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(54) METHOD FOR PROVIDING AN EMBOSSED NONWOVEN FABRIC

(57) A method is provided for obtaining an embossed nonwoven fabric. The method comprises the following steps, performed continuously one after the other: providing a substrate of unbonded fibers of the nonwoven fabric; performing a bonding of the substrate fibers with a thermal process that reaches a bonding temperature at which bonding of the substrate fibers occurs and obtaining a bonded substrate of the nonwoven fabric; and, after the bonding step, performing a three-dimensional type embossing of the bonded substrate at an embossing temperature lower than the bonding temperature and obtaining the embossed nonwoven fabric.

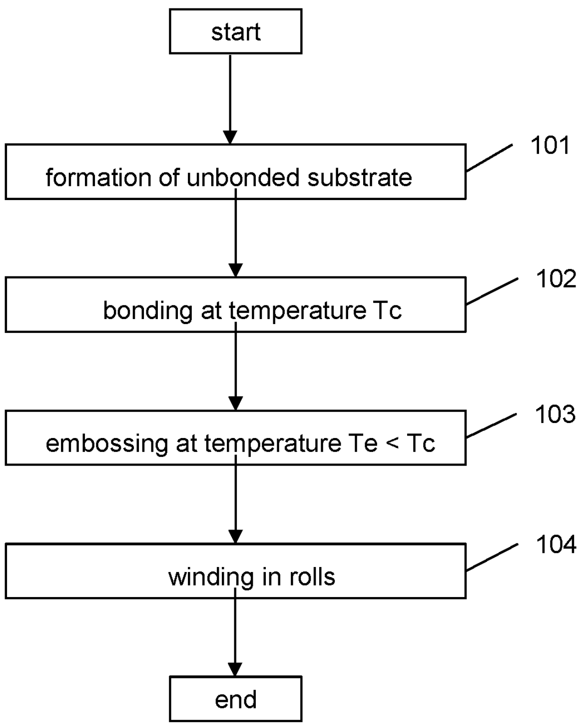

Fig. 1

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Description

Technical field

[0001] The present invention relates to the field of nonwoven fabrics. In particular, the present invention relates to a method for providing a nonwoven fabric, more specifically a nonwoven fabric embossed in three dimensions.

State of the art

[0002] As known, a nonwoven fabric (NWF) is a material comprising fibers, more precisely staple fibers or continuous extruded filaments of fiber, which are bonded together by means of chemical, mechanical or thermal treatment.

[0003] The first step in the production of a nonwoven fabric is the formation of a substrate of unbonded fibers (also known as unbonded substrate or web), starting from the staple fibers or the continuous fiber filaments. For example, the unbonded substrate can be formed by carding the staple fiber material.

[0004] The bonding by means of thermal treatment typically occurs by exploiting the thermoplastic properties of some synthetic fibers which form fixing points in the substrate when the substrate is heated until reaching the melting temperature of said fibers. The bonding, in particular, can occur by means of a calender composed of two heated counter-rotating metal rollers between which the nonwoven fabric substrate passes. Sometimes this step is used to finish the nonwoven fabric with geometric patterns such as to confer given mechanical bonding properties together with embossing characteristics. For this purpose, the upper roller can be provided with positive reliefs (for example, having a honeycomb pattern) so that the combined action of the pressure exerted by means of these reliefs, the speed and the temperature produces fixing points in the substrate; once solidified, these fixing points cause bonding of the fibers.

[0005] Alternatively, the process known as Air Through Bonding (ATB) is a process that entails a thermal treatment to bond the fibers without direct pressure, by means of a hot air oven, thus resulting in softer nonwoven fabrics. Said process is applied, for example, to a substrate made of (or comprising) synthetic fibers with low melting point. In particular, bicomponent fibers can be used, namely fibers having one component with low melting point or low-melting component. In particular, for example, PET/PE fibers can be used having a core made of polyethylene terephthalate (PET), belonging to the category of polyesters, and a coating (or sheath) made of polyethylene (PE). The bicomponent fibers of this type are fibers in which the core and sheath are made of materials with different melting points. In particular, the core has a high melting point and provides structural rigidity while the coating has a low melting point, thus melting easily to bond the fibers.

