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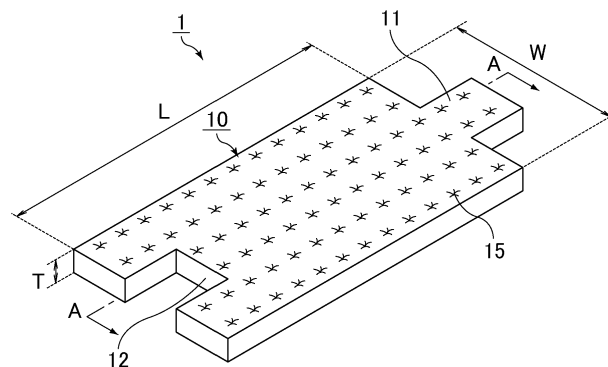
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(54) **MAT MATERIAL, EXHAUST GAS PURIFICATION DEVICE, AND METHOD FOR PRODUCING MAT MATERIAL**

(57) A mat material including: inorganic fibers; and multiple entanglement points formed by needling at least one of a front surface or a back surface of the mat material, wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, at least one of a 4 mm $\times$ 4 mm first region without the entanglement

points or a 3 mm $\times$ 8 mm second region without the entanglement points is arranged in a 25 mm $\times$ 25 mm region, and the mat material contains an inorganic binder and has a shear modulus of 0.20 or more and a post-firing surface pressure of 50 kPa or more.

FIG. 1



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a mat material, an exhaust gas conversion apparatus, and a method for producing a mat material.

BACKGROUND ART

10 **[0002]** Exhaust gas discharged from an internal combustion engine such as a diesel engine contains a particulate matter (hereinafter, also referred to as "PM"). Adverse effects of PM on the environment and human bodies have been problems. The exhaust gas also contains harmful gas components such as CO, HC, and NOx. This causes concerns about the effects of such harmful gas components on the environment and human bodies.

15 **[0003]** In view of the above, various exhaust gas conversion apparatuses that collect PM in exhaust gas and convert harmful gas components have been proposed. Such an exhaust gas conversion apparatus includes an exhaust gas treatment unit including porous ceramic such as silicon carbide or cordierite, a casing for housing the exhaust gas treatment unit, and a holding sealing material (mat material) between the exhaust gas treatment unit and the casing. The holding sealing material (mat material) is disposed mainly, for example, for preventing the exhaust gas treatment unit from being damaged by contact with the casing that covers the periphery of the exhaust gas treatment unit due to vibrations and
20 impacts caused by operation of automobiles or the like, and for preventing exhaust gas leakage from a space between the exhaust gas treatment unit and the casing.

[0004] Patent Literature 1 discloses that a sheet material having both a required strength and a strong repulsion can be obtained by adjusting the density ρ of entanglement points formed by needling to $0.5 \text{ pcs/cm}^2 \leq \rho < 20 \text{ pcs/cm}^2$. Patent Literature 1 also discloses that an organic binding material is added to the sheet material to improve adhesion between
25 fibers and prevent fiber scattering during handling of the sheet material.

CITATION LIST

- Patent Literature

30 **[0005]** Patent Literature 1: JP 2007-292040 A

SUMMARY OF INVENTION

35 - Technical Problem

[0006] In Patent Literature 1, only the organic binder is attached, so that the mat has a low shear modulus, and its holding power is smaller than expected. In addition, the organic binding material contained in the sheet material is thermally decomposed and burned out by a high-temperature exhaust gas immediately after use of an exhaust gas conversion
40 apparatus, resulting in a low holding power.

- Solution to Problem

45 **[0007]** The present invention was made in view of the above problems and aims to provide a mat material having a high shear modulus and a high holding power.

[0008] Specifically, the mat material of the present invention includes inorganic fibers and multiple entanglement points formed by needling at least one of a front surface or a back surface of the mat material, wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged in a $25 \text{ mm} \times 25 \text{ mm}$
50 region, and the mat material contains an inorganic binder and has a shear modulus of 0.20 or more and a post-firing surface pressure of 50 kPa or more.

[0009] In the mat material of the present invention, the density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, and at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged. When the density ρ of the entanglement points is low, the shear modulus tends to be low. However, in the case of the mat material of the present invention, although the density ρ of the entanglement points is low, the shear modulus is as high as 0.20 or more, because the mat material includes at least one of
55 the first region or the second region and contains an inorganic binder. Further, the inorganic binder will not be burned out even when a high-temperature exhaust gas is flowed into an exhaust gas conversion apparatus, so that the mat material

has a high holding power and has a post-firing surface pressure of 50 kPa or more. Further, since the inorganic binder is also present on the surface of the mat material, displacement of the mat material due to vibration or impact can be prevented or reduced.

[0010] In the mat material of the present invention, preferably, a weight ratio of the inorganic binder to the mat material (weight of inorganic binder/weight of mat material) is more than 0 wt% and 10 wt% or less.

[0011] When the weight ratio of the inorganic binder to the mat material is in the above range, the holding power can be sufficiently increased.

[0012] Preferably, the mat material of the present invention further contains an organic binder.

[0013] The organic binder, when further contained in the mat material, improves adhesion between the fibers and prevents fiber scattering during handling of the mat material.

[0014] In the mat material of the present invention, preferably, a weight ratio of the organic binder to the mat material, i.e., weight of organic binder/weight of mat material, is more than 0 wt% and 10 wt% or less.

[0015] At a weight ratio of the organic binder to the mat material in the above range, an effect of preventing fiber scattering and a high holding power can be both achieved.

[0016] Preferably, in the mat material of the present invention, the inorganic binder and the organic binder are attached in an individually dispersed state to a surface of each inorganic fiber.

[0017] When the inorganic binder and the organic binder are attached in an individually dispersed state to the surface of each inorganic fiber, the inorganic binder is in a dispersed state in a coating formed from the organic binder. The coating in such a state has excellent mechanical strength and thus can prevent the inorganic fibers from slipping on each other and increase the holding power.

[0018] Preferably, the mat material of the present invention further contains a polymeric dispersant.

[0019] When the mat material further contains a polymeric dispersant, the organic binder and the inorganic binder can be easily attached in a dispersed state to the surface of each inorganic fiber.

[0020] In the mat material of the present invention, preferably, aggregates of the inorganic binder and the organic binder are attached to the surface of each inorganic fiber.

[0021] The aggregates of the inorganic binder and the organic binder can form irregularities on the surface of each inorganic fiber, which can increase the friction between the inorganic fibers and improve the holding power.

[0022] In the mat material of the present invention, preferably, the surface of each inorganic fiber is at least partially covered with a coating layer containing a mixture of the inorganic binder and the organic binder.

[0023] The coating layer containing a mixture of the inorganic binder and the organic binder has a higher mechanical strength than a coating layer containing only the organic binder. Thus, the coating layer is less likely to peel off, making it possible to increase the frictional resistance between the inorganic fibers.

[0024] In the mat material of the present invention, preferably, the coating layer is formed from a continuous flaky mixture of the inorganic binder and the organic binder.

[0025] When the coating layer is formed from the flaky mixture, many irregularities derived from the flaky mixture are formed on a surface of the coating layer, which can further increase the frictional resistance between the inorganic fibers.

[0026] In the mat material of the present invention, preferably, the coating layer has a stepped shape.

[0027] When the coating layer has a stepped shape, the frictional resistance between the inorganic fibers can be further increased.

[0028] In the mat material of the present invention, preferably, a particulate mixture of the inorganic binder and the organic binder is attached to the surface of the coating layer.

[0029] When the particulate mixture of the inorganic binder and the organic binder is attached to the surface of the coating layer, the frictional resistance between the inorganic fibers can be further increased than when no such particulate mixture is attached to the coating layer.

[0030] In the mat material of the present invention, preferably, the mat material has a shear modulus that is 105% or more of a shear modulus of a mat material with same conditions except that no inorganic binder is contained.

[0031] The "mat material with same conditions except that no inorganic binder is contained" corresponds to one in which the inorganic binder is removed from the mat material of the present invention.

[0032] In the mat material of the present invention, preferably, at least one of the first region or the second region is arranged in a plural number in the 25 mm × 25 mm region.

[0033] When at least one of the first region or the second region is arranged in a plural number in the 25 mm × 25 mm region, the surface pressure of the mat material can be increased.

[0034] Preferably, the mat material of the present invention further includes a protective sheet on at least one of the front surface of the back surface.

[0035] The protective sheet, when further placed on the surface of the mat material, prevents or reduces displacement and/or dense wrinkles of the mat material and generation of a gap in a fitting portion when the mat material is wound around an exhaust gas treatment unit.

[0036] Preferably, the mat material of the present invention is used in an exhaust gas conversion apparatus.

[0037] The mat material of the present invention has a high shear modulus and a high holding power, and thus can be suitably used in an exhaust gas conversion apparatus.

[0038] An exhaust gas conversion apparatus of the present invention includes an exhaust gas treatment unit, a metal casing for housing the exhaust gas treatment unit, and a mat material arranged between the exhaust gas treatment unit and the metal casing for holding the exhaust gas treatment unit, wherein the mat material is the mat material of the present invention.

[0039] The exhaust gas conversion apparatus of the present invention can stably hold the exhaust gas treatment unit owing to the arrangement of the mat material of the present invention between the exhaust gas treatment unit and the metal casing.

[0040] A method for producing a mat material according to a first embodiment of the present invention includes an attaching step of attaching an inorganic binder to an inorganic fiber mass, the inorganic fiber mass including inorganic fibers and multiple entanglement points formed by needling at least one of a front surface or a back surface of the inorganic fiber mass, wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, and at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged in a $25 \text{ mm} \times 25 \text{ mm}$ region.

[0041] A method for producing a mat material according to a second embodiment of the present invention includes an attaching step of attaching both an inorganic binder and an organic binder to an inorganic fiber mass, the inorganic fiber mass including inorganic fibers and multiple entanglement points formed by needling at least one of a front surface or a back surface of the inorganic fiber mass, wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, and at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged in a $25 \text{ mm} \times 25 \text{ mm}$ region.

[0042] In the second embodiment of the method for producing a mat material of the present invention, preferably, in the attaching step, a dispersion in which the inorganic binder and the organic binder are dispersed in a dispersion medium is attached to the inorganic fiber mass.

[0043] In the second embodiment of the method for producing a mat material of the present invention, preferably, in the attaching step, an aggregated dispersion in which the inorganic binder and the organic binder are aggregated is attached to the inorganic fiber mass.

