed. By concentrating the electric potential, it is possible to increase plasma discharge efficiency in each portion. In addition, the dielectric material may be formed so that gas entering through the first opening of the metal plate is discharged from the second opening through a space formed between the metal plate 1 and the dielectric material 2. Alternatively, the dielectric material also may be formed so that gas entering from a first surface of the metal plate through the first opening is discharged from a second surface opposite to the first surface of the metal plate through the second opening. The through-holes are arranged in a flow direction of gas to be processed, and thus it is possible to extend time period during which the gas to be processed is being in contact with plasma generated in the plasma reactor.

[0016] In addition, the first opening and the second opening may have the same shape, and may have a circular shape or a triangular shape.

[0017] With the configuration according to the invention as described above, when a voltage is applied, electric potential is concentrated in the plurality of portions, and thus, it is possible to increase plasma discharge efficiency in each portion. Accordingly, at the time of use, the plasma is efficiently generated by these portions, and thus it is possible to form space where plasma uniformly exists in the substantially entire range of the electrode surface.

Brief Description of the Drawings

[0018]

Fig. 1 is a top plan view and a front view illustrating a first embodiment of the invention.

Fig. 2 is a perspective view illustrating an enlarged part of the first embodiment.

Fig. 3 is a front view illustrating a combination when the electrodes of the first embodiment are used in a plasma reactor.

Fig. 4 is a picture illustrating a plasma radiation state in the first embodiment.

Fig. 5 is a perspective view illustrating a second embodiment of the invention and corresponding to Fig. 2 in the first embodiment.

Best Mode for Carrying Out the invention

[0019] Hereinafter, an embodiment of the invention will be described with reference to Figs. 1 to 3.

[0020] An electrode 100 for plasma reactor according to the first embodiment (hereinafter, it is referred to an electrode) includes a metal plate 1 of which a cross-section has a substantially wave shape and a dielectric material 2 that has a plate shape and is disposed on one surface thereof. The metal plate 1 that constitutes the electrode 100 is made of, for example, nickel, copper, iron, stainless, tungsten, or the like. A thickness of the metal plate 1 is, for example, 200×10^{-6} m (meter), but the thickness is not limited to this when the thickness can obtain stiffness enough to maintain the substantially wave shape as described above.

[0021] The metal plate 1 has convex portions 3 and concave portions 4 arranged thereon to alternately continue in a transverse direction thereof. In addition, the metal plate 1 also has convex portions 3 and concave portions 4 arranged thereon to alternately continue in a longitudinal direction. Here, the longitudinal direction (the direction of an arrow 5 in Fig. 2) represents a direction in which exhaust gas flows in a case where the electrode 100 is attached to the plasma reactor, for example, the case of a car engine. On the contrary, the transverse direction (the direction of an arrow 6 in Fig. 2) represents a direction substantially orthogonal to the longitudinal direction.

[0022] In the longitudinal direction of the metal plate 1, each of the concave portions 4 alternately continues between the convex portion 3 and convex portion 3. Therefore, in the same manner as a cross-section 7 in the longitudinal direction of the metal plate 1, a plurality of cut surfaces 8 are formed so as to be exposed to the boundaries between the convex portions 3 and the concave portions 4 in the longitudinal direction. The cut surfaces 8, which are electric-potential concentrating portions when a voltage is applied to the electrode 100, are formed by cutting the convex portions 3 in the case where, for example, the convex portions 3 continuing in the longitudinal direction are formed to be concave

at a predetermined interval. In addition, in the first embodiment, partially the convex portions 3 and the concave portions 4 alternately continue in a transverse direction, and thus the convex portions 3 and the concave portions 4 has a partially continuous shape. However, as might expected, the invention includes not only such the shape but also a structure that the convex portions 3 and the concave portions 4 having the same length alternately continue in the transverse direction. In the electrode 100 having the structure mentioned above, exhaust gas entering through one opening of the convex portion 3 is discharged from the other opening of the convex portion 3 through a space formed between the metal plate 1 and the dielectric material 2.

[0023] The metal plate 1 mentioned above can be manufactured by, for example, pressing and passing the metal plate material between two rotating bodies having a patterned indented surface. Accordingly, the metal plate material having a predetermined width is continuously processed, and thus it is possible to easily make the metal plates 1 having the same shape and decrease production cost. Moreover, in the same manner as the first embodiment, by using the metal plate having a small thickness, it is possible to decrease weight of the electrode 100.