[0006] JP 2020 039518 A describes a method for producing a nonwoven fabric with uneven surface for an absorbent article which has: a step of forming an upper layer nonwoven web and of forming an upper layer nonwoven fabric by means of an air-through process; a step of superimposing a lower web containing thermocontracting fibers on the upper layer nonwoven fabric and partially bonding it; and an unevenness shaping step to form an uneven nonwoven fabric with protrusions on the upper layer nonwoven fabric, thermally treating a laminate of the partially bonded upper layer nonwoven fabric and the lower web, and performing heat contracting in the lower web.

[0007] JP 2011 137249 A describes a method for producing the nonwoven fabric with uneven surface that comprises forming a web bonded by means of hot air with an air-through bond method on a web containing a thermally extensible fiber composed of a conjugate fiber containing a component with high melting point and a component with low melting point with melting point lower than that of the component with high melting point, extending the length by heating, and embossing the bonded web using an embossing device having an embossing roller and a flat roller. The temperature of the hot air blown onto the web is set at a temperature not lower than the melting point of the component with low melting point and lower than the melting point of the component with high melting point. In the embossing, the surface blown with hot air in the bonded web is brought into contact with the embossing roller and the opposite surface of the surface blown with hot air is brought into contact with the flat roller.

Summary of the invention

[0008] An in-line production process of a nonwoven fabric indicates a continuous production process in which the various component steps are carried out in a continuous sequential manner, namely one after the other. The steps are performed in continuous sequence by passage of the product being processed from one point to another of the production line, namely from one step to the next step, without interruption. This improves efficiency and reduces production costs and times.

[0009] In the state-of-the-art processes, the embossing is carried out by means of a calender, composed of two metal rollers, typically both made of iron or metal alloy, in which the upper roller has a relief pattern to be transferred onto the substrate. Both rollers are typically heated to a temperature near to the melting temperature of the fibers.

[0010] A high productivity process line of a nonwoven fabric with short fibers can produce, depending on the basis weight, from approximately 80 meters per minute to approximately 300 meters per minute with roll heights that can reach approximately 4.2 meters and diameters up to approximately 3 meters.

[0011] The metal rollers of the calender used in the state-of-the-art systems for in-line embossing of nonwoven fabrics typically have heights between 2 meters and 3 meters. If the heights are greater, it is difficult to maintain the temperature of the roller constant, both longitudinally and radially. If the temperature is not uniform, the embossing can be compromised and likewise the mechanical and chemical-physical properties of the resulting nonwoven fabric. It is therefore clear that the embossing process, in particular three-dimensional embossing, carried out as above, is disadvantageously not suitable for inclusion in high productivity process lines, namely in process lines that require roll heights exceeding 3 meters.

[0012] Lastly, it should be noted that in the processes with bonding by means of ATB thermal treatment, the embossing operation is typically carried out before passing through the oven, at a temperature near to the melting temperature of the fibers. This disadvantageously causes pre-bonding of the fibers which in turn can compromise the mechanical and physical-chemical properties of the nonwoven fabric, for example in terms of softness and fluffiness not only to touch but also to sight.

[0013] In the light of the above, the Applicant has set itself the objective of devising a method for providing a nonwoven fabric which comprises an embossing step, in particular three-dimensional embossing, which can be included in a high productivity process line as defined above.

[0014] In particular, the Applicant has set itself the objective of devising a method for providing a nonwoven fabric with an embossing step included in a high productivity process line, which provides a three-dimensional embossed nonwoven fabric without compromising the mechanical and chemical-physical properties of the nonwoven fabric and therefore with improved characteristics compared to the embossed nonwoven fabrics produced with the state-of-the-art processes.

[0015] According to the present invention, the "three-dimensional embossing" operation is performed by means of a calender composed of two rollers and, in particular, refers to the transfer of a pattern, preferably in low relief, present on a heated roller of the calender, onto a bonded substrate of a nonwoven fabric through a counter-pressure exerted by the second roller having a lower hardness than the first roller. Heating of the substrate obtained by means of the pressure between the two rollers occurs at a temperature that allows softening and therefore three-dimensional deformation of the substrate without compromising the performance thereof.

[0016] In the present description and in the claims, the term "height" referring to a roller or a cylinder or a roll will indicate the longitudinal dimension of said roller or cylinder or roll.