[0044] The method for producing a mat material of the present invention can easily produce the mat material of the present invention.

BRIEF DESCRIPTION OF DRAWINGS

[0045]

FIG. 1 is a schematic perspective view of an example of a mat material of the present invention.

FIG. 2 is a cross-sectional view taken along line A-A in FIG. 1.

FIG. 3 is a schematic view of an example of arrangement of entanglement points in the mat material of the present invention.

FIG. 4 is a schematic view of an example of the mat material in which the entanglement points are evenly arranged.

FIG. 5 is an example of an enlarged electron microscope image of the mat material of the present invention.

FIG. 6 is another example of an enlarged electron microscope image of the mat material of the present invention.

FIG. 7 is still another example of an enlarged electron microscope image of the mat material of the present invention.

FIG. 8 is still another example of an enlarged electron microscope image of the mat material of the present invention.

FIG. 9 is a conceptual schematic view of a shear failure load testing device.

FIG. 10 is a schematic perspective view of another example of the mat material of the present invention.

FIG. 11 is a schematic cross-sectional view of an example of the exhaust gas conversion apparatus of the present invention.

DESCRIPTION OF EMBODIMENTS

[0046] Hereinafter, embodiments of the present invention are specifically described. The present invention is not limited to the embodiments described below, and suitable modifications may be made without departing from the scope of the present invention.

[Mat Material]

[0047] The mat material of the present invention includes inorganic fibers and multiple entanglement points formed by needling at least one of a front surface or a back surface of the mat material, wherein a density ρ of the entanglement points

is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged in a $25 \text{ mm} \times 25 \text{ mm}$ region, and the mat material contains an inorganic binder and has a shear modulus of 0.20 or more and a post-firing surface pressure of 50 kPa or more.

[0048] FIG. 1 is a schematic perspective view of an example of the mat material of the present invention. FIG. 2 is a cross-sectional view taken along line A-A in FIG. 1.

[0049] As shown in FIG. 1, a mat material 1 of the present invention includes a flat plate-like mat 10 having a generally rectangular shape in a plan view, with a predetermined length (hereinafter indicated by an arrow L in FIG. 1), a predetermined width (indicated by an arrow W in FIG. 1), and a predetermined thickness (indicated by an arrow T in FIG. 1).

[0050] The mat 10 shown in FIG. 1 includes a protrusion 11 and a recess 12 respectively at one end and the other end in a longitudinal direction of the mat 10. The protrusion 11 and the recess 12 of the mat 10 have shapes that perfectly fit each other when the mat 10 is wound around an exhaust gas treatment unit to assemble an exhaust gas conversion apparatus (described later). The protrusion 11 and the recess 12 result in better sealing properties when the mat 10 is arranged in the exhaust gas conversion apparatus (described later).

[0051] The mat 10 includes multiple entanglement points 15 (also referred to as "needle-punched marks") formed on a main surface thereof, which are formed by needling.

[0052] The mat 10 includes two main surfaces. One of them is a front surface, and the other is a back surface.

[0053] Neither the protrusion nor the recess may be provided at the ends of the mat material of the present invention.

[0054] Each end of the mat may have an L-shape such that the ends fit each other when the mat material is wound around an object.

[0055] The mat may be a mat material by itself, or the mat may further include a protective sheet (described later) on at least one surface of the mat.

[0056] As shown in FIG. 2, the entanglement points 15 are formed in a straight line and oriented perpendicular to a thickness direction of the mat 10. Each entanglement point 15 may have a curved shape or may be inclined with respect to the thickness direction of the mat 10. The entanglement points 15 may not penetrate in the thickness direction of the mat 10.

[0057] The mat thickness is not limited but is preferably 2 to 40 mm. At a mat thickness of more than 40 mm, the mat loses its flexibility, which makes handling difficult when the mat material is wound around an exhaust gas treatment unit, and which also makes the mat material prone to winding wrinkles and cracking.

[0058] At a mat thickness of less than 2 mm, the exhaust gas treatment unit easily falls out due to insufficient holding power of the mat material. In addition, when changes occur in the volume of the exhaust gas treatment unit, the mat material is less likely to absorb such changes in the volume of the exhaust gas treatment unit. Thus, the exhaust gas treatment unit becomes prone to cracking and the like.

[0059] The mat includes inorganic fibers.

[0060] Any inorganic fibers may be used, but the inorganic fibers preferably include at least one selected from the group consisting of alumina fibers, silica fibers, alumina silica fibers, mullite fibers, biosoluble fibers, and glass fibers.

[0061] The inorganic fibers including at least one selected from alumina fibers, silica fibers, alumina silica fibers, and mullite fibers have excellent heat resistance, so that the properties or the like will not change, even when the exhaust gas treatment unit is exposed to sufficiently high temperatures, and the mat material can sufficiently maintain its function. In the case where the inorganic fibers are biosoluble fibers, for example, even when a worker inhales the inorganic fibers that are scattered during production of the exhaust gas conversion apparatus using the mat material, the inorganic fibers will dissolve *in vivo* and thus cause no harm to the health of the worker.

[0062] The alumina fibers may contain, in addition to alumina, additives such as calcia, magnesia, and zirconia.

[0063] The compositional ratio of the alumina silica fibers by weight is preferably $\text{Al}_2\text{O}_3:\text{SiO}_2 = 60:40$ to $80:20$, more preferably $\text{Al}_2\text{O}_3:\text{SiO}_2 = 70:30$ to $74:26$.

[0064] The mat can be produced by needling.

[0065] The average fiber length of the inorganic fibers is preferably 1 to 150 mm, more preferably 10 to 80 mm.

[0066] Inorganic fibers having an average fiber length of less than 1 mm are too short in length, so that such inorganic fibers are insufficiently entangled with each other and result in poor winding properties of the mat material when the mat material is wound around the exhaust gas treatment unit, making the mat material easily breakable. Inorganic fibers having an average fiber length of more than 150 mm are too long in length, so that there are fewer fibers constituting the mat material, reducing the denseness of the mat material. As a result, the mat material has a low shear strength.

[0067] Entanglement points are formed on the front surface or back surface of the mat material.

[0068] The density ρ of the entanglement points is in the range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$.

[0069] When the entanglement points are formed on both the front surface and back surface of the mat material, the density ρ of the entanglement points is the density of the entanglement points measured on a main surface, either the front surface or the back surface, with a higher density of the entanglement points.

[0070] At least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region

without the entanglement points is arranged in a 25 mm × 25 mm region of the front surface or back surface of the mat material.

[0071] The mat material of the present invention exhibits a high surface pressure owing to the arrangement of at least one of the first region or the second region.

[0072] The main surface of the mat material to be checked to determine whether at least one of the first region or the second region is arranged thereon is the main surface on which the density of the entanglement points is measured.

[0073] Preferably, both the first region and the second region are arranged in the 25 mm × 25 mm region of the front surface or back surface of the mat material of the present invention.

[0074] The first region and the second region may be separately arranged, but preferably, the first region and the second region overlap with each other. When the first region and the second region overlap with each other, the area without the entanglement points increases, which can increase the surface pressure of the mat material.

[0075] FIG. 3 is a schematic view of an example of arrangement of entanglement points in the mat material of the present invention.

[0076] In FIG. 3, multiple entanglement points 15 are unevenly arranged. This arrangement is considered as including first regions 17 that are 4 mm × 4 mm regions without the entanglement points 15 (regions indicated with squares in solid lines in FIG. 3) and second regions 18 that are 3 mm × 8 mm regions without the entanglement points 15 (regions indicated with rectangles in dashed lines in FIG. 3).

[0077] FIG. 3 does not show all the first regions 17 or all the second regions 18.

[0078] FIG. 4 is a schematic view of an example of the mat material in which the entanglement points are evenly arranged.

[0079] In FIG. 4, the entanglement points 15 are evenly arranged at intervals of 2.8 mm.

[0080] Each of the 4 mm × 4 mm squares and the 3 mm × 8 mm rectangles shown in FIG. 4 includes one or more entanglement points. A symbol "×" is added to each of the 4 mm × 4 mm squares not corresponding to the first regions and the 3 mm × 8 mm rectangles not corresponding to the second regions.

[0081] Accordingly, neither the first regions nor the second regions can be arranged in the mat material shown in FIG. 4.

[0082] The number of the first regions and the second regions in the 25 mm × 25 mm region can be counted by the following method.

(1) A 4 mm × 4 mm region (first region) in which no entanglement points are formed is located. At this point, multiple first regions that do not overlap with each other are selected.

(2) A 3 mm × 8 mm region (second region) in which no entanglement points are formed is located. At this point, multiple second regions that do not overlap with each other are selected. The second region and the first region may overlap with each other.

(3) A 25 mm × 25 mm region in which the total number of non-overlapping first regions and non-overlapping second regions is the maximum is selected.

[0083] The above operation is performed for ten samples, and the average is calculated.

[0084] The above operation may be performed using commercially available image processing software or the like.

[0085] Preferably, at least one of the first region or the second region is arranged in a plural number in the 25 mm × 25 mm region.

[0086] When at least one of the first region or the second region is arranged in a plural number in the 25 mm × 25 mm region, the surface pressure of the mat material can be increased.

[0087] That "at least one of the first region or the second region is arranged in a plural number" refers to a case where the total number of the first regions and the second regions is two or more, which includes, for example, a case where multiple first regions are arranged, a case where multiple second regions are arranged, and a case where multiple first regions and multiple second regions are arranged.

[0088] Preferably, a third region, which is a 4 mm × 4 mm region including four or more entanglement points, is arranged in the 25 mm × 25 mm region on the front surface or back surface of the mat material.

[0089] The arrangement of the third region can increase the shear strength of the mat material because the inorganic fibers in the third region are strongly entangled with each other.

[0090] The method for counting the number of the third regions in the 25 mm × 25 mm region is the same as the method for counting the number of the first regions described above.

[0091] The mat material contains an inorganic binder (also referred to as "inorganic binding material").

[0092] The mat material of the present invention, which contains an inorganic binder, has a high shear modulus. Further, the mat material has a high holding power because the inorganic binder will not be burned out even when a high-temperature exhaust gas is flowed into an exhaust gas conversion apparatus. Further, since the inorganic binder is also present on the surface of the mat material, displacement of the mat material due to vibration or impact can be prevented or reduced.

[0093] Examples of the inorganic binder include alumina sol and silica sol.

