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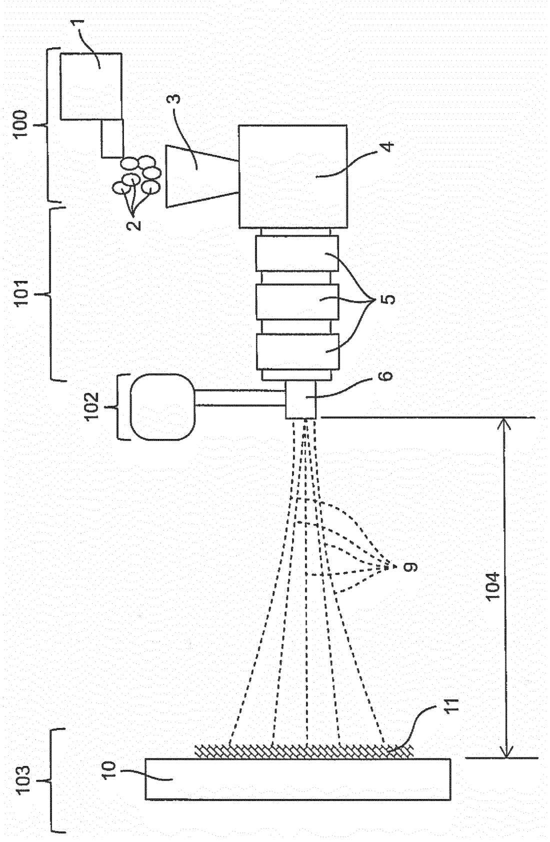
(54) NON-WOVEN FABRIC, NON-WOVEN FABRIC PRODUCING METHOD AND ACOUSTIC ABSORBENT

(57) A non-woven fabric, non-woven fabric producing method and an acoustic absorbent of desirable properties are provided. The non-woven fabric is a non-woven fabric including a plurality of ultrafine fibers configured from a thermoplastic resin, and comprises: a base portion configured by entangling of some of the plurality of ultrafine fibers; and a fiber bundle configured by entangling and bundling of other ultrafine fibers in the plurality of ultrafine fibers, and that is entangled with the base portion. The fiber bundle has a lower void fraction than a void fraction of the base portion.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a non-woven fabric, non-woven fabric producing method and an acoustic absorbent using an ultrafine fiber of thermoplastic resin.

BACKGROUND

[0002] Non-woven fabric has been used in a wide range of fields from consumer products such as clothes, daily commodities, and medical supplies to industrial products. Non-woven fabric is also used for many different purposes, including not only clothing fabrics but filters, absorbents and adsorbents, acoustic absorbents, and heat insulating materials. Many of these non-woven fabrics are configured from thermoplastic resin fibers having a diameter ranging from several micrometers to several tens of micrometers, though it varies with the intended use.

[0003] A more recent example is a fiber structure using an ultrafine fiber having a diameter of 1 μm or less, as disclosed in JP-A-2013-139655.

[0004] A non-woven fabric having a fiber diameter as small as 1 μm or less has a much larger fiber surface area than traditional non-woven fabrics of the same fiber weight, and such non-woven fabrics are known to have improved properties (for example, acoustic insulation, and heat insulation).

[0005] A problem, however, is that the mechanical strength of a fiber decreases as the diameter of the constituent fibers becomes smaller, and the non-woven fabric suffers from poor mechanical strength. One way of reducing the mechanical strength drop is to combine ultrafine fibers with fibers of a larger diameter, as described in, for example, JP-A-2013-147771. However, the use of thick fibers with ultrafine fibers is detrimental to the properties developed by using the ultrafine fibers. It might be possible to increase mechanical strength by using a material having a high strength. However, considering the melt viscosity of resin, it is difficult to form an ultrafine fiber using a high-strength resin.

SUMMARY

[0006] The present disclosure is intended to solve the foregoing problems, and to provide a non-woven fabric and an acoustic absorbent having improved mechanical strength without losing the properties developed by using ultrafine fibers.

[0007] According to a first aspect of the present disclosure, there is provided a non-woven fabric that includes a plurality of ultrafine fibers configured from a thermoplastic resin,
the non-woven fabric comprising:

a base portion configured by entangling of some of the plurality of ultrafine fibers; and
a fiber bundle configured by entangling and bundling of other ultrafine fibers in the plurality of ultrafine fibers, and that is entangled with the base portion,
wherein the fiber bundle has a lower void fraction than the base portion.

[0008] According to a second aspect of the present disclosure, the non-woven fabric of the first aspect may be such that the plurality of ultrafine fibers has a median size of 1 μm or less and 0.1 μm or more.

[0009] According to a third aspect of the present disclosure, the non-woven fabric of the first or second aspect may be such that the fiber bundle has a width of 0.2 mm or more and 7.5 mm or less.

[0010] According to a fourth aspect of the present disclosure, the non-woven fabric of any one of the first to third aspects may be such that the proportion of the fiber bundle in the non-woven fabric is 15% or more and 96% or less.

[0011] According to a fifth aspect of the present disclosure, the non-woven fabric of any one of the first to fourth aspects may be such that the fiber bundle has a void fraction of 90% or more and less than 99%.

[0012] According to a sixth aspect of the present disclosure, the non-woven fabric of any one of the first to fifth aspects may be such that the fiber bundle has a length of 10 mm or more and 1,000 mm or less.

[0013] According to a seventh aspect of the present disclosure, there is provided an acoustic absorbent comprising a layer of the non-woven fabric of any one of the first to sixth aspects.

[0014] According to an eight aspect of the present disclosure, there is provided a non-woven fabric producing method comprising:

forming a plurality of ultrafine fibers from a thermoplastic resin;
configuring a base portion by entangling a first part of the plurality of ultrafine fibers;
configuring a fiber bundle by entangling and bundling a second part of the plurality of ultrafine fibers; and
entangling the fiber bundle with the base portion to provide the fiber bundle with a lower void fraction than a void

fraction of the base portion.

[0015] According to a ninth aspect of the present disclosure, the non-woven fabric producing method according to the eight aspect may be such that a melt-blown method is used that blows high-speed hot air to a molten thermoplastic resin, and stretches the thermoplastic resin to form the plurality of ultrafine fibers.

[0016] In the non-woven fabric and the acoustic absorbent of the aspects of the present disclosure, the fiber bundle has a lower void fraction than the base portion. This makes it possible to provide high mechanical strength without losing the properties developed by using ultrafine fibers, despite that the non-woven fabric is configured from ultrafine fibers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 is a diagram representing an example of a non-woven fabric producing device of an embodiment of the present disclosure.

FIG. 2 is a diagram representing the structure of a spinning nozzle, and how ultrafine fibers are produced in the embodiment of the present disclosure.

FIG. 3 is a diagram representing an example of how a plurality of resin discharge holes is disposed in the spinning nozzle in the embodiment of the present disclosure.