[0024] The dielectric material 2 has a flat plate shape and is disposed on one surface of the metal plate 1. Disposition of the electrodes in the plasma reactor is configured so that the electrode 100 has the dielectric material 2 and the electrode 200 has only the metal plates 1 with the dielectric material 2 interposed therebetween. In this case, a thickness of the dielectric material 2 is set to be the same as a distance enough to generate plasma when a predetermined voltage is applied to the electrode 100 and electrode 200.

[0025] In the configuration as described above, when the electrode 100 and the electrode 200 are mounted on the plasma reactor, the dielectric material 2 is interposed between the electrode 100 and the electrodes 200. Thus, one set of electrode section is formed in the plasma reactor (Fig. 3). In this case, each of the metal plates 1 of the electrodes 100 and 200 has the same size and shape, and each of the metal plates faces to each other so that the convex portions 3 of the electrode 200 are positioned to correspond to the convex portions 3 of the electrode 100. As a result, a distance between the metal plate 1 of the electrode 100 and the metal plate 1 of the electrode 200 is uniform in the entire range of the metal plates 1.

[0026] In the electrode 100 and the electrode 200, the plurality of cut surfaces 8 are exposed in the longitudinal direction. By forming such the cut surfaces 8, the cut surfaces 8 protrude from the boundaries between the convex portions 3 and the concave portions 4 in the longitudinal direction of the metal plate 1. In the cut surfaces 8, when a voltage is applied to the electrodes 100 and 200, the electric potential is concentrated. The electric potential concentration remarkably occurs in the edge portion of the cut surfaces 8. Hence, electron discharge from the cut surfaces 8 where electric potential is concentrated is activated as compared with the surfaces of the convex portions 3 and the concave portions 4. Thus, it is possible to decrease an inception voltage for plasma discharge and power consumption. Accordingly, even when the inception voltage for plasma discharge is low, it is possible to generate plasma with high discharge efficiency between the electrode 100 and electrode 200. Fig. 4 illustrates a plasma radiation state when the one sheet of the dielectric material is disposed between two electrodes. Plural pairs of the electrodes and the dielectric materials are laminated, and the plasma reactor is formed, and thus it is possible to perform uniform discharge in the entire reactor. Fig. 4 illustrates a microscopic radiation state and a uniform state as a whole in a macroscopic view.

[0027] In the electrodes 100 and 200 of the first embodiment, gas to be processed flows in the longitudinal direction. Therefore, it is possible to extend time period during which the gas to be processed is being in contact with plasma generated in the plasma reactor. Moreover, since the convex portions 3 and the concave portions 4 are flow passages of gas to be processed, it is possible to decrease flow resistance, and so it is possible to increase process ability.

[0028] In addition, in the first embodiment as described above, the cross-section in the transverse direction of the metal plate 1 is configured to have a semicircular shape, that is, a substantially wave shape, but it is allowed to employ a sine wave shape, a parabolic shape, an equilateral triangular shape, a polygonal shape, and the like. These shapes may be employed when the shapes are selected in consideration of processing convenience.

[0029] In addition, in the first embodiment as described above, the dielectric material 2 is provided on one side surface of the metal plate 1. However, in the configuration that a plurality of electrodes are laminated in the plasma reactor, the dielectric materials 2 may be provided on both side surfaces of the metal plate. In addition, in the first embodiment, there is described the case where the portion allowing the electric potential to be concentrated is the cut surfaces 8. However, the invention is not limited to this, and it is possible to form the portion allowing the electric potential to be concentrated by disposing protrusions or ribs on the surface of the metal plate 1.

[0030] Table 1 represents a research about a condition at the time of radiating plasma in a primary output voltage of 300V and a primary power outputting condition at the time of starting discharge by using a conventional electrode of which both surfaces have grooves formed thereon, an electrode according to the invention, and a pulse power supply that is boosted as much as two stages. A voltage at the time of radiating plasma and generation of a whisker-shaped waveform that is a characteristic waveform at the time of generating plasma are judged by an oscilloscope, and are measured by using a system capable of judging the inception voltage for plasma discharge. From the table 1, it is possible to realize that the inception voltage for plasma discharge is low in the case where the electrode according to the invention is used as compared with the case where the conventional electrode is used.