[0094] Preferably, the weight ratio of the inorganic binder to the mat material (weight of inorganic binder/weight of mat material) is more than 0 wt% and 10 wt% or less.

[0095] When the weight ratio of the inorganic binder to the mat material is in the above range, the holding power can be sufficiently increased.

[0096] The mat material may further contain an organic binder (also referred to as "organic binding material").

[0097] The organic binder, when further contained in the mat material, improves adhesion between the fibers and prevents fiber scattering during handling of the mat material.

[0098] Examples of the organic binder include water-soluble organic polymers such as acrylic resin, acrylate latex, rubber latex, carboxymethylcellulose, and polyvinyl alcohol; thermoplastic resins such as styrene resin; and thermosetting resins such as epoxy resin.

[0099] Preferably, the weight ratio of the organic binder to the mat material (weight of organic binder/weight of mat material) is more than 0 wt% and 10 wt% or less.

[0100] At a weight ratio of the organic binder to the mat material in the above range, the effect of preventing fiber scattering and the high holding power can be both achieved.

[0101] The amounts of the organic binder and the inorganic binder in the mat material can be measured by the following method, for example.

[0102] First, a certain weight of a sample is taken out from a mat material in which the amounts of the organic binder and the inorganic binder therein are intended to be measured. Subsequently, an organic solvent (e.g., tetrahydrofuran) that dissolves the organic binder in the sample is selected, and the organic binder is dissolved in a Soxhlet extractor to separate the organic binder from the sample. At this point, the inorganic binder in the dissolved organic binder is also separated from the sample, so that the organic binder and the inorganic binder are both extracted in the organic solvent.

[0103] Next, the organic solvent containing the organic binder and the inorganic binder is placed in a crucible, and the organic solvent is removed by evaporation with heat. The amount (weight %) of the residue remaining in the crucible relative to the weight of the mat material is calculated, assuming that the weight of the residue is the total weight of the organic binder and the inorganic binder relative to the mat material.

[0104] Further, the crucible is heated at 600°C for one hour to burn out the organic binder. Since the inorganic binder remains in the crucible, the amount of the inorganic binder is calculated, assuming that the amount of the residue is the amount (weight %) of the inorganic binder relative to the total of the organic binder and the inorganic binder. The balance is the amount (weight %) of the organic binder.

[0105] In the mat material, preferably, the inorganic binder and the organic binder are attached in an individually dispersed state to the surface of each inorganic fiber.

[0106] When the inorganic binder and the organic binder are attached in an individually dispersed state to the surface of each inorganic fiber, the inorganic binder is in a dispersed state in a coating formed from the organic binder. The coating in such a state has excellent mechanical strength and thus can prevent the inorganic fibers from slipping on each other and increase the holding power.

[0107] In the mat material, preferably, the surface of each inorganic fiber is at least partially covered with a coating layer containing a mixture of the inorganic binder and the organic binder.

[0108] The coating layer containing a mixture of the inorganic binder and the organic binder has a higher mechanical strength than a coating layer containing only the organic binder. Thus, the coating layer is less likely to peel off, making it possible to increase the frictional resistance between the inorganic fibers.

[0109] Preferably, the coating layer is formed from a continuous flaky mixture (mixture of the inorganic binder and the organic binder).

[0110] When the coating layer is formed from the flaky mixture, many irregularities derived from the flaky mixture are formed on the surface of the coating layer, which can further increase the frictional resistance between the inorganic fibers.

[0111] FIG. 5 is an example of an enlarged electron microscope image of the mat material of the present invention.

[0112] As shown in FIG. 5, the surface of an inorganic fiber 20 is partially covered with a coating layer 30 containing a mixture of the inorganic binder and the organic binder. The coating layer 30 is formed from a continuous flaky mixture of the inorganic binder and the organic binder. A particulate mixture 40 of the inorganic binder and the organic binder is attached to the surface of the inorganic fiber 20.

[0113] Whether the coating layer and the particles contain a mixture of the inorganic binder and the organic binder can be confirmed by a combination of field observation under an electronic microscope and elemental analysis.

[0114] FIG. 6 is another example of an enlarged electron microscope image of the mat material of the present invention.

[0115] As shown in FIG. 6, the surface of the inorganic fiber 20 is partially covered with the coating layer 30 containing a mixture of the inorganic binder and the organic binder. The coating layer 30 is formed from a continuous flaky mixture of the inorganic binder and the organic binder. The particulate mixture 40 of the inorganic binder and the organic binder is attached to the surface of the inorganic fiber 20.

[0116] The coating layer may or may not have a uniform thickness.

[0117] The shape of the coating layer having a non-uniform thickness is also referred to as "stepped shape".

[0118] That the coating layer has a stepped shape means that there are irregularities on the surface of the coating layer, so that the frictional resistance between the inorganic fibers can be further increased.

[0119] Whether the coating layer has irregularities on the surface, i.e., whether the coating layer has a stepped shape, can be determined by enlarging the surface of each inorganic fiber to a magnification of 3000 times using a scanning electronic microscope and checking for the presence or absence of irregularities on the surface of the coating layer.

[0120] FIG. 7 is still another example of an enlarged electron microscope image of the mat material of the present invention.

[0121] As shown in FIG. 7, the surface of the inorganic fiber 20 is partially covered with the coating layer 30 containing a mixture of the inorganic binder and the organic binder. The coating layer 30 has a stepped shape with a non-uniform thickness.

[0122] The particulate mixture 40 of the inorganic binder and the organic binder is attached to the surface of the inorganic fiber 20.

[0123] Preferably, particles containing a mixture of the inorganic binder and the organic binder are attached to the surface of the coating layer.

[0124] When the particles containing a mixture of the inorganic binder and the organic binder are attached to the surface of the coating layer, the frictional resistance between the inorganic fibers can be further increased than when no such particles are attached to the coating layer.

[0125] FIG. 8 is still another example of an enlarged electron microscope image of the mat material of the present invention.

[0126] As shown in FIG. 8, the surface of the inorganic fiber 20 is partially covered with the coating layer 30 containing a mixture of the inorganic binder and the organic binder. The coating layer 30 is formed from a continuous flaky mixture of the inorganic binder and the organic binder. The coating layer 30 has a stepped shape with a non-uniform thickness. The particulate mixture 40 of the inorganic binder and the organic binder is attached to the surface of the coating layer 30.

[0127] Preferably, the mat material further contains a polymeric dispersant.

[0128] When the mat material further contains a polymeric dispersant, the organic binder and the inorganic binder can be easily attached in a dispersed state to the surface of each inorganic fiber.

[0129] Preferably, the amount of the polymeric dispersant is 50 to 1000 ppm relative to the weight of the inorganic fibers.

[0130] In the mat material, preferably, aggregates of the inorganic binder and the organic binder are attached to the surface of each inorganic fiber.

[0131] The aggregates of the inorganic binder and the organic binder can form irregularities on the surface of each inorganic fiber, which can increase the friction between the inorganic fibers and improve the holding power.

[0132] The mat material may further contain a flocculant.

[0133] When the mat material further contains a flocculant, the organic binder and the inorganic binder can be easily attached in an aggregated state to the surface of each inorganic fiber.

[0134] Whether the inorganic binder and the organic binder attached to the surface of each inorganic fiber are either dispersed or aggregated can be checked by observing the surface of each inorganic fiber by SEM-EDX or the like.

[0135] The mat material of the present invention has a shear modulus of 0.20 or more.

[0136] At a shear modulus of 0.20 or more, the mat material is less likely to shear when an exhaust gas treatment unit is pressed into a metal casing using the mat material of the present invention.

[0137] The shear modulus is determined by dividing the shear failure load by the reduced surface pressure.

[0138] The shear failure load can be measured by a shear failure load testing device shown in FIG. 9.

[0139] FIG. 9 is a conceptual schematic view of a shear failure load testing device.

[0140] A shear failure load testing device 70 shown in FIG. 9 includes specimens 1a and 1b, one on each side of a stainless-steel plate 73. The specimens 1a and 1b are sandwiched between a left jig 71 and a right jig 72. Many protruding members 74 are disposed on a specimen-contacting surface of each of the left jig 71 and the right jig 72 and specimen-contacting surfaces of the stainless-steel plate 73.

[0141] The specimens 1a and 1b are pierced by the protruding members 74 and are thereby fixed to the left jig 71, the right jig 72, and the stainless-steel plate 73.

[0142] In this state, the specimens are compressed to a bulk density (GBD) of 0.3 g/cm³.

[0143] Next, the stainless-steel plate 73 is moved at a rate of 5 mm/min toward the direction (upward) indicated by an arrow in FIG. 9. Yet, the stainless-steel plate 73 cannot slip out of the specimens 1a and 1b because the stainless-steel plate 73 is fixed to the specimens 1a and 1b with the protruding members 74. Thus, a shear failure occurs in the specimens 1a and 1b when a shear force equal to or greater than the shear failure load of the specimen is applied to the specimens 1a and 1b.

[0144] The shear force applied to the stainless-steel plate when a shear failure occurred in the specimens is determined.

[0145] The resulting shear force is divided by the area of the specimens, whereby the shear failure load (kPa) can be determined. The shear failure load may be measured using specimens obtained by cutting out portions of the mat material.

[0146] The reduced surface pressure can be measured by the following procedure.

[0147] First, the mat material is compressed to a bulk density of 0.3 g/cm^3 at room temperature and kept in the state for 20 minutes. Then, the load is measured.

[0148] The resulting load is divided by the area of the specimen, whereby the reduced surface pressure (kPa) can be determined. The reduced surface pressure may be measured using specimen obtained by cutting out portions of the mat material.

[0149] The post-firing surface pressure of the mat material is 50 kPa or more.

[0150] The post-firing surface pressure of the mat material can be measured by the following method using a hot surface pressure measurement device including a heater in a plate that compresses the mat material as a specimen.

[0151] First, a specimen (mat material) is compressed to a bulk density of 0.3 g/cm^3 at room temperature and kept in the state for 10 minutes. Subsequently, while the specimen is being compressed, the temperature is raised to 900°C on one side and 650°C on the other side at a heating rate of 45°C . Meanwhile, the compression is released to a bulk density of 0.27 g/cm^3 , and the state is kept for five minutes. Subsequently, the plate that compresses the mat material is moved at a rate of 1 inch (25.4 mm)/min to compress the mat material to a bulk density of 0.3 g/cm^3 . A cycle of release of compression to a bulk density of 0.27 g/cm^3 and compression to a bulk density 0.3 g/cm^3 is repeated 1000 times. Subsequently, the load at a bulk density of 0.27 g/cm^3 is measured. The resulting load is divided by the area of the specimen to determine the surface pressure (kPa) as the post-firing surface pressure.