FIG. 4 is a diagram representing how fiber bundles are produced in the embodiment of the present disclosure.

FIG. 5 shows a SEM image (275-times magnification) of a non-woven fabric of solely a base portion.

FIG. 6 shows a SEM image (275-times magnification) of fiber bundles.

FIG. 7 shows a stereomicrograph of a non-woven fabric with fiber bundles contained in the base portion.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] An illustrative embodiment of the present disclosure is described below with reference to the accompanying drawings.

Exemplary Configuration

[0019] A non-woven fabric of an embodiment of the present disclosure is a non-woven fabric 11 configured from a plurality of ultrafine fibers 9 of a thermoplastic resin, and the non-woven fabric 11 is configured to include a base portion 13 and a fiber bundle 12.

[0020] The base portion 13 is formed by entangling some of the plurality of ultrafine fibers 9. Specifically, the base portion 13 is formed of the plurality of ultrafine fibers 9 entangled in an irregular fashion.

[0021] The fiber bundle 12 is where other ultrafine fibers in the plurality of ultrafine fibers 9 are entangled and bundled to one another. The fiber bundle 12 is also entangled with the base portion 13. Specifically, the fiber bundle 12 is where the plurality of ultrafine fibers 9 forms a dense bundle by being irregularly entangled to one another.

[0022] The fiber bundle 12 is also irregularly entangled with the base portion 13.

[0023] The fiber bundle 12 has a lower void fraction than the base portion 13 so that the ultrafine fibers 9 exist with a higher density in the fiber bundle 12 than in the base portion 13.

Non-Woven Fabric Producing Method

[0024] The non-woven fabric 11 of the embodiment of the present disclosure is produced most suitably by a method that blows high-speed hot air to a molten thermoplastic resin, and stretches the thermoplastic resin to form the ultrafine fibers 9. A typical example of this method is a melt-blown method. The method of production of the non-woven fabric of the embodiment of the present disclosure is not limited to this, and it is possible to use methods, for example, such as a spunbond method, and a spunlace method.

[0025] The method of production of the non-woven fabric 11 used in the embodiment of the present disclosure is described below in detail.

[0026] FIG. 1 shows an example of a device for producing the non-woven fabric 11 of the embodiment of the present disclosure. The non-woven fabric producing device includes a material feeding unit 100, a material heating unit 101, a hot air generating unit 102, a spinning nozzle 6, and a collection unit 103. FIG. 2 shows an enlarged view of the structure of the spinning nozzle 6.

[0027] The material feeding unit 100 functions to feed a feedstock 2 to the material heating unit 101 with a resin extruder 4 after a feedstock feeder 1 has supplied the feedstock 2 to a hopper 3. The material feeding unit 100 is configured from the feedstock feeder 1 and the hopper 3. In this example, the feedstock feeder 1 continuously supplies a certain quantity of feedstock 2 to the hopper 3. However, a required amount of feedstock 2 may be supplied to the hopper 3 in advance, without using the feedstock feeder 1. For stable production of the ultraf ine fibers 9, the hopper 3 may be one equipped with a vibration mechanism that inhibits bridging of the feedstock 2.

[0028] The feedstock 2 of the ultrafine fibers 9 is a thermoplastic resin, which may be, for example, polyolefin resin, polyester resin, polyethylene resin, polycarbonate resin, polylactic acid resin, polyamide resin, polyvinyl resin, polystyrene resin, polyether resin, or engineering plastic. The feedstock 2 is used after being processed into a pellet, a powder, or a pellet-powder mixture. The feedstock 2 may be a thermoplastic resin itself, or a mixture containing one or more different thermoplastic resins.

[0029] The material heating unit 101 is configured from the resin extruder 4 having a heater 5, and functions to heat melt the feedstock 2 using the heater 5 after the feedstock 2 is supplied into the resin extruder 4 from the material feeding unit 100, and to supply the feedstock 2 to the spinning nozzle 6 at the tip of the resin extruder 4. The material heating unit 101 is configured from the resin extruder 4 and the heater 5. The resin extruder 4 is not limited, and may be one that is suitably selected according to the feedstock 2 used (for example, a monoaxial full-flight screw). The heater 5 is not limited, and may be, for example, a band heater used by being wrapped around the resin extruder 4, as long as the heater 5 has the capacity to heat the feedstock 2 to the melting point or higher temperatures as may be decided according to the extrusion performance of the resin extruder 4. A gear pump (not illustrated) may be installed on the exit side of the material heating unit 101 when high extrusion pressure is needed, or when the discharge amount needs to be accurately controlled.

[0030] The hot air generating unit 102 is joined to the spinning nozzle 6, and functions to heat gas (for example, compressed air), and send it to the spinning nozzle 6. The mechanism used to generate hot air 8 is not limited, as long as it has the capacity to heat gas to the desired temperature (for example, a torch heater). The gas entering the hot air generating unit 102 may be set so that the gas is expelled out of a hot air discharge hole 111 of the spinning nozzle 6 at a rate of 30 m/s to 150 m/s. The temperature of the hot air 8 may be set to 200°C to 500°C in the case of, for example, polypropylene resin, though the suitable temperature depends on the feedstock 2. Preferably, the pipe joining the hot air generating unit 102 to the spinning nozzle 6 should be made as short as possible because the temperature of the heated gas tends to decrease before the gas enters the spinning nozzle 6.

[0031] As illustrated in FIG. 2, the spinning nozzle 6 has resin discharge holes 110 through which the molten resin 7 from the material heating unit 101 is discharged, and hot air discharge holes 111 through which the hot air 8 from the hot air generating unit 102 is expelled. The resin discharge holes 110 and the hot air discharge holes 111 are disposed with a certain distance provided in between such holes. As an example, the discharge holes 111 are disposed a certain distance away from and above the resin discharge hole 110, as shown in FIG. 2. The resin discharge holes 110 are disposed at predetermined intervals (pitch 113) in a horizontal direction crossing the discharge direction. Likewise, the discharge holes 111 are disposed at predetermined intervals (pitch 113) in a horizontal direction crossing the discharge direction. The cross sectional shapes of the resin discharge holes 110 and the hot air discharge holes 111 are not limited, and may be circular or elliptical, or a slit shape. For example, when the resin discharge holes 110 and the hot air discharge holes 111 are both circular in shape, the ultrafine fibers 9 can be stably produced by setting the inner diameter of the resin discharge holes 110 to 0.1 mm to 5 mm, and clogging of the resin discharge holes 110 can be reduced for more stable production of ultrafine fibers 9 by setting the inner diameter of the resin discharge holes 110 to 0.5 mm to 5 mm. The molten resin 7 can be efficiently stretched when the hot air discharge holes 111 have an inner diameter of 0.1 mm to 5 mm. Clogging due to an inflow of the molten resin 7 into the hot air discharge holes 111 can be reduced when the hot air discharge holes 111 have an inner diameter of 0.5 mm to 3 mm. The molten resin 7 and the hot air 8 can gently meet in the manner shown in FIG. 2, and it becomes easier to produce long fibers when the resin discharge holes 110 and the hot air discharge holes 111 are separated from each other by a distance of 0.5 mm to 5 mm. In a melt-blown method, the discharge directions of the molten resin 7 and the hot air 8 are typically not parallel to each other, and the molten resin 7 and the hot air 8 meet with an angle. It is, however, preferable for ease of making a long fiber that the discharge directions of the molten resin 7 and the hot air 8 are parallel to each other. The resin discharge holes 110 and the hot air discharge holes 111 may be provided in separate nozzles, rather than in the same nozzle. In this case, the two nozzles may be disposed adjacent to each other. The resin discharge holes 110 and the hot air discharge hole 111 may be provided in numbers that vary with the spinning range and the spinning amount of ultrafine fibers 9. Here, the resin discharge holes 110 and the hot air discharge hole 111 may be disposed in any fashion, provided that the molten resin 7 can meet the hot air 8 and stretch. However, stable spinning is possible when the resin discharge holes 110 and the hot air discharge hole 111 are disposed in pair (pair 112) with certain intervals, as shown in FIG. 3.