Table 1

		CHARACTERI STIC FOR THE PLASMA AT INCEPTION VOLTAGE (PRIMARY VOLTAGE)	CHARACTER ISTIC FOR THE LASMA AT 300V (PRIMARY VOLTAGE)
WAVE SHAPE ELECTRODE (EXAMPLE)	VOLTAGE (V)	150	300
	CURRENT (A)	0.01	0.03
	POWER CONSUMPTION (W)	71	110
	POWER FACTOR (COSΦ)	0.54	0.56
CONVENTIONAL ELECTRODE	VOLTAGE (V)	161	300
	CURRENT (A)	0.02	0.09
(COMPARATIVE EXAMPLE)	POWER CONSUMPTION (W)	79	118
	POWER FACTOR (COSΦ)	0.55	0.56

[0031] Next, a second embodiment will be described with reference to Fig. 5.

[0032] In the second embodiment, in the metal plate 301, a plurality of electric-potential concentrating portions are formed to protrude from one surface of a flat metal plate material by being cut and raised therefrom. Specifically, the metal plate 301 is provided with protruding portions 310 that are arranged at a predetermined distance away from each others, that is, at a predetermined pitch in a longitudinal direction and a transverse direction. The protruding portions are formed in a trigonal pyramid shape by being cut and raised. In addition, the longitudinal direction and transverse direction of the second embodiment are the same as those of the first embodiment mentioned above.

[0033] In the protruding portion 310, the bottom side of the trigonal pyramid shape is formed as a through-hole, and side walls 312 are formed to cover the through-hole. In the two side walls 312, the front side thereof in the longitudinal direction is cut off from the metal plate and the rear side thereof in the longitudinal direction is connected to the metal plate. With such a configuration, an opening 313 having a triangular shape is formed at the front side of the protruding portion 310 in the longitudinal direction, and a cut surface 314 having the substantially same thickness as the metal plate material is formed around the opening 313. In the embodiment, the protruding portion 310 is disposed not to overlap with the front thereof and be located on an intermediate position between the protruding portions 310 of the front row, in the longitudinal direction. Specifically, the protruding portion 310 is formed to be centered on each tip point of triangular meshes.

[0034] In the protruding portion 310, a ridge portion 315 is formed on the rear side thereof by the side walls 312 of each protruding portion, and a tip portion 316 is located on the opening 313. Edge of the ridge portion and the tip portion has a sharp shape, and electric field is remarkably concentrated on the edge along with the edge portion forming the cut surfaces 314.

[0035] In the metal plate 310 having the configuration as described above, the plurality of the cut surfaces 314 are disposed to protrude. Therefore, it is possible to obtain the same effect of the aforementioned embodiment.

[0036] In addition, the protruding portions 310 do not need to be formed at the predetermined pitch, and may be randomly or optionally disposed, respectively. The protruding portions 310 are easily manufactured to have the same heights when the cutting off processing is performed. However, the protruding portions do not need to have the same heights if the protruding portions include the cut surfaces 314 clearly formed and the tip portion 316 having a sharp end.

[0037] In addition, in the embodiments mentioned above, the dielectric material 2 having a flat plate shape was described, but the dielectric material may be provided by coating the metal plates 1 and 301. The dielectric material may be formed by coating at least one surface (in the second embodiment, which is the surface of the side on which the protruding portions 310 are provided) of the metal plates 1 and 301. In addition, the entire metal plates 1 and 301 may be coated with the dielectric material.

[0038] As described above, in the method that the dielectric material is formed on the metal plates 1 and 301 by the coating process, the cut surfaces may be also coated with the dielectric material.

[0039] When the dielectric material is formed by coating the metal plate 301, exhaust gas entering through the opening

313 from the surface where the protruding portions 310 of the metal plate 301 exist is discharged from the surface opposite thereto through the other opening 323 including the end portion 311.

[0040] With respect to the detailed configuration about each part, the invention is not limited to the embodiment mentioned above, and may be modified in various forms without departing from the technical spirit of the invention.

Industrial Applicability

[0041] Exemplary applications of the invention include a plasma reactor of a device installed to process exhaust gas including PM such as an exhaust gas purification device for car, and an exhaust gas processing device in a facilities like a plant which discharges smoke. In addition, it is possible to be employed as a reforming device and the like for generating hydrogen used in a fuel cell.