[0152] The mat material may further include a protective sheet on at least one surface thereof.

[0153] The protective sheet is placed on at least one surface of the mat.

[0154] The protective sheet, when further placed on the surface of the mat, prevents or reduces displacement and/or dense wrinkles of the mat material and generation of a gap in a fitting portion when the mat material is wound around an exhaust gas treatment unit.

[0155] The protective sheet may be made of any material, but, for example, a flexible resin such as polypropylene is preferred.

[0156] The protective sheet may be a non-woven fabric made of flexible resin fibers, for example.

[0157] The protective sheet may be made of a combination of two or more different materials.

[0158] The two or more materials may make up the same non-woven fabric, or two or more different non-woven fabrics may be stacked together to form the protective sheet.

[0159] The protective sheet thickness is not limited but is preferably $1 \text{ }\mu\text{m}$ to 1 mm.

[0160] At a protective sheet thickness of less than $1 \text{ }\mu\text{m}$, the effect of reducing deformation of the mat may not be sufficient.

[0161] At a protective sheet thickness of more than 1 mm, the ease of handling may be reduced.

[0162] The ratio of the protective sheet thickness to the mat thickness is not limited but is preferably in the range of about 1:10 to about 1:1000, more preferably in the range of about 1:50 to about 1:200.

[0163] The protective sheet may be adhered to the mat by any method, such as one in which hot melt powder is placed between the protective sheet and the mat and is melted by heat.

[0164] Preferably, the surface on which the protective sheet is disposed is the surface that faces the outside when the mat material is wound around an exhaust gas treatment unit.

[0165] The protective sheet may include a slit formed therein.

[0166] The slit may be oriented in any direction. It may be oriented in the longitudinal or width direction of the mat material.

[0167] FIG. 10 is a schematic perspective view of another example of the mat material of the present invention.

[0168] A mat material 2 shown in FIG. 10 includes the mat 10 and a protective sheet 50 on one surface of the mat 10.

[0169] The protective sheet may be disposed only on one surface of the mat or on each surface of the mat.

[Exhaust Gas Conversion Apparatus]

[0170] An exhaust gas conversion apparatus of the present invention includes an exhaust gas treatment unit, a metal casing for housing the exhaust gas treatment unit, and a mat material arranged between the exhaust gas treatment unit and the metal casing for holding the exhaust gas treatment unit, wherein the mat material is the mat material of the present invention.

[0171] The exhaust gas conversion apparatus of the present invention can stably hold the exhaust gas treatment unit owing to the arrangement of the mat material of the present invention between the exhaust gas treatment unit and the metal casing.

[0172] FIG. 11 is a schematic cross-sectional view of an example of the exhaust gas conversion apparatus of the present invention.

[0173] As shown in FIG. 11, an exhaust gas conversion apparatus 100 includes a metal casing 120, an exhaust gas treatment unit 130 housed in the metal casing 120, and the mat material 1 arranged between the exhaust gas treatment

unit 130 and the metal casing 120. The mat material 1 is the mat material of the present invention.

[0174] The exhaust gas treatment unit 130 has a pillar shape in which many cells 131 are arranged in parallel in a longitudinal direction with cell walls 132 between the cells. If necessary, an inlet tube for introducing exhaust gas discharged from an internal combustion engine and an outlet tube for discharging the exhaust gas that has passed through the exhaust gas conversion apparatus are connected to ends of the casing 120.

[0175] In the exhaust gas conversion apparatus 100 shown in FIG. 11, although the exhaust gas treatment unit 130 is an exhaust gas filter (honeycomb filter) in which one of the ends of each cell is plugged with a plug 133, the exhaust gas treatment unit 130 may be a catalyst carrier not plugged with plugs at either end surface.

[0176] As shown in FIG. 11, the exhaust gas that was discharged from the internal combustion engine and that flowed into the exhaust gas conversion apparatus 100 (in FIG. 11, the exhaust gas is denoted by G, and the exhaust gas flow is indicated by arrows) flows into one of the cells 131 open at an exhaust gas inlet-side end 130a of the exhaust gas treatment unit (honeycomb filter) 130, and then passes through the cell wall 132 between the cells 131. At this point, PM in the exhaust gas is collected by the cell wall 132, and the exhaust gas is converted. The converted exhaust gas flows out from another cell 131 open at an exhaust gas discharge-side end 130b and is discharged to the outside.

[Method for Producing Mat Material]

[0177] A method for producing a mat material according to the first embodiment of the present invention includes an attaching step of attaching an inorganic binder to an inorganic fiber mass, the inorganic fiber mass including inorganic fibers and multiple entanglement points formed by needling at least one of a front surface or a back surface of the inorganic fiber mass, wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, and at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged in a $25 \text{ mm} \times 25 \text{ mm}$ region.

[0178] The inorganic fiber mass for use in the first embodiment of the method for producing a mat material of the present invention can be obtained by, for example, a spinning step of spinning a spinning mixture containing at least an inorganic compound and an organic polymer to produce an inorganic fiber precursor; a compressing step of compressing the inorganic fiber precursor to produce a sheet; a needle-punching step of needle-punching at least one surface of the sheet to produce a needle-punched article; and a firing step of firing the needle-punched article.

[0179] Hereinafter, specific examples of the spinning step, the compressing step, the needle-punching step, and the firing step are described.

[Spinning Step]

[0180] In the spinning step, the spinning mixture containing at least an inorganic compound and an organic polymer is spun to produce an inorganic fiber precursor.

[0181] In the spinning step, for example, a spinning mixture containing an aqueous solution of basic aluminum chloride, silica sol, and the like as raw materials is spun by blowing, whereby an inorganic fiber precursor having an average fiber diameter of 3 to 10 μm is produced.

[Compressing Step]

[0182] In the compressing step, the inorganic fiber precursor obtained in the spinning step is compressed to produce a continuous sheet having a predetermined size.

[Needle-Punching Step]

[0183] In the needle-punching step, at least one surface of the sheet obtained in the compressing step is needle-punched to produce a needle-punched article.

[0184] In the needle-punching step, preferably, the needle arrangement density is set to 0.5 needles/cm^2 or more and less than 18 needles/cm^2 .

[0185] In the needle-punching step, the positions where the needles are arranged correspond to the entanglement points in the mat material. Thus, when the needle arrangement density is set to 0.5 needles/cm^2 or more and less than 18 needles/cm^2 , a mat material in which the density ρ of the entanglement points is in the range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$ can be obtained by single needle-punching.

[0186] The needle arrangement density is not limited to the above range when the same sheet is needle-punched several times.

[0187] By intentionally unevenly arranging the needles in the needle-punching step, the arrangement of the entanglement points to be formed on the needle-punched article can be varied in density so as to form a $4 \text{ mm} \times 4 \text{ mm}$ region without

the entanglement points (first region) and/or a 3 mm × 8 mm region without the entanglement points in a 25 mm × 25 mm (second region) in a 25 mm × 25 mm region, while the density ρ of the entanglement points is in the range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$.

[0188] Examples of methods for intentionally unevenly arranging the entanglement points include a method that includes needle-punching such that the entanglement points are evenly arranged and then additionally needle-punching some portions. Other examples include a method that includes performing needle-punching several times while moving the inorganic fiber precursor, and a method that include performing needle-punching using a needle board on which needles are not arranged at equal intervals.

[0189] In the needle-punching step, the needles may or may not penetrate in the thickness direction of the sheet.

[Firing Step]

[0190] In the firing step, the needle-punched article is fired to obtain an inorganic fiber mass including inorganic fibers.

[0191] The firing temperature of the needle-punched article is not limited but is preferably 1000°C to 1600°C.

[Attaching Step]

[0192] In the attaching step, an inorganic binder is attached to the inorganic fiber mass.

[0193] Examples of methods for attaching an inorganic binder to the inorganic fiber mass include a method that includes bringing an inorganic binder mixture of a solvent and an inorganic binder into contact with the inorganic fiber mass and then drying the inorganic binder mixture.

[0194] Examples of methods for bringing an inorganic binder mixture into contact with the inorganic fiber mass include a method that includes immersing the inorganic fiber mass in an inorganic binder mixture and a method that includes dropping an inorganic binder mixture onto the inorganic fiber mass by curtain coating or the like.

[0195] A mat constituting the mat material can be obtained by attaching an inorganic binder to the inorganic fiber mass.

[0196] Preferably, the amount of the inorganic binder in the inorganic binder mixture is 0.05 wt% or more and 5 wt% or less.

[0197] The inorganic binder mixture may contain a polymeric dispersant.

[0198] When the inorganic binder mixture contains a polymeric dispersant, the inorganic binder is in a dispersed state in the inorganic binder mixture. When the inorganic binder mixture in such a state is brought into contact with the inorganic fiber mass, the inorganic binder can be attached in a dispersed state to the surface of each inorganic fiber.

[0199] Examples of the polymeric dispersant include synthetic hydrophilic polymeric substances including anionic polymeric dispersants such as polycarboxylic acid and/or a salt thereof, a naphthalenesulfonate formalin condensate and/or a salt thereof, polyacrylic acid and/or a salt thereof, polymethacrylic acid and/or a salt thereof, and polyvinyl sulfonic acid and/or a salt thereof, and nonionic polymeric dispersants such as polyvinyl alcohol, polyvinylpyrrolidone, and polyethylene glycol; natural hydrophilic polymers such as gelatin, casein, and water-soluble starch; and semi-synthetic hydrophilic polymeric substances such as carboxymethylcellulose.

[0200] Of these, synthetic hydrophilic polymeric substances are preferred, and anionic polymeric dispersants are more preferred.

[0201] One of these polymeric dispersants may be used alone or two or more of these may be used in combination. A polymeric dispersant having both a structure that exhibits properties as an anionic polymeric dispersant and a structure that exhibits properties as a nonionic polymeric dispersant may also be used.

[0202] The inorganic binder mixture may contain a flocculant.

[0203] When the inorganic binder mixture contains a flocculant, the inorganic binder is in an aggregated state in the inorganic binder mixture. When the inorganic binder mixture in such a state is brought into contact with the inorganic fiber mass, the inorganic binder can be attached in an aggregated state to the surface of each inorganic fiber.