[0032] At the collection unit 103, a collector 10 collects the ultrafine fibers 9 produced, and the non-woven fabric 11 is formed. A roll or a conveyer, for example, may be used as the collector 10 when the non-woven fabric 11 needs to be continuously formed into a sheet shape at the collection unit 103. The surface of the collector 10 needs to be a material or a structure that does not cause the airborne ultrafine fibers 9 to slide down the surface, and, for example, a non-woven fabric or a metal mesh may be used for this purpose. When the distance between the opening end of the resin discharge holes 110 and the surface of the collection unit 103 is spinning distance 104, the collection unit 103 may be disposed at any spinning distance 104. However, when the spinning distance 104 is too short, the stretched molten resin 7 will be captured by the collection unit 103 before being sufficiently cooled, and the fibers will fuse with each other. The ultrafine fibers 9 cannot reach the collector 10 when the spinning distance 104 is too long. For these reasons, the collection unit 103 is installed at a spinning distance 104 of 100 mm to 5,000 mm. Preferably, the spinning distance 104 is 500 mm to 5, 000 mm for the production of the fiber bundle 12 with the base portion 13 (described below).

Production of Base Portion and Fiber Bundle

[0033] The fiber bundle 12 is formed as the ultrafine fibers 9 become entangled in their flight to the collection unit 103 after fiber formation. Because the hot air 8 is flowing fast near the spinning nozzle 6, a plurality of ultrafine fibers 201 near the spinning nozzle 6 travel with the flow of hot air 8 in a relatively straight line, rather than being bent, as shown in FIG. 4. For this reason, in a typical spinning distance range of less than 500 mm adopted by a melt-blown method, the ultrafine fibers 201 do not easily become entangled, and form a non-woven fabric of only the base portion 13, without forming a fiber bundle, as shown in FIG. 5.

[0034] On the other hand, the hot air 8 has a slow flow rate, and encounters air resistance in locations distant from the spinning nozzle 6 (500 mm or a longer range). The ultrafine fibers 202 at such distant locations from the spinning nozzle 6 (500 mm or a longer range) take a complex bent shape, and easily form a bundle as the adjacent ultrafine fibers 202 become entangled with each other, as shown in FIG. 4. A plurality of fiber bundles 12, and the base portion 13 can thus be formed when the spinning distance 104 is 500 mm or more, as shown in FIG. 6. Here, the non-woven fabric 11 has a structure in which a plurality of fiber bundles 12 occur in the base portion 13 in an irregular fashion, as shown in FIG. 7.

[0035] The extent of entanglement of the ultrafine fibers 9 varies with the spinning distance 104. A longer spinning distance 104 promotes more entanglement of the ultrafine fibers 9, and makes the fiber bundles 12 wider, increasing the proportion of the fiber bundles 12 in the non-woven fabric 11. When the spinning nozzle 6 has laterally disposed resin discharge holes 110, the ultrafine fibers 9 produced through the adjacent resin discharge holes 110 becomes more likely to become entangled as the pitch 113 of the resin discharge holes 110 becomes smaller. This widens the fiber bundles 12, and increases the proportion of the fiber bundles 12.

[0036] In this manner, the width or the proportion of the fiber bundles 12 can be controlled by adjusting the spinning distance 104 or the pitch 113 of the resin discharge holes 110.

Effects of Fiber Bundles

[0037] Formation of the fiber bundles 12 improves the overall mechanical strength of the non-woven fabric 11. This is because the ultrafine fibers 9 become less likely to deform as the entangled ultrafine fibers 9 mutually restrain the deformation occurring in each ultrafine fiber 9 under an applied tensile or compression load on the fiber bundle 12. This produces the same effect as that obtained when thick fibers are contained. The fiber bundle 12 has a width of preferably 0.2 mm to 7.5 mm, more preferably 3 mm to 7.5 mm, further preferably 3 mm to 4 mm. Increasing the width of the fiber bundle 12 improves the mechanical strength of the non-woven fabric 11. However, the mechanical strength of the fiber bundle 12 itself will be poor when the width is less than 3 mm, and a non-woven fabric having sufficient mechanical strength cannot be produced unless properties such as the median size of the ultrafine fiber 9, and the proportion of the fiber bundles 12 are accurately controlled. The mechanical strength of the fiber bundle 12 itself will be even weaker when the width of the fiber bundle 12 is less than 0.2 mm, and the mechanical strength of the non-woven fabric hardly improves even with the fiber bundles 12. The mechanical strength improves when the width of the fiber bundle 12 is more than 4 mm. However, it reduces the ultrafine fibers 9 constituting the base portion 13, and the base portion 13 will have a region devoid of ultrafine fibers 9. This deteriorates the functions developed by using the ultrafine fibers 9. When the width of the fiber bundle 12 is more than 7.5 mm, a region devoid of ultrafine fibers 9 further increases, and the inner structure of the non-woven fabric becomes simplified. This severely deteriorates the functions developed by using the ultrafine fibers 9.

[0038] The proportion of fiber bundles 12 is preferably 15% to 96%, more preferably 40% to 96%. The mechanical strength of the non-woven fabric 11 improves as the proportion of fiber bundles 12 increases. The effect of improving the mechanical strength of the non-woven fabric by the formation of fiber bundles 12 becomes weaker when the proportion of fiber bundles 12 is less than 40%, and a non-woven fabric having sufficient mechanical strength cannot be produced unless properties such as the median size of the ultrafine fiber 9, and the thickness of the fiber bundles 12 are accurately controlled. Formation of fiber bundles 12 fails to provide sufficient mechanical strength when the proportion of fiber bundles 12 is less than 15%. A proportion of fiber bundles 12 above 96% improves the mechanical strength. However, the ultrafine fibers constituting the base portion 13 become greatly reduced, and the base portion 13 will have a region devoid of ultrafine fibers. This deteriorates the functions developed by using the ultrafine fibers.