Claims

1. An electrode for a plasma reactor comprising a plurality of electric-potential concentrating portions that are formed on at least one surface of a metal plate so as to protrude from the surface.

2. The electrode for the plasma reactor according to Claim 1, wherein convex portions and concave portions are alternately arranged to continue in a longitudinal direction and a transverse direction, and the electric-potential concentrating portions are cut surfaces formed at the boundaries between the convex portions and the concave portions in the longitudinal direction.

3. The electrode for the plasma reactor according to Claim 2, wherein the longitudinal direction is a gas flow direction.

4. The electrode for the plasma reactor according to Claim 1, 2 or 3, wherein the metal plate includes a dielectric material formed on one surface thereof.

5. An electrode for a plasma reactor comprising:

   a metal plate a part of which protrudes to form a through-hole having a first opening and a second opening; and a dielectric material that is formed on one surface of the metal plate.

6. The electrode for the plasma reactor according to Claim 5, wherein the dielectric material is formed so that gas entering through the first opening of the metal plate is discharged from the second opening through a space formed between the metal plate 1 and the dielectric material 2.

7. The electrode for the plasma reactor according to Claim 5, wherein the first opening and the second opening are formed in the same shape.

8. The electrode for the plasma reactor according to Claim 5, wherein at least one of the first opening and the second opening is formed in a circular shape.

9. The electrode for the plasma reactor according to Claim 5, wherein at least one of the first opening and the second opening is formed in a triangular shape.

10. The electrode for the plasma reactor according to Claim 5, wherein the dielectric material is formed so that gas entering from a first surface of the metal plate through the first opening is discharged from a second surface opposite to the first surface of the metal plate through the second opening.