[0204] A method for producing a mat material according to the second embodiment of the present invention includes an attaching step of attaching both an inorganic binder and an organic binder to an inorganic fiber mass, the inorganic fiber mass including inorganic fibers and multiple entanglement points formed by needling at least one of a front surface or a back surface of the inorganic fiber mass, wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, and at least one of a 4 mm × 4 mm first region without the entanglement points or a 3 mm × 8 mm second region without the entanglement points is arranged in a 25 mm × 25 mm region.

[0205] The second embodiment of the method for producing a mat material of the present invention is the same as the first embodiment of the method for producing a mat material of the present invention, except that in the attaching step, both an inorganic binder and an organic binder are attached to the inorganic fiber mass.

[0206] Thus, the attaching step of attaching both an inorganic binder and an organic binder to the inorganic fiber mass is described below.

[0207] Examples of methods for attaching both an inorganic binder and an organic binder to the inorganic fiber mass

include a method that includes bringing a binder mixture of a solvent, an inorganic binder, and an organic binder into contact with the inorganic fiber mass and then drying the binder mixture.

[0208] Preferably, the amount of the inorganic binder in the binder mixture is 0.05 wt% or more and 5 wt% or less.

[0209] Preferably, the amount of the organic binder in the binder mixture is 0.05 wt% or more and 5 wt% or less.

[0210] The binder mixture may contain a polymeric dispersant.

[0211] When the binder mixture contains a polymeric dispersant, the inorganic binder and the organic binder are in a dispersed state in the binder mixture. In other words, the binder mixture is a dispersion in which the inorganic binder and the organic binder are dispersed in a dispersion medium. When the binder mixture (dispersion) in such a state is brought into contact with the inorganic fiber mass, the inorganic binder and the organic binder can be attached in a dispersed state to the surface of each inorganic fiber.

[0212] The binder mixture may contain a flocculant.

[0213] When the mixture contains a flocculant, the inorganic binder and the organic binder are in an aggregated state in the mixture. In other words, the binder mixture is an aggregated dispersion in which the aggregates of the inorganic binder and the organic binder are dispersed in a dispersion medium. When the binder mixture (aggregated dispersion) in such a state is brought into contact with the inorganic fiber mass, the inorganic binder and the organic binder can be attached in an aggregated state to the surface of each inorganic fiber.

[0214] The attaching of an inorganic binder and the attaching of an organic binder may be separately performed.

[0215] Examples of methods for separately performing the attaching of an inorganic binder and the attaching of an organic binder include a method that includes bringing an inorganic binder mixture containing an inorganic binder into contact with the inorganic fiber mass to attach the inorganic binder thereto and then further bringing an organic binder mixture containing an organic binder into contact with the inorganic fiber mass to attach the organic binder thereto. The inorganic binder and the organic binder may be attached in any order. The inorganic binder may be attached first, or the organic binder may be attached first.

EXAMPLES

[0216] The following describes Examples that more specifically disclose the present invention. The present invention is not limited to these Examples.

(Example 1)

(a) Spinning Step

[0217] To an aqueous solution of basic aluminum chloride prepared to have an Al content of 70 g/L and an Al:Cl ratio of 1:1.8 (atomic ratio) was added silica sol to give a compositional ratio of $\text{Al}_2\text{O}_3:\text{SiO}_2$ of 72:28 (weight ratio) in inorganic fibers after firing. Then, an organic polymer (polyvinyl alcohol) was further added thereto in an appropriate amount, whereby a mixture was prepared.

[0218] The resulting mixture was concentrated to obtain a spinning mixture, and the spinning mixture was spun by blowing, whereby an inorganic fiber precursor having an average fiber diameter of 5.1 μm was produced.

(b) Compressing Step

[0219] The inorganic fiber precursor obtained in the spinning step (a) was compressed to produce a continuous sheet.

(c) Needle-Punching Step

[0220] The sheet obtained in the compressing step (b) was needle-punched several times using a needle board with needles at a predetermined density, whereby a needle-punched article was produced.

[0221] First, a needle board with needles attached thereto at a predetermined density was provided. Next, this needle board was set above one surface of the sheet. Then, the needle board was moved up and down once in the thickness direction of the sheet to perform needle-punching. This needle-punching was repeated several times while the inorganic fiber precursor was moved, whereby a needle-punched article was produced. At this point, the needles were allowed to penetrate the sheet until barbs formed on the tips of the needles had completely penetrated the sheet from one surface to the other surface.

(d) Firing Step

[0222] The needle-punched article obtained in the needle-punching step (c) was continuously fired at a maximum

temperature of 1250°C, whereby a fired sheet containing inorganic fibers including alumina and silica at a ratio of parts by weight of 72:28 was produced. The average fiber diameter of the inorganic fibers was 5.1 μm. The minimum fiber diameter was 3.2 μm. The thus-obtained fired sheet had a bulk density of 0.15 g/cm³ and a basis weight of 1400 g/m². The density ρ of the entanglement points was 9 pcs/cm². Ten first regions (4 mm × 4 mm regions without the entanglement points) and four second regions (3 mm × 8 mm regions without the entanglement points) were arranged in a 25 mm × 25 mm region.

[0223] The fired needle-punched article was cut to produce an inorganic fiber mass.

(e) Attaching Step

(e-1) Organic Binder Mixture Preparing Step

[0224] Acrylate latex as an organic binder was diluted with water, whereby an organic binder mixture having a solids concentration of 2.0 wt% was prepared.

(e-2) Inorganic Binder Mixture Preparing Step

[0225] Alumina as the inorganic binder was diluted with water and blended with a polymeric dispersant, followed by sufficient stirring. Thereby, an inorganic binder mixture was prepared in which the solids concentration of the inorganic particles was 2.0 wt% and the concentration of the polymeric dispersant was 1000 ppm.

(e-3) Binder Mixture Preparing Step

[0226] The organic binder mixture obtained in the organic binder mixture preparing step (e-1) was added to the inorganic binder mixture obtained in the inorganic binder mixture preparing step (e-2) to give a weight ratio of 1:1, followed by sufficient stirring. Thereby, a binder mixture was prepared in which the solids concentration of the organic binder was 1.0 wt%, the solids concentration of the inorganic binder was 1.0 wt%, and the concentration of the polymeric dispersant was 500 ppm.

(e-4) Contacting Step

[0227] The binder mixture obtained in the binder mixture preparing step (e-3) was brought into contact by curtain coating with the inorganic fiber mass obtained in the firing step (d).

(e-5) Dehydrating Step

[0228] The inorganic fiber mass to which the binder mixture was added, which was obtained in the contacting step (e-4) above, was sucked and dehydrated by a dehydrator such that the amount of the binder mixture added was adjusted to 100 parts by weight relative to 100 parts by weight of the inorganic fibers, whereby a mat was obtained.

(e-6) Drying Step

[0229] The mat that underwent the dehydrating step (e-5) was dried in a dryer, whereby a mat material according to Example 1 was produced.

(Example 2)

[0230] A mat material according to Example 2 was produced by the same procedure as in Example 1, except that the solids concentration of the organic binder mixture prepared in the organic binder mixture preparing step (e-1) was changed to 0.2 wt%.

(Example 3)

[0231] A mat material according to Example 3 was produced by the same procedure as in Example 1, except that the organic binder mixture preparing step (e-1) was not performed and that in the binder mixture preparing step (e-3), the inorganic binder mixture obtained in the inorganic binder mixture preparing step (e-2) was mixed with water at a weight ratio of 1:1 and stirred to adjust the solids concentration of the inorganic particles to 1.0 wt%.

(Comparative Example 1)

[0232] A mat material according to Comparative Example 1 was produced by the same procedure as in Example 1, except that the inorganic binder mixture preparing step (e-2) was not performed and that in the binder mixture preparing step (e-3), the organic binder mixture obtained in the organic binder mixture preparing step (e-1) was mixed with water containing a polymeric dispersant at a concentration of 500 ppm at a weight ratio of 1:1 and stirred to adjust the solids concentration of the organic binder to 1.0 wt%.

(Post-Firing Surface Pressure Measurement)

[0233] The post-firing surface pressure was measured for each of the mat materials of Examples 1 to 3 and Comparative Example 1. The post-firing surface pressure was measured by the method described in the description of the embodiments of the present invention. Table 1 shows the results.

(Shear Modulus Measurement)

[0234] The shear failure load and the reduced surface pressure were measured for each of the mat materials of Examples and Comparative Examples, and the shear modulus of each mat material was determined. The shear failure strength and the reduced surface pressure were measured by the methods described in the description of the embodiments of the present invention. Table 1 shows the results.

[Table 1]

	Density ρ of entanglement points [pcs/cm ²]	Weight ratio of organic binder [wt%]	Weight ratio of inorganic binder [wt%]	Number of first regions in 25 mm $\times$ 25 mm region	Number of second regions in 25 mm $\times$ 25 mm region	Post-firing surface pressure [kPa]	Shear modulus
Example 1	9.0	1.0	1.0	10	4	51	0.25
Example 2	9.0	0.1	1.0	10	4	53	0.49
Example 3	9.0	0	1.0	10	4	57	0.65
Comparative Example 1	9.0	1.0	0	10	4	48	0.19

[0235] As shown in Table 1, the mat material of the present invention was found to have a high shear modulus of 0.20 or more.

[0236] The shear modulus of the mat material according to Example 1 was about 132% of the shear modulus of the mat material according to Comparative Example 1, which was a mat material with same conditions except that no inorganic binder was contained.

[0237] In the mat materials according to Examples 1 to 3, the shear modulus increased as the weight ratio of the organic binder decreased. The shear modulus was the highest in Example 3 in which no organic binder was contained. The mat material according to Example 1 also had a shear modulus of 0.20 or more and a post-firing surface pressure of 50 kPa or more. Thus, it is considered that the effect of preventing fiber scattering and the high holding power owing to the organic binder can be both achieved.

(Examples 4 and 5, Comparative Examples 2 and 3)

[0238] Mat materials according to Examples 4 and 5 and Comparative Examples 2 and 3 were produced by the same procedure as in Example 1, except that the type of the needle board used in the needle-punching step (c) and the number of times of needling were changed to change the density of the entanglement points and the number of the first regions and the second regions in a 25 mm $\times$ 25 mm region as shown in Table 2. Then, the post-firing surface pressure and the shear modulus were measured. Table 2 shows the results.