[0039] The void fraction of the fiber bundle 12 is preferably 90% or more and less than 99%. The ultrafine fibers 9 become denser as the void fraction of the fiber bundle 12 decreases. This makes it difficult for gases (for example, air) to pass between the ultrafine fibers 9, and the structure becomes similar to that containing thick fibers. The functions developed by using the ultrafine fibers 9 will thus deteriorate when the void fraction of the fiber bundle 12 is less than 90%. With a void fraction of 99% or higher, the ultrafine fibers 9 forming the fiber bundle 12 will be weakly entangled, and the mechanical strength improving effect becomes insufficient.

[0040] The fiber bundle 12 has a length of preferably 10 mm to 1,000 mm.

[0041] As shown in FIG. 7, the fiber bundles 12 are randomly disposed in the non-woven fabric, and some of the fiber bundles 12 are side by side to each other, acting as a skeleton and preventing deformation. Here, the adjoining regions of fiber bundles 12 become smaller, and the fiber bundles 12 fail to function as a skeleton when the length of fiber bundles 12 is less than 10 mm. By designing fiber bundles 12 of a length that is at least 10 mm, the fiber bundles 12 becomes more likely to occur side by side, and the mechanical strength of the non-woven fabric improves. When the length of the fiber bundles 12 is above 1,000 mm, the ultrafine fibers 9 become overly entangled when forming the fiber bundles 12, and the width or the void fraction of the fiber bundles 12 falls outside of the preferred range. This deteriorates the functions developed by using the ultrafine fibers 9.

[0042] The ultrafine fibers 9 constituting the non-woven fabric have a median size of 0.1 μm to 1 μm. High acoustic absorbent or heat insulation can be obtained when the median size is 1 μm or less. With a median size of less than 0.1 μm, the ultrafine fibers 9 will be too weak, and sufficient mechanical strength cannot be obtained even with the fiber bundles 12.

Measurement Methods

[0043] The following describes the methods used to evaluate the non-woven fabric 11 of the present embodiment.

[0044] The non-woven fabric was measured for modulus of compressive elasticity as an index of mechanical strength evaluation, and for normal incidence sound absorption coefficient as an index for evaluation of properties developed by using the ultrafine fibers.

Fiber Diameter

[0045] The fiber diameter was measured in a 10,000-times magnified two-dimensional image using a scanning electron microscope (Phenom G2 Pro available from PHENOM-World). The diameter was measured for a total of 200 fibers randomly selected from different locations of a sample, and the median size was calculated. The sample was subjected to Au sputtering in advance to prevent charge up.

Width, Length, and Proportion of Fiber Bundles

[0046] The width, the length, and the proportion of fiber bundles were measured under a stereomicroscope (SZ61 available from OLYMPUS) in a zoom magnification of 0.67 times. Fiber bundle measurements were taken in a continuous region formed by entangling of a plurality of ultrafine fibers, and in which the void fraction was smaller than the void fraction of the whole non-woven fabric as measured by a void fraction measurement to be described later, more specifically in a part of the continuous region where the transverse length was 0.2 mm or more, and the aspect ratio was 10 or more. For the measurement, a sample was used that had been processed into a thickness of 0.2 mm without altering the density or the inner structure of the non-woven fabric, and the fiber bundles were measured in a randomly selected 1,000-mm^2 measurement area of the sample in a screen. The largest width and the largest length of the fiber bundles in a screen were taken as the fiber bundle width and the fiber bundle length. The proportion of fiber bundles was determined as the area occupied by fiber bundles in an area of the screen with the fibers.

Void Fraction

[0047] The void fraction of the whole non-woven fabric was calculated from the density of the feedstock, and the thickness and the weight of a non-woven fabric that had been processed into a 100 mm x 100 mm size without altering the density or inner structure. The void fractions of the fiber bundle and the base portion are values obtained by dividing the void area by focal depth in a screen showing a 1,000-times magnified two-dimensional image produced by a scanning electron microscope (Phenom G2 Pro available from PHENOM-World). The sample was subjected to Au sputtering in advance to prevent charge up.

Modulus of Compressive Elasticity

[0048] Modulus of compressive elasticity was measured using a method according to the JIS L-1096: 2010 testing methods for woven and knitted fabrics, using a Texture Analyzer TA.XTplus available from Stable Micro Systems.
[0049] The sample had a square shape with a side length of 50 mm, and a weight per unit of 450 g/m^2, and a thickness of 20 mm. Measurements were made with a non-woven fabric (spunbond non-woven fabric available from Asahi Kasei under the trade name Eltas P03020) of the same size placed on a sample surface, using a probe (ϕ = 10 mm).

Normal Incidence Sound Absorption Coefficient

[0050] Normal incidence sound absorption coefficient was measured with an acoustic tube (SR-4100 Type-B available from Ono Sokki Co., Ltd.), using a method according to JIS A 1405-2/ISO 10534-2. The sample had a diameter ϕ of 29 mm, a thickness of 20 mm, and a weight of 0.3 g. The normal incidence sound absorption coefficient of the sample was measured at 1 kHz after the sample was squeezed into a jig adapted to accommodate the sample without a gap.

Comparative Example

[0051] As a Comparative Example, a non-woven fabric formed of fibers with a median size of more than 1 μm was produced. A polypropylene resin was used as feedstock. The polypropylene resin was heated to 200°C, and 300°C hot air was blown onto the polypropylene resin at a rate of 50 m/s to form fibers, using a spinning nozzle having resin discharge holes of 0.7 mm diameter. The non-woven fabric was formed at a spinning distance of 300 mm. The non-woven fabric produced had a median size of 1.57 μm, a modulus of compressive elasticity of 66%, and a normal incidence sound absorption coefficient of 36%. There was no fiber bundle that was 0.2 mm or wider.

Example 1

[0052] A polypropylene resin was used as feedstock. The polypropylene resin was heated to 240°C, and hot air of the same temperature was blown onto the polypropylene resin at a rate of 60 m/s to form ultrafine fibers 9, using the spinning nozzle 6 having resin discharge holes 110 of 0.1 mm diameter disposed at 0.25-mm intervals. The non-woven fabric 11 was formed at a spinning distance of 500 mm. The non-woven fabric 11 produced had a fiber diameter of 0.51 μm, a modulus of compressive elasticity of 69%, and a normal incidence sound absorption coefficient of 43%. The modulus of compressive elasticity was comparable to that of Comparative Example despite the smaller fiber diameter. The fiber bundles 12 in the non-woven fabric 11 were as thick as 0.55 mm, and had a void fraction of 96.8%, and a length of 10 mm or more. The proportion of fiber bundles 12 in the non-woven fabric 11 was 16.2%.