FIG. 1

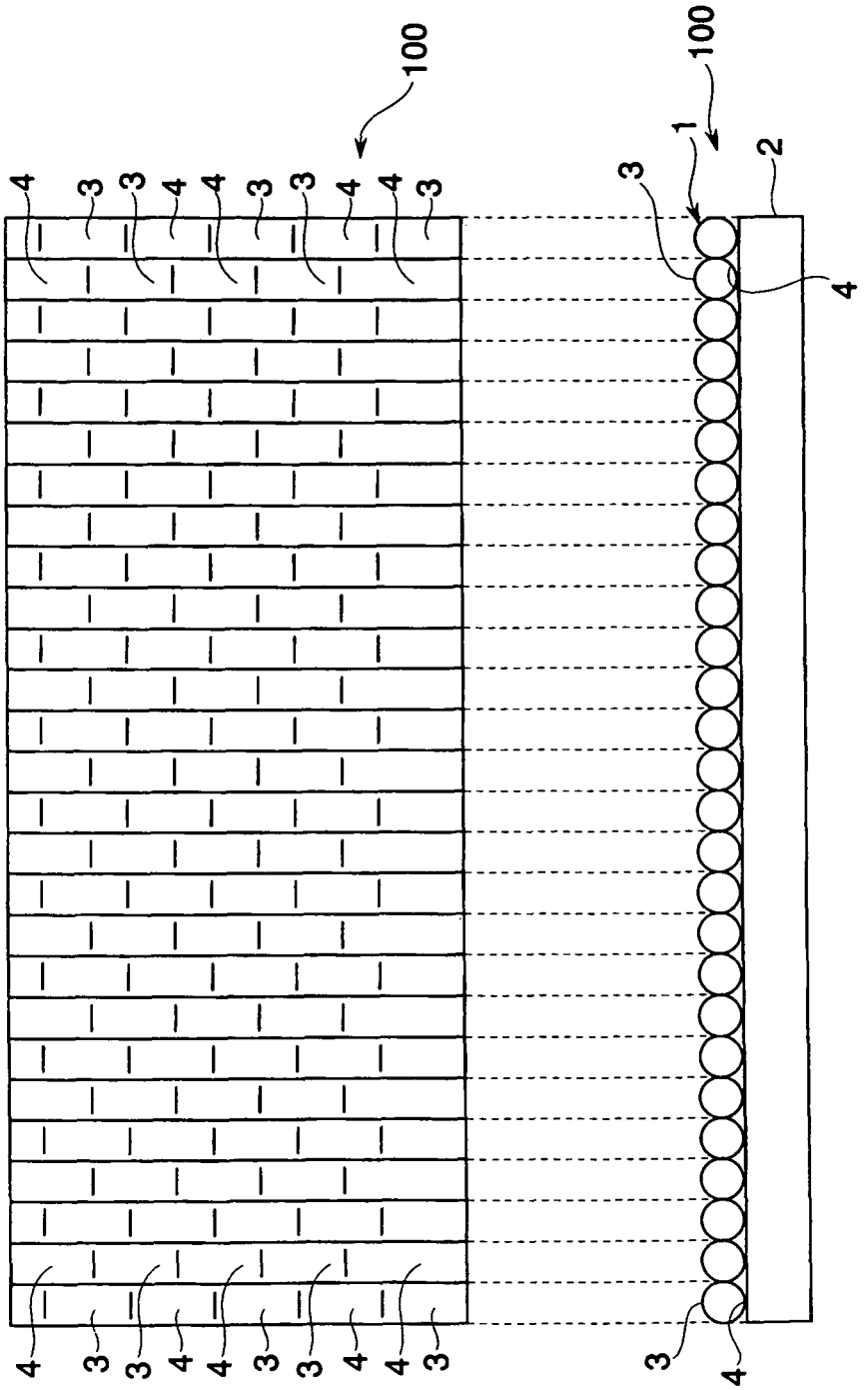
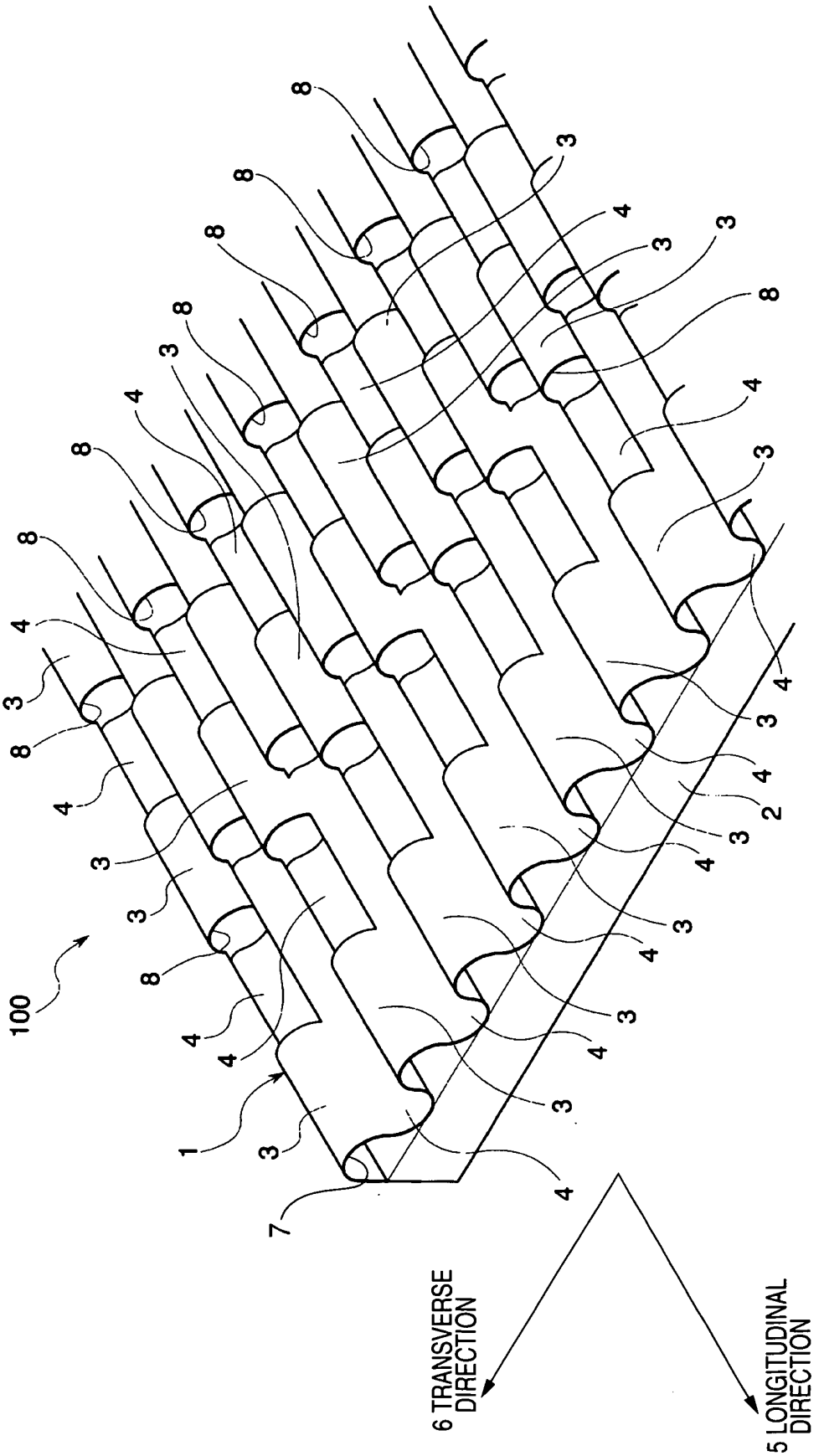