(Comparative Example 4)

[0239] A mat material according to Comparative Example 4 was produced by the same procedure as in Comparative

Example 1, except that the type of the needle board used in the needle-punching step (c) and the number of times of needling were changed to change the density of the entanglement points and the number of the first regions and the second regions in a 25 mm × 25 mm region as shown in Table 2. Then, the post-firing surface pressure and the shear modulus were measured. Table 2 shows the results.

[Table 2]

	Density ρ of entanglement prints [pcs/cm ²]	Weight ratio of organic binder [wt%]	Weight ratio of inorganic binder [wt%]	Number of first regions in 25 mm × 25 mm region	Number of second regions in 25 mm × 25 mm region	Post-firing surface pressure [kPa]	Shear modulus
Example 4	9.9	1.0	1.0	10	4	51	0.25
Example 5	5.6	1.0	1.0	4	4	60	0.33
Comparative Example 2	20.0	1.0	1.0	0	0	44	0.25
Comparative Example 3	9.1	1.0	1.0	0	0	44	0.33
Comparative Example 4	20.0	1.0	0.0	0	0	22	0.23

[0240] As shown in Table 2, the post-firing surface pressure was higher in the mat materials according to Examples 4 and 5 in which the first regions and/or the second regions were arranged in the 25 mm × 25 mm region than in the mat materials according to Comparative Examples 2 to 4 in which neither the first regions nor the second regions were arranged in the 25 mm × 25 mm region.

REFERENCE SIGNS LIST

[0241]

- 1, 2 mat material
- 1a, 1b specimen
- 10 mat
- 11 protrusion
- 12 recess
- 15 entanglement point
- 17 first region
- 18 second region
- 20 inorganic fibers
- 30 coating layer
- 40 particulate mixture
- 50 protective sheet
- 70 shear failure load testing device
- 71 left jig
- 72 right jig
- 73 stainless-steel plate
- 74 protruding member
- 100 exhaust gas conversion apparatus
- 120 metal casing
- 130 exhaust gas treatment unit
- 130a exhaust gas inlet-side end
- 130b exhaust gas discharge-side end
- 131 cell
- 132 cell wall
- 133 plug

Claims

1. A mat material comprising:

inorganic fibers; and
multiple entanglement points formed by needling at least one of a front surface or a back surface of the mat material,
wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged in a $25 \text{ mm} \times 25 \text{ mm}$ region, and
the mat material contains an inorganic binder and has a shear modulus of 0.20 or more and a post-firing surface pressure of 50 kPa or more.

2. The mat material according to claim 1,
wherein a weight ratio of the inorganic binder to the mat material, i.e., weight of inorganic binder/weight of mat material, is more than 0 wt% and 10 wt% or less.

3. The mat material according to claim 1 or 2, further comprising an organic binder.

4. The mat material according to claim 3,
wherein a weight ratio of the organic binder to the mat material, i.e., weight of organic binder/weight of mat material, is more than 0 wt% and 10 wt% or less.

5. The mat material according to claim 3 or 4,
wherein the inorganic binder and the organic binder are attached in an individually dispersed state to a surface of each inorganic fiber.

6. The mat material according to any one of claims 1 to 5, further comprising a polymeric dispersant.

7. The mat material according to claim 3 or 4,
wherein aggregates of the inorganic binder and the organic binder are attached to a surface of each inorganic fiber.

8. The mat material according to claim 7,
wherein the surface of each inorganic fiber is at least partially covered with a coating layer containing a mixture of the inorganic binder and the organic binder.

9. The mat material according to claim 8,
wherein the coating layer is formed from a continuous flaky mixture of the inorganic binder and the organic binder.

10. The mat material according to claim 8 or 9,
wherein the coating layer has a stepped shape.

11. The mat material according to any one of claims 8 to 10,
wherein a particulate mixture of the inorganic binder and the organic binder is attached to a surface of the coating layer.

12. The mat material according to any one of claims 1 to 11,
wherein the mat material has a shear modulus that is 105% or more of a shear modulus of a mat material with same conditions except that no inorganic binder is contained.

13. The mat material according to any one of claims 1 to 12,
wherein at least one of the first region or the second region is arranged in a plural number in the $25 \text{ mm} \times 25 \text{ mm}$ region.

14. The mat material according to any one of claims 1 to 13,
wherein the mat material is for use in an exhaust gas conversion apparatus.

15. The mat material according to any one of claims 1 to 14, further comprising a protective sheet on at least one of the front surface or the back surface.

16. An exhaust gas conversion apparatus comprising:

an exhaust gas treatment unit;
a metal casing for housing the exhaust gas treatment unit; and
a mat material arranged between the exhaust gas treatment unit and the metal casing for holding the exhaust gas treatment unit,
wherein the mat material is the mat material according to any one of claims 1 to 15.

17. A method for producing a mat material, comprising

an attaching step of attaching an inorganic binder to an inorganic fiber mass, the inorganic fiber mass including inorganic fibers and multiple entanglement points formed by needling at least one of a front surface or a back surface of the inorganic fiber mass, wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, and at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged in a $25 \text{ mm} \times 25 \text{ mm}$ region.

18. A method for producing a mat material, comprising

an attaching step of attaching both an inorganic binder and an organic binder to an inorganic fiber mass, the inorganic fiber mass including inorganic fibers and multiple entanglement points formed by needling at least one of a front surface or a back surface of the inorganic fiber mass, wherein a density ρ of the entanglement points is in a range of $0.5 \text{ pcs/cm}^2 \leq \rho < 18 \text{ pcs/cm}^2$, and at least one of a $4 \text{ mm} \times 4 \text{ mm}$ first region without the entanglement points or a $3 \text{ mm} \times 8 \text{ mm}$ second region without the entanglement points is arranged in a $25 \text{ mm} \times 25 \text{ mm}$ region.

19. The method for producing a mat material according to claim 18,

wherein in the attaching step, a dispersion in which the inorganic binder and the organic binder are dispersed in a dispersion medium is attached to the inorganic fiber mass.

20. The method for producing a mat material according to claim 18,

wherein in the attaching step, an aggregated dispersion in which the inorganic binder and the organic binder are aggregated is attached to the inorganic fiber mass.

FIG. 1

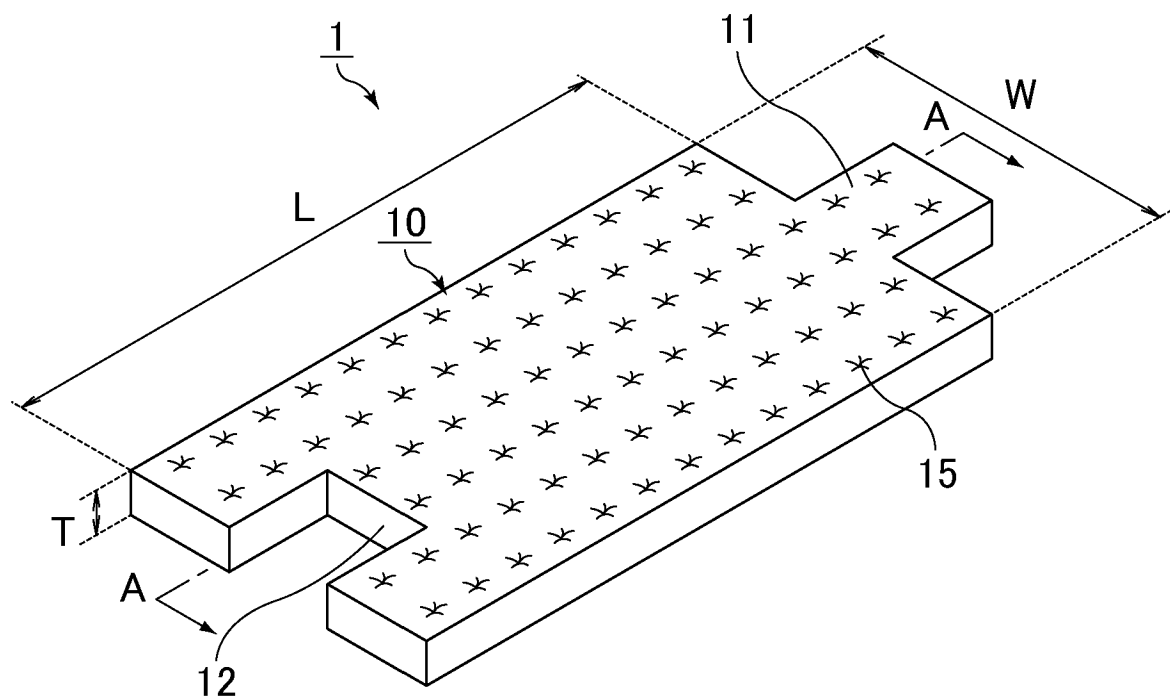
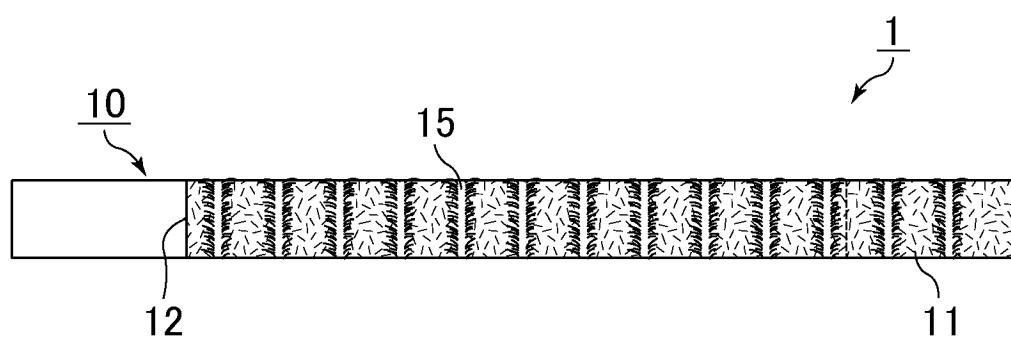