Example 2

[0053] A polypropylene resin was used as feedstock. The polypropylene resin was heated to 240°C, and hot air of the same temperature was blown onto the polypropylene resin at a rate of 60 m/s to form ultrafine fibers 9, using the spinning nozzle 6 having resin discharge holes 110 of 0.1 mm diameter disposed at 0.25-mm intervals. The non-woven fabric 11 was formed at a spinning distance of 1,400 mm. The non-woven fabric 11 produced had a median size of 0.51 μm, a modulus of compressive elasticity of 76%, and a normal incidence sound absorption coefficient of 41%. The modulus of compressive elasticity was higher than in Example 1, despite that the fiber diameter was about the same. The fiber bundles 12 in the non-woven fabric 11 were as thick as 4.43 mm, and had a void fraction of 97.1%, and a length of 10 mm or more. The proportion of fiber bundles 12 in the non-woven fabric 11 was 42.7%.

Example 3

[0054] A polypropylene resin was used as feedstock. The polypropylene resin was heated to 280°C, and hot air of the same temperature was blown onto the polypropylene resin at a rate of 80 m/s to form ultrafine fibers 9, using the spinning nozzle 6 having resin discharge holes 110 of 0.1 mm diameter disposed at 0.25-mm intervals. The non-woven fabric 11 was formed at a spinning distance of 1, 000 mm. The non-woven fabric 11 produced had a median size of 0.54 μm, a modulus of compressive elasticity of 73%, and a normal incidence sound absorption coefficient of 79%. In the non-woven fabric 11 produced in Example 3, the volume ratio of fibers with a diameter of 1 μm or less was about three times higher than in Example 2, and the number of ultrafine fibers 9 was larger than in Example 2, even though the fiber diameter was about the same in Examples 2 and 3. Specifically, despite the larger numbers of ultrafine fibers 9 and the higher sound absorption coefficient than in Example 2, the same level of modulus of compressive elasticity was obtained, and the sound absorption coefficient and the modulus of compressive elasticity were both desirable. The fiber bundles

12 in the non-woven fabric 11 were as thick as 3.13 mm, and had a void fraction of 96.7%, and a length of 10 mm or more. The proportion of fiber bundles 12 in the non-woven fabric 11 was 40.1%.

Example 4

[0055] A polypropylene resin was used as feedstock. The polypropylene resin was heated to 280°C, and hot air of the same temperature was blown onto the polypropylene resin at a rate of 100 m/s to form ultrafine fibers 9, using the spinning nozzle 6 having resin discharge holes 110 of 0.7 mm diameter disposed at 60-mm intervals. The non-woven fabric 11 was formed at a spinning distance of 1,250 mm. The non-woven fabric 11 produced had a fiber diameter of 0.74 μm, a modulus of compressive elasticity of 67%, and a normal incidence sound absorption coefficient of 81%. The modulus of compressive elasticity was comparable to that of Comparative Example despite the smaller fiber diameter. Specifically, the sound absorption coefficient, and the modulus of compressive elasticity were both desirable. In other words, the same effect was obtained even with the spinning nozzle 6 of a different structure from Examples 1 to 3. The fiber bundles 12 in the non-woven fabric 11 were as thick as 3.17 mm, and had a void fraction of 97.0%, and a length of 10 mm or more. The proportion of fiber bundles 12 in the non-woven fabric 11 was 89.7%.

Example 5

[0056] A polypropylene resin was used as feedstock. The polypropylene resin was heated to 280°C, and hot air of the same temperature was blown onto the polypropylene resin at a rate of 100 m/s to form ultrafine fibers 9, using the spinning nozzle 6 having resin discharge holes 110 of 0.7 mm diameter disposed at 10-mm intervals. The non-woven fabric 11 was formed at a spinning distance of 2,000 mm. The non-woven fabric 11 produced had a fiber diameter of 0.64 μm, a modulus of compressive elasticity of 77%, and a normal incidence sound absorption coefficient of 71%. The modulus of compressive elasticity was higher than in Example 4 despite the smaller fiber diameter. The normal incidence sound absorption coefficient was lower than in Example 4. The fiber bundles 12 in the non-woven fabric 11 were as thick as 7.05 mm, and had a void fraction of 98.5%, and a length of 10 mm or more. The proportion of fiber bundles 12 in the non-woven fabric 11 was 95.4%.

[0057] The results are summarized in Table 1. It can be seen from Comparative Example and Examples 1 to 5 that a high modulus of compressive elasticity can be obtained while maintaining or improving the normal incidence sound absorption coefficient when the non-woven fabric 11 using ultrafine fibers 9 contains the fiber bundles 12. It can be seen from Examples 3 and 4 that the highest normal incidence sound absorption coefficient can be obtained while maintaining the modulus of compressive elasticity when the width and the proportion of fiber bundles are confined within the optimum ranges.

Table 1

	Com. Ex. 1	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5
Fiber diameter [μm]	1.57	0.51	0.51	0.54	0.74	0.64
Modulus of compressive elasticity [%]	66	69	76	73	67	77
Normal incidence sound absorption coefficient [%]	36	43	41	79	81	71
Largest fiber bundle width [mm]	0.2 <	0.55	4.43	3.13	3.17	7.05
Proportion of fiber bundle [%]	0	16.2	42.7	40.1	89.7	95.4
Void fraction of fiber bundle [%]	-	96.8	97.1	96.7	97	98.5

[0058] As described in the embodiment above, the non-woven fabric 11 including the base portion 13 formed by entangling of some of the ultrafine fibers 9, and the fiber bundle 12 formed by entangling and bundling of other ultrafine fibers in the ultrafine fibers 9 has a lower void fraction in the fiber bundle 12 than in the base portion 13, and can have improved mechanical strength without losing the properties developed by using ultrafine fibers 9, even though the non-woven fabric 11 is configured from ultrafine fibers 9.

[0059] The present disclosure is not limited to the foregoing embodiment, and may be implemented in various different forms. For example, the disclosure has use as an acoustic absorbent having a layer formed of the non-woven fabric of the embodiment. An acoustic absorbent configured from a layer of the non-woven fabric of the embodiment can have more desirable acoustic absorbent with a higher normal incidence sound absorption coefficient than that obtained in Comparative Example, as described above.

[0060] An embodiment based on a proper combination of any of the embodiments or variations described above can exhibit the effects of the individual embodiments or variations. A combination of different embodiments or examples, or a combination of an embodiment and an example may also be made. It is also possible to combine the features of different embodiments or examples.

[0061] Although the present disclosure has been described with reference to the aforementioned embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments as well as alternative embodiments of the invention will become apparent to persons skilled in the art. It is therefore contemplated that the appended claims will cover any such modifications or embodiments.