FIG. 2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5 LONGITUDINAL DIRECTION
6 TRANSVERSE DIRECTION
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FIG. 3

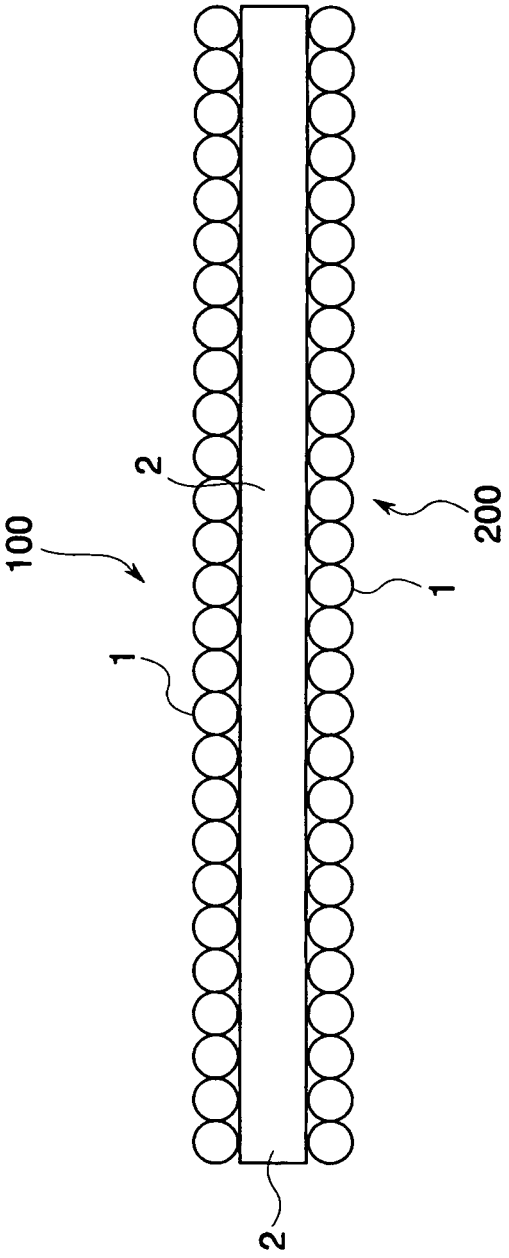
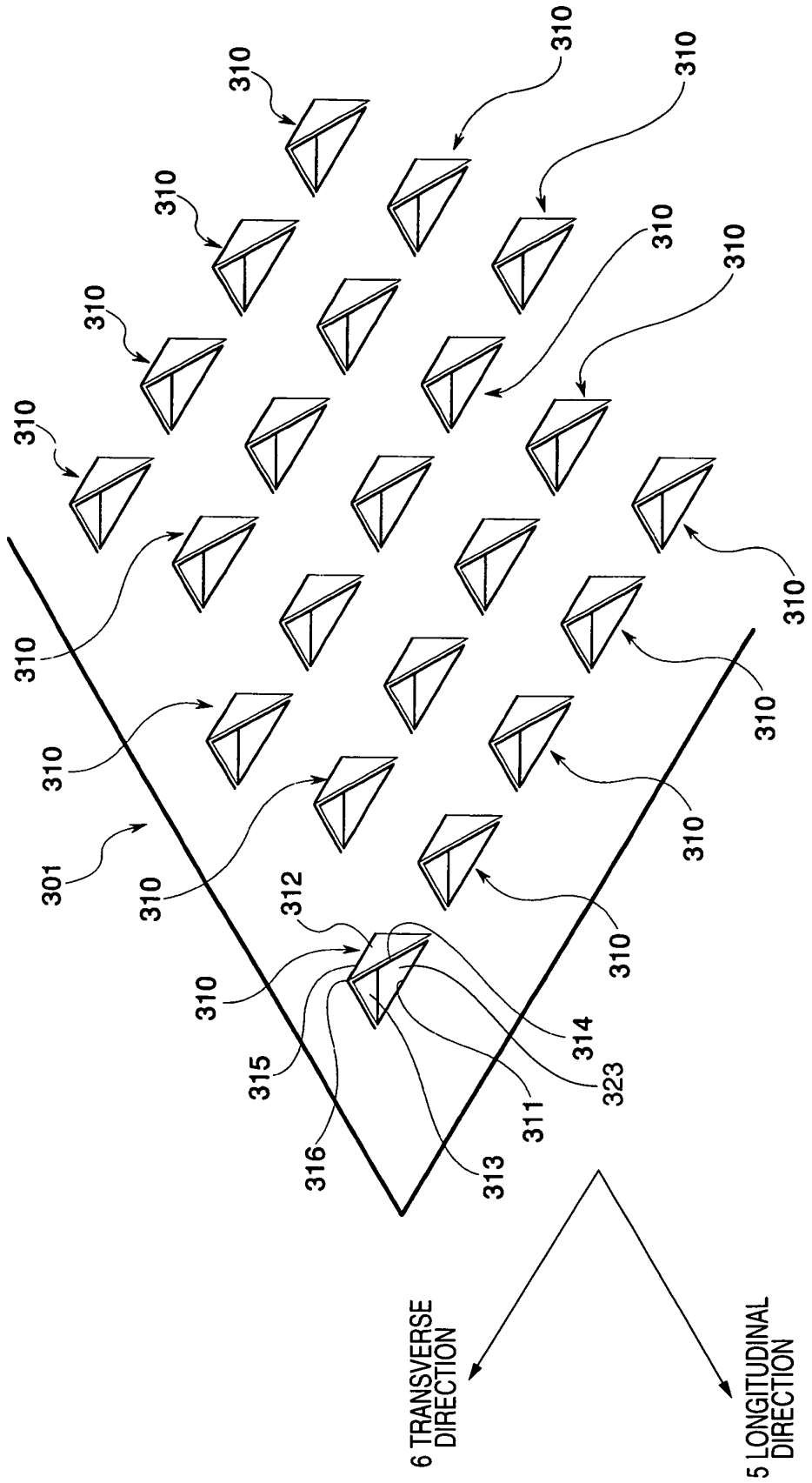