FIG. 2



Cross-sectional view taken along line A-A

FIG. 3

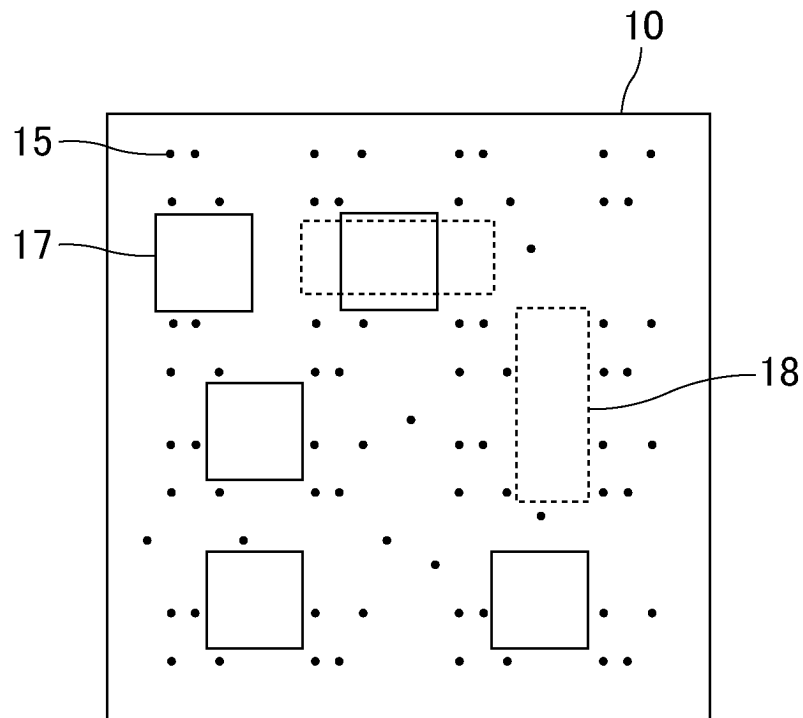


FIG. 4

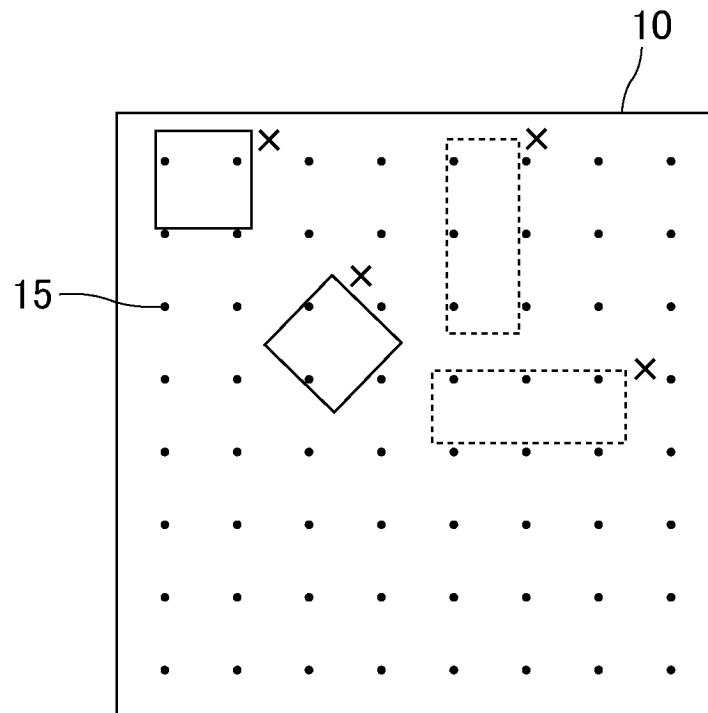


FIG. 5

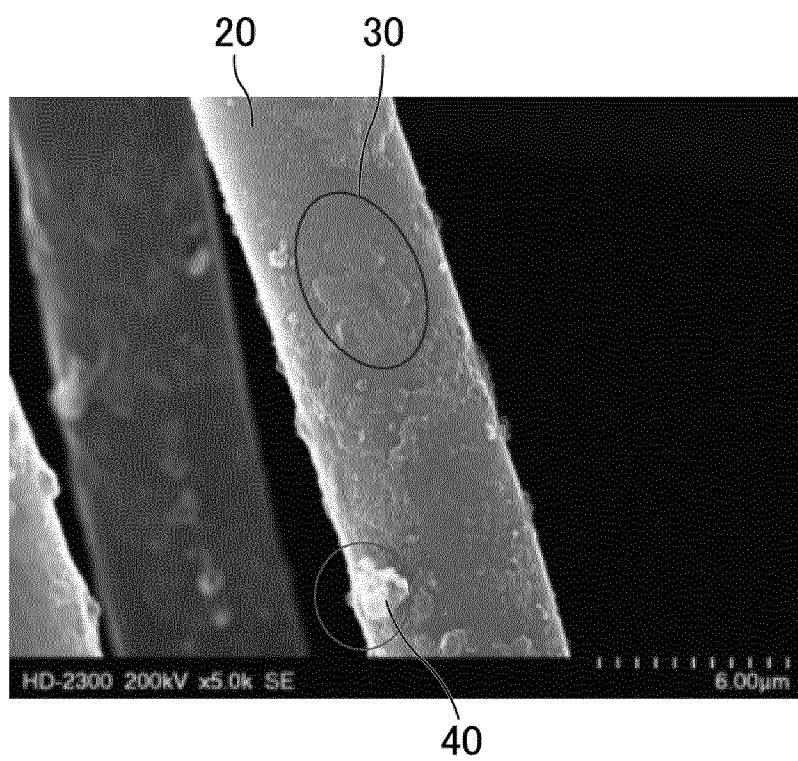


FIG. 6

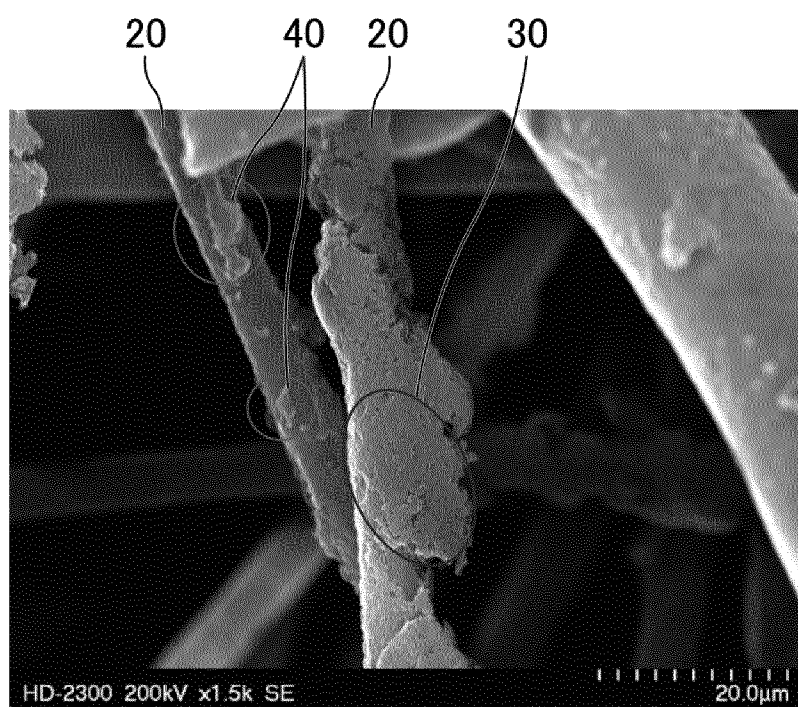


FIG. 7

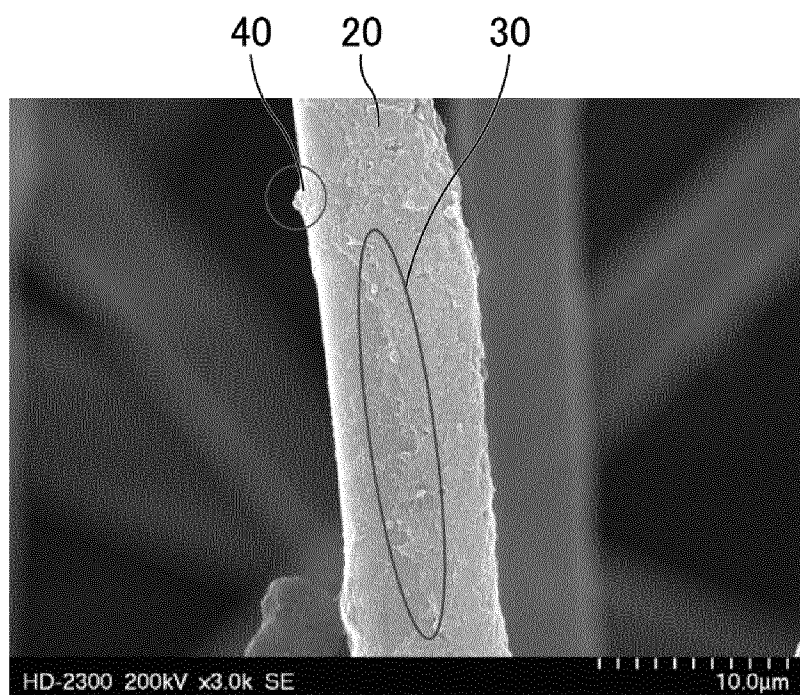


FIG. 8

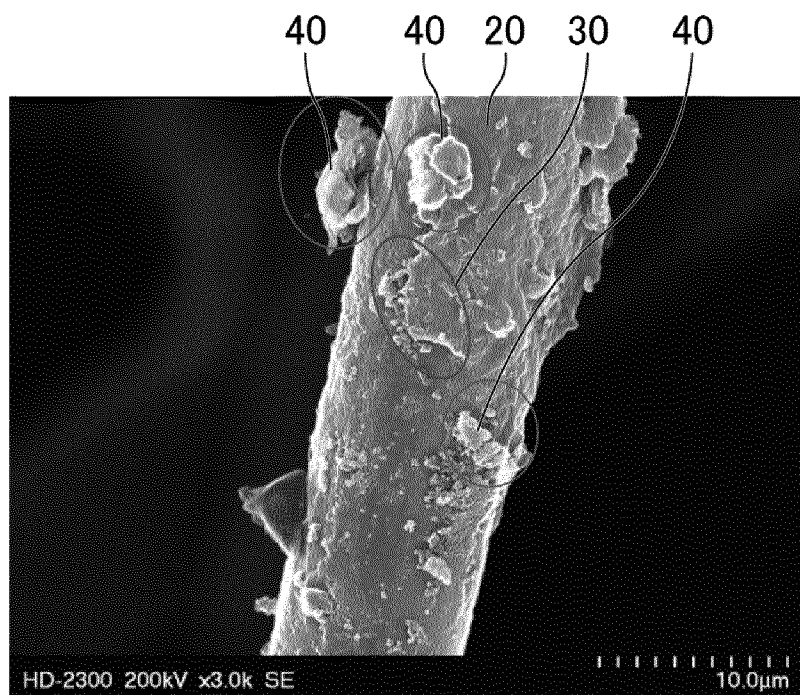


FIG. 9

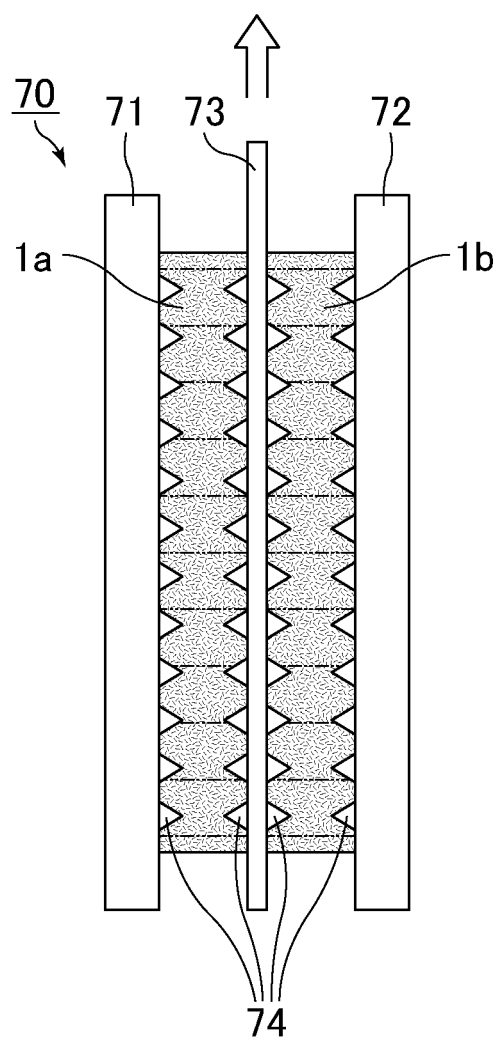


FIG. 10

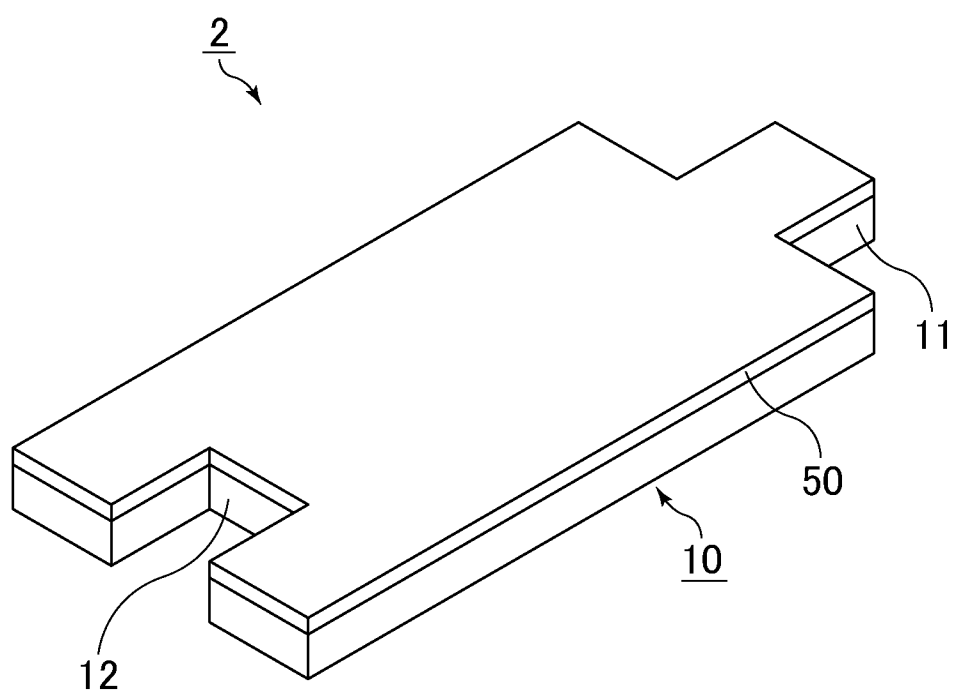
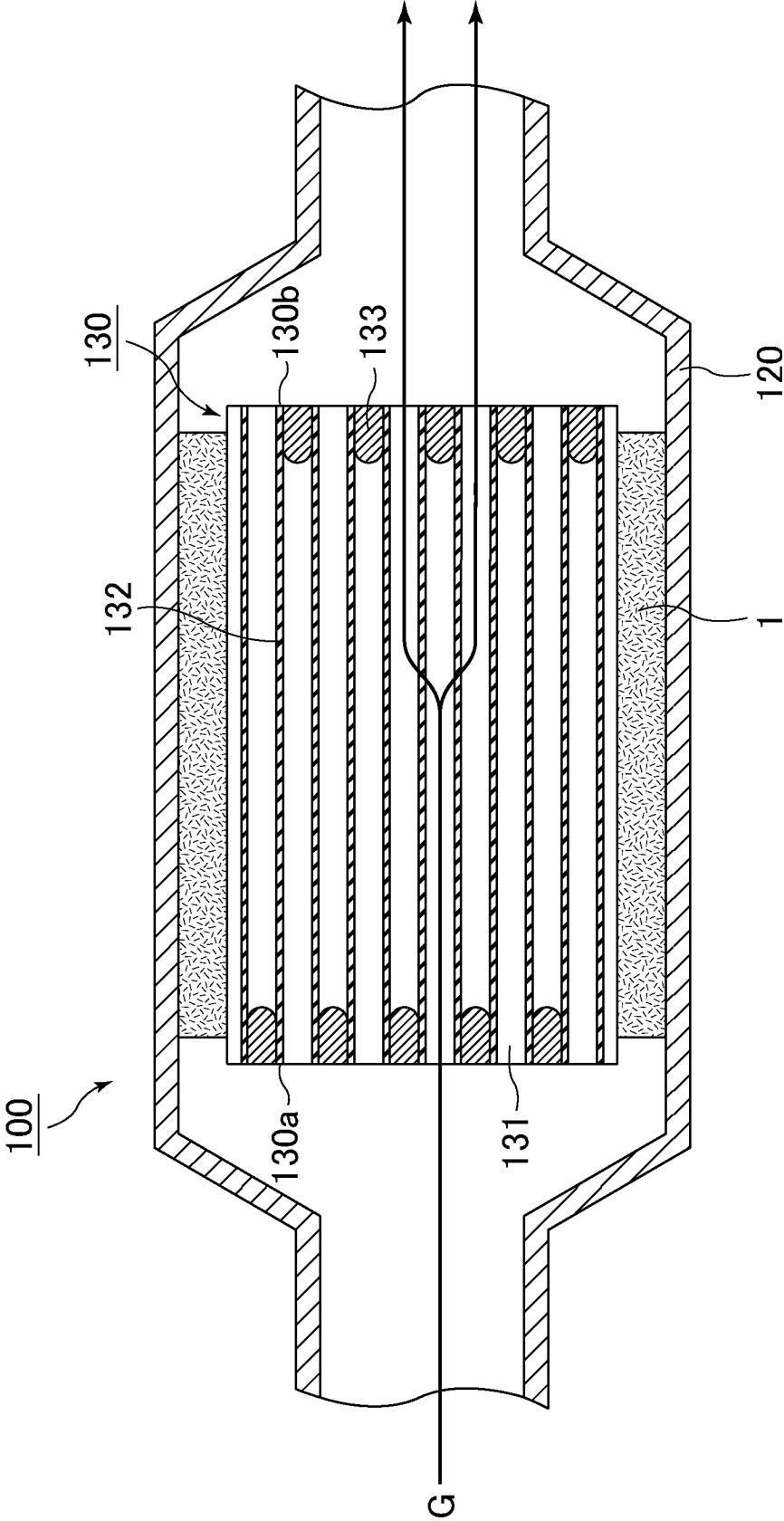


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/006346

A. CLASSIFICATION OF SUBJECT MATTER

D04H 1/488(2012.01)i; **B01D 46/00**(2022.01)i; **B01D 53/94**(2006.01)i; **D06M 11/45**(2006.01)i; **D06M 11/79**(2006.01)i; **D06M 15/263**(2006.01)i; **F01N 3/28**(2006.01)i
 FI: D04H1/488; B01D46/00 302; B01D53/94 ZAB; D06M11/45; D06M11/79; D06M15/263; F01N3/28 311N; F01N3/28 311S

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)

D04H1/00-18/04; B01D46/00; B01D53/94; D06M11/45; D06M11/79; D06M15/263; F01N3/28

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.
Y	WO 2015/045636 A1 (IBIDEN CO., LTD.) 02 April 2015 (2015-04-02) claims 1, 3, 5-6, 8, paragraphs [0011], [0012], [0043], [0056]-[0068], example 1, fig. 1	1-8, 10-20
Y	JP 2001-65337 A (IBIDEN CO., LTD.) 13 March 2001 (2001-03-13) claims 1, 5, paragraphs [0001], [0008], [0027]-[0031], example 1, fig. 2	1-8, 10-20