Industrial Applicability

[0062] The non-woven fabric according to the embodiment of the present disclosure can have improved mechanical strength without losing the functions developed by using ultrafine fibers. The non-woven fabric has potential use in a range of industrial applications, including, for example, acoustic absorbents, heat insulating materials, adsorbents, absorbers, filters, ...etc.

Claims

1. A non-woven fabric that includes a plurality of ultrafine fibers configured from a thermoplastic resin, the non-woven fabric comprising:

a base portion configured by entangling of a first part of the plurality of ultrafine fibers; and
a fiber bundle configured by entangling and bundling of a second part of the plurality of ultrafine fibers,
wherein the fiber bundle is entangled with the base portion, and
wherein the fiber bundle has a lower void fraction than a void fraction of the base portion.

2. The non-woven fabric according to claim 1, wherein the plurality of ultrafine fibers has a median size of at least 0.1 μm and no greater than 1 μm.

3. The non-woven fabric according to claim 1, wherein the fiber bundle has a width at least 0.2 mm an no greater than 7.5 mm

4. The non-woven fabric according to claim 1, wherein a proportion of the fiber bundle in the non-woven fabric is at least 15% and no greater than 96%.

5. The non-woven fabric according to claim 1, wherein the fiber bundle has the lower void fraction of at least 90% and no greater than 99%.

6. The non-woven fabric according to claim 1, wherein the fiber bundle has a length of at least 10 mm and no greater than 1,000 mm.

7. An acoustic absorbent comprising a layer of the non-woven fabric of claim 1.

8. A non-woven fabric producing method comprising:

forming a plurality of ultrafine fibers from a thermoplastic resin;
configuring a base portion by entangling a first part of the plurality of ultrafine fibers;
configuring a fiber bundle by entangling and bundling a second part of the plurality of ultrafine fibers; and
entangling the fiber bundle with the base portion to provide the fiber bundle with a lower void fraction than a void fraction of the base portion. 9. The non-woven fabric producing method according to claim 8, further comprising:

using a melt-blown method that blows high-speed hot air to a molten thermoplastic resin, and stretches the thermoplastic resin to form the plurality of ultrafine fibers.