FIG. 4

FIG. 5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5 LONGITUDINAL DIRECTION

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/320238

A. CLASSIFICATION OF SUBJECT MATTER
H05H1/24(2006.01)i, *B01J19/08*(2006.01)i, *F01N3/02*(2006.01)i, *F01N3/08*(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)
H05H1/24, B01J19/08, F01N3/02, F01N3/08

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 1996-2006
Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2002-361028 A (Daikin Industries, Ltd.), 17 December, 2002 (17.12.02), Par. Nos. [0001], [0045]; Fig. 3 (Family: none)	1 2-4 5-10
Y A	JP 2005-203362 A (NGK Insulators, Ltd.), 28 July, 2005 (28.07.05), Par. Nos. [0001] to [0003], [0029] to [0031]; Figs. 5 to 7 (Family: none)	2-4 5-10
Y	JP 2005-268129 A (Zaidan Hojin Chikyu Kankyo Sangyo Gijutsu Kenkyu Kiko), 29 September, 2005 (29.09.05), Par. No. [0004]; Fig. 3 (Family: none)	3,4

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

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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
12 December, 2006 (12.12.06)	26 December, 2006 (26.12.06)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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Patent documents cited in the description

- JP 2005138098 A **[0005]**
- JP 2005203362 A **[0006]**