Y	WO 2015/170610 A1 (IBIDEN CO., LTD.) 12 November 2015 (2015-11-12) claims 1-2, 9, paragraphs [0001], [0007], fig. 1, 2	7-8, 10-11, 20
Y	JP 2014-190191 A (IBIDEN CO., LTD.) 06 October 2014 (2014-10-06) claims 1-2, 10-11, paragraphs [0001], [0027]	15
A	JP 2003-266572 A (NICHIAS CORP.) 24 September 2003 (2003-09-24) whole document	1-20
A	US 2014/0248814 A1 (ZOLTEK COMPANIES, INC.) 04 September 2014 (2014-09-04) whole document	1-20

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Date of the actual completion of the international search

15 May 2023

Date of mailing of the international search report

30 May 2023

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
 Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2023/006346

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2015/045636 A1	02 April 2015	EP 3051186 A1 claims 1, 3, 5-6, 8, paragraphs [0022]-[0025], [0097], [0119]- [0183], example 1, fig. 1	
JP 2001-65337 A	13 March 2001	(Family: none)	
WO 2015/170610 A1	12 November 2015	(Family: none)	
JP 2014-190191 A	06 October 2014	US 2014/0290228 A1 claims 1-2, 12-13, paragraphs [0003], [0031], [0047]	
		EP 2784283 A2	
JP 2003-266572 A	24 September 2003	US 2002/0168492 A1 whole document	
		EP 1245718 A2	
US 2014/0248814 A1	04 September 2014	WO 2013/052723 A2 whole document	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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