FIG. 1

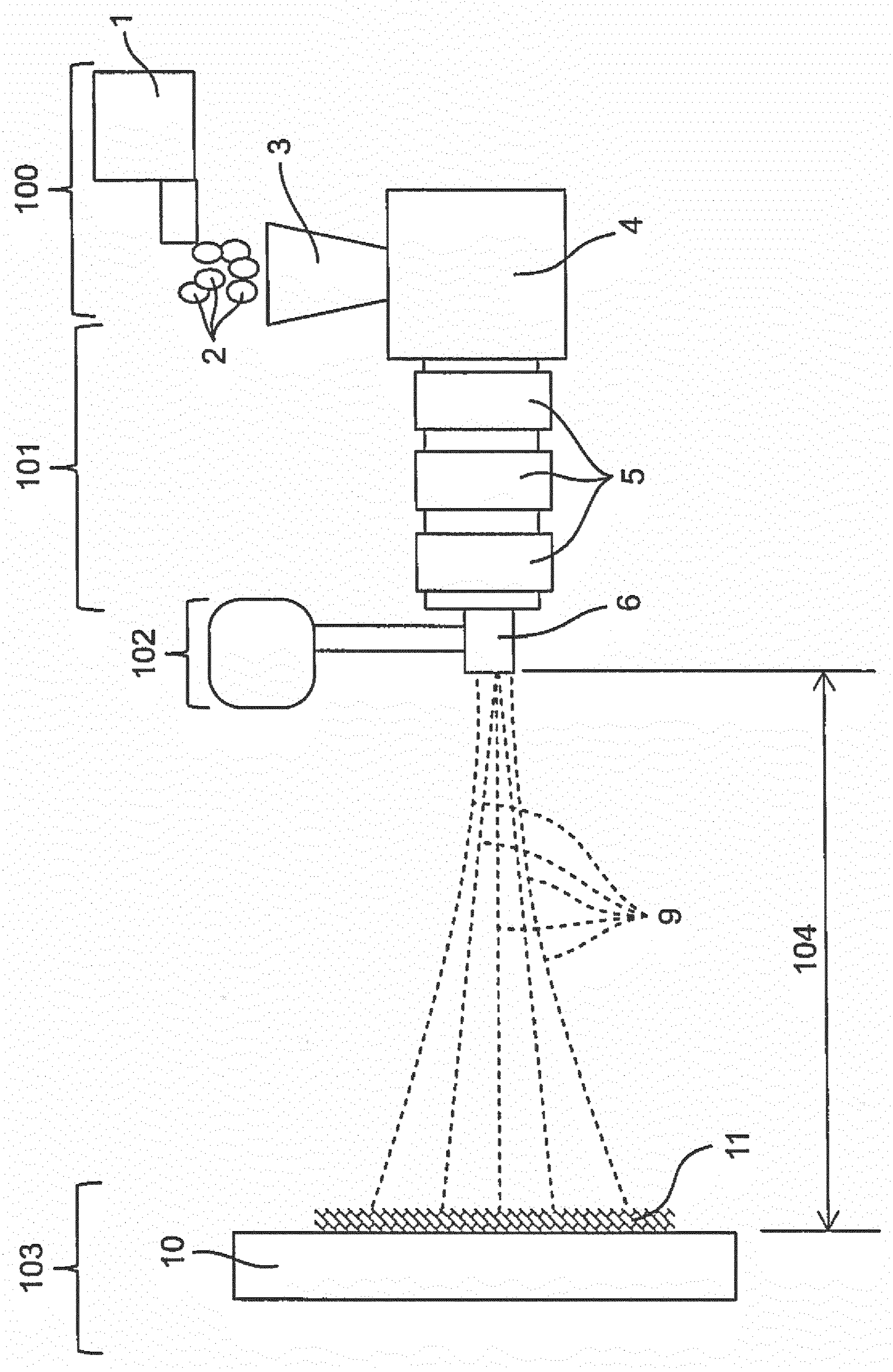

FIG. 2

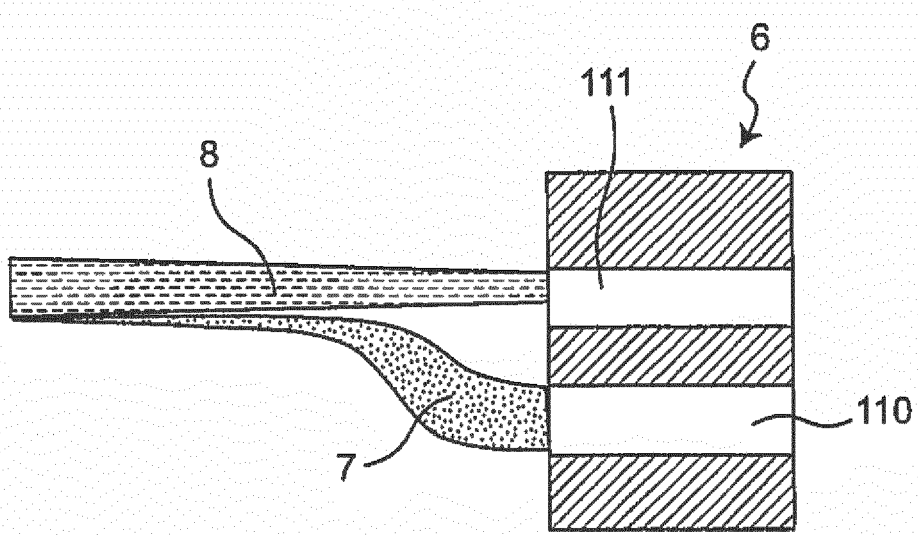

FIG. 3

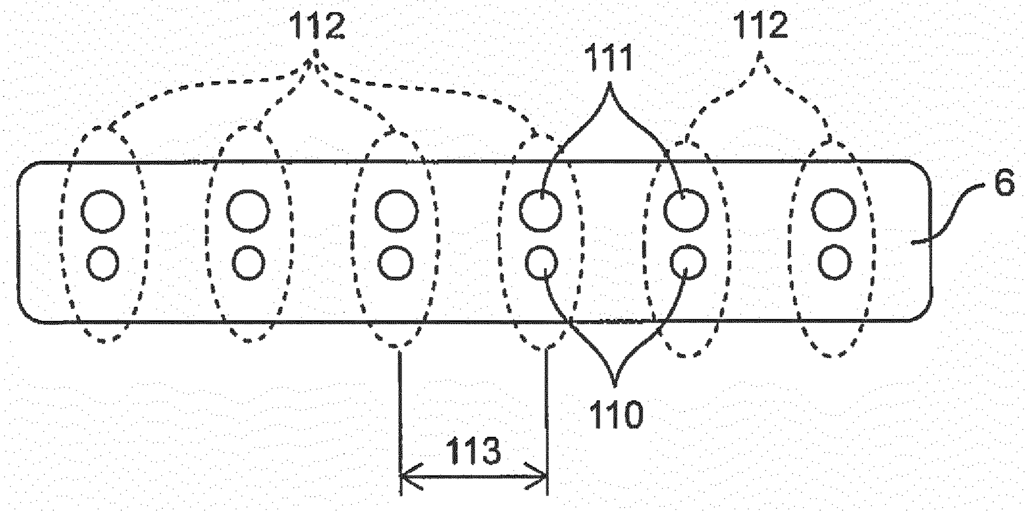

FIG. 4

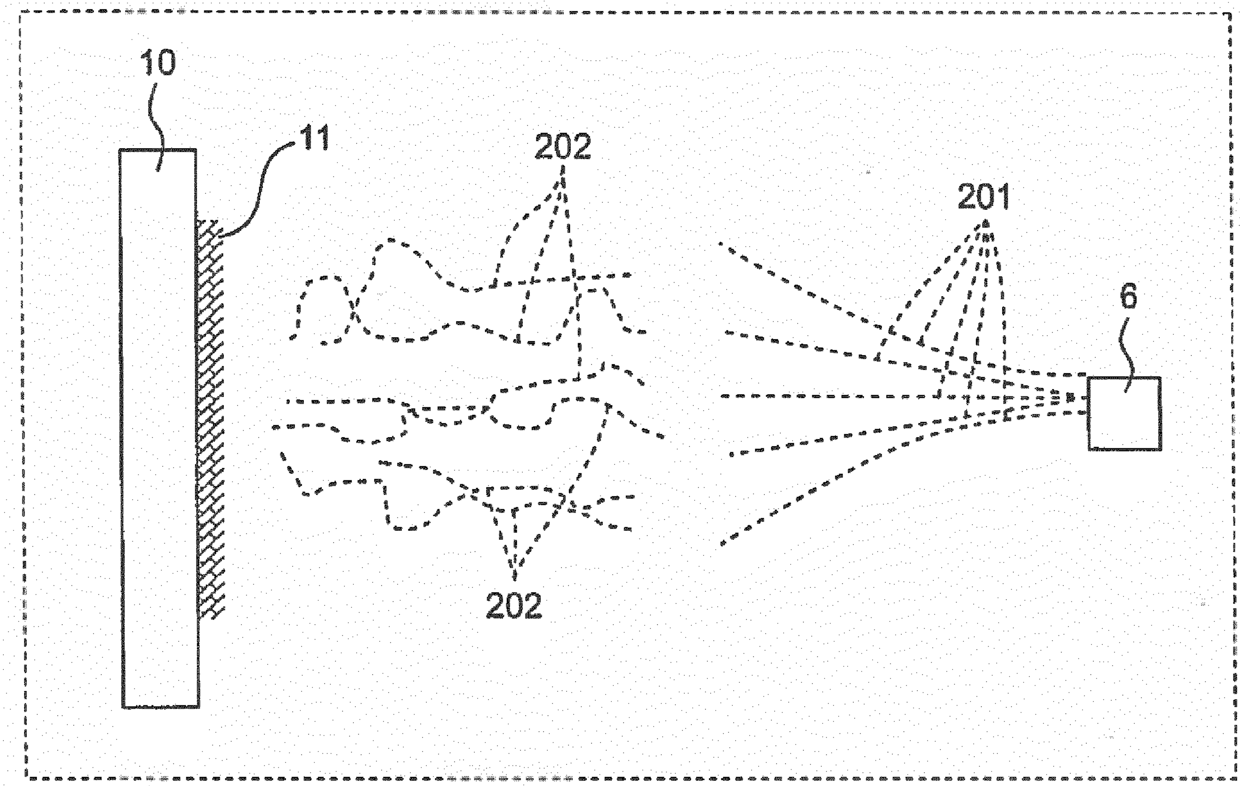

FIG. 5

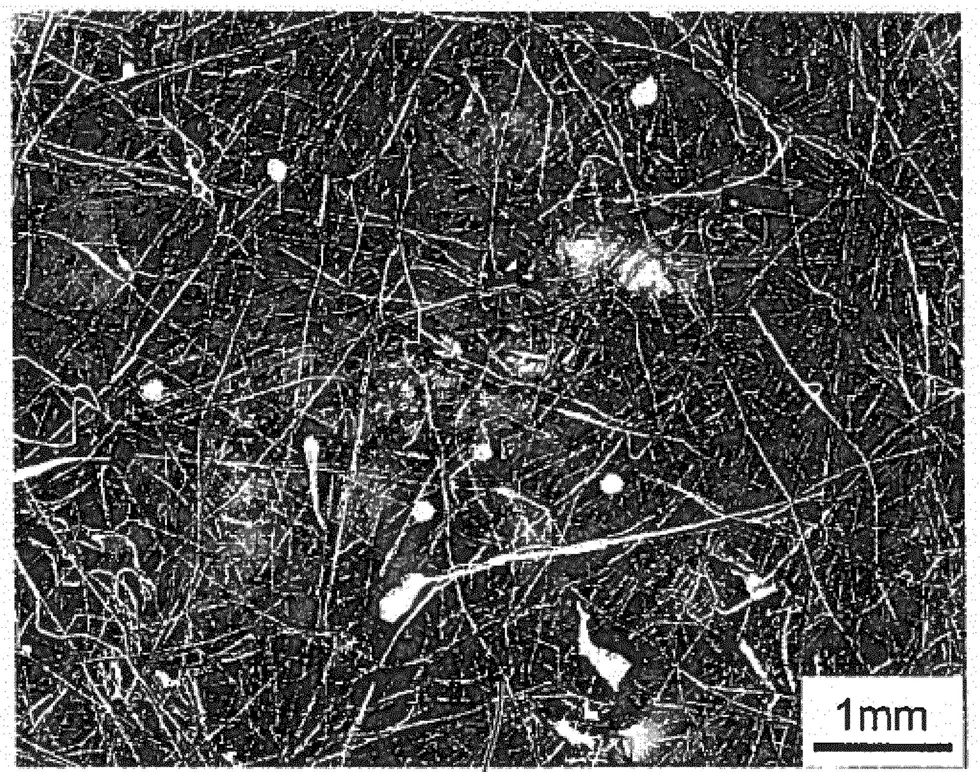

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FIG. 6

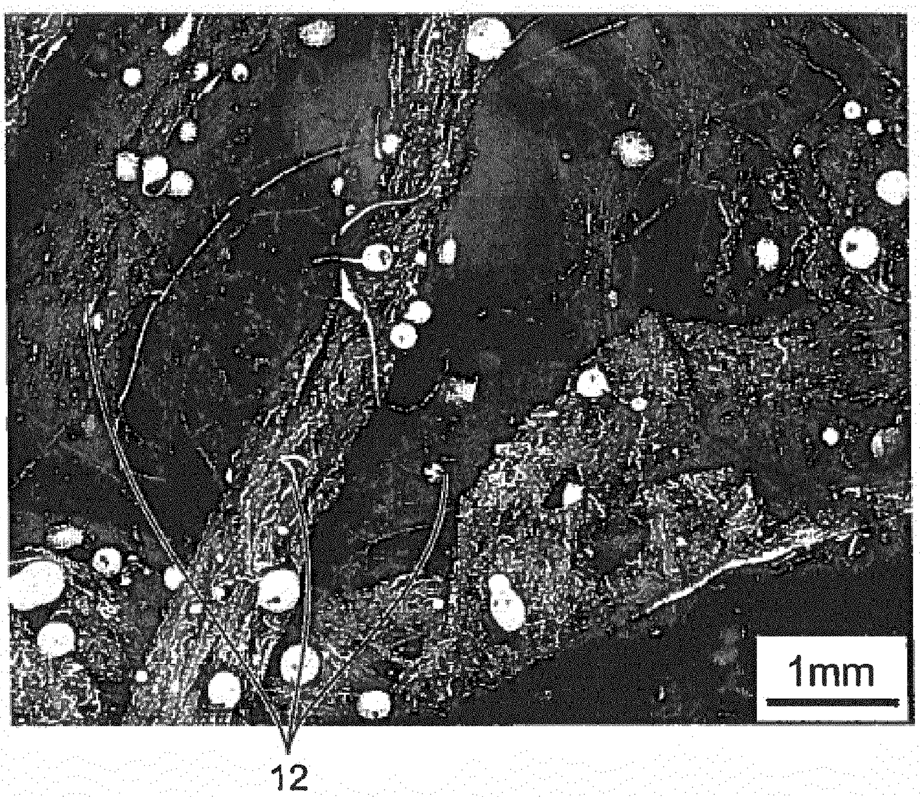
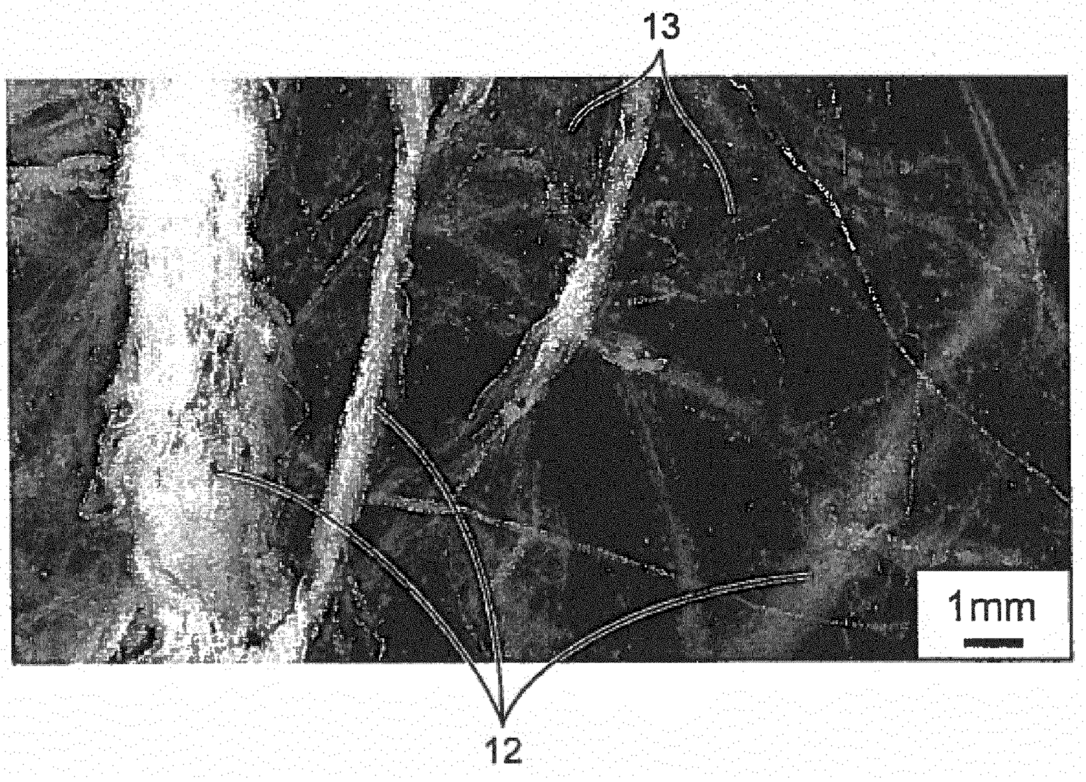


FIG. 7



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Application Number
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Place of search	Date of completion of the search	Examiner
Munich	10 August 2017	Elsässer, Ralf

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