[0017] For the materials of the fibers considered in the present description (for example, the already cited PE or PET), the melting temperature can vary within a range comprising a minimum value and a maximum value. In the following part of the present description and in the claims, the expression "melting temperature" associated with a given fiber material will indicate the maximum value of the above range. In the case of a mixture of different fibers, the expression "melting temperature" of the fibers will indicate the minimum melting temperature from among the melting temperatures of the materials of the various fibers composing the blend. In the case of bicomponent fibers or blends comprising bicomponent fibers, said expression will indicate the minimum melting temperature from among the melting temperatures of the materials composing the fibers. In particular, in the case of bicomponent fibers with core and sheath, the expression "melting temperature" associated with said bicomponent fibers will indicate the melting temperature of the sheath material.

[0018] According to a first aspect, the present invention provides a method for providing an embossed nonwoven fabric, the method comprising the following steps, carried out continuously one after the other:

a) providing a substrate of unbonded fibers of the nonwoven fabric;
b) performing bonding of the substrate fibers with a thermal process that reaches a bonding temperature at which bonding of the substrate fibers occurs and obtaining a bonded substrate of the nonwoven fabric; and
c) after step b), performing three-dimensional embossing of the bonded substrate at an embossing temperature lower than the bonding temperature and obtaining the embossed nonwoven fabric.

[0019] According to the present invention, step c) is performed by means of an embossing apparatus comprising one or more calenders, each calender consisting of a first roller and a second roller,

wherein the first roller comprises, at an external surface thereof, an embossing pattern,
wherein the first roller is made of a thermally conductive material and is heated,
wherein the second roller comprises, at an external surface thereof, a material with a lower hardness than the material of the first roller.

[0020] According to embodiments of the present invention, the bonding is performed by means of an air through bonding type process.

[0021] According to embodiments, the substrate of unbonded fibers comprises bicomponent fibers.

[0022] Preferably, the difference between the bonding temperature and the embossing temperature is between 10°C and 80°C. More preferably, the difference between the bonding temperature and the embossing temperature is between

13°C and 45°C.

[0023] According to these embodiments, the embossing temperature corresponds to an external surface temperature of the first roller. Preferably, the second roller is at ambient temperature.

[0024] According to embodiments, the first roller is configured to perform also a perforation of the bonded substrate.

[0025] Preferably, the first roller is made of a material with thermal conductivity greater than 5 $W \cdot m^{-1} \cdot K^{-1}$. According to embodiments, the first roller is made of a metallic material.

[0026] Preferably, the material of the second roller is a polymer material, in particular selected from among the following materials: rubber, EVA, TPU, TPE, PTFE, D3O. Preferably, the polymer material of the second roller has a hardness between 35 and 75 on the Shore A scale.

[0027] Preferably, the first roller is engraved, on the external surface thereof, with a negative embossing pattern and the second roller has a smooth external surface.

[0028] According to embodiments, the second roller is a hollow metallic cylinder coated, at the external surface thereof, by a sheath consisting of one or more layers of a polymer material (in particular selected from among the materials indicated above). The external surface of the sheath is preferably smooth. Alternatively it can comprise bristles.

[0029] According to embodiments, the second roller is provided with a cooling system.

[0030] Preferably, the first roller and the second roller have a height between 3 m and 5 m.

[0031] According to some embodiments, the method further comprises, between step b) and step c), a cooling step of the bonded substrate, in which the cooling step comprises cooling the bonded substrate to a temperature equal to or greater than the ambient temperature.

[0032] According to a second aspect, the present invention provides a system for providing an embossed nonwoven fabric, said system comprising:

- a substrate forming apparatus configured to form a substrate of unbonded fibers of the nonwoven fabric;
- a bonding apparatus configured to implement a bonding process of the substrate fibers, the bonding process being a thermal type process that reaches a bonding temperature at which bonding of the substrate fibers occurs and obtain a bonded substrate of the nonwoven fabric; and
- an embossing apparatus configured to emboss the bonded substrate provided by the bonding apparatus at an embossing temperature lower than the bonding temperature and obtain the embossed nonwoven fabric,

wherein the substrate forming apparatus, the bonding apparatus and the embossing apparatus are configured to perform the steps of, respectively, forming the substrate, implementing the bonding process and embossing the bonded substrate continuously one after the other.

[0033] The embossing apparatus comprises one or more calenders, each calender consisting of a first roller and a second roller,

wherein the first roller comprises, at an external surface thereof, an embossing pattern,
wherein the first roller is made of a thermally conductive material and is heated,
wherein the second roller comprises, at an external surface thereof, a material with lower hardness than the material of the first roller.

Brief description of the drawings

[0034] The present invention will become clearer from the following detailed disclosure, provided by way of non-limiting example, to be read with reference to the attached drawings in which:

- Figure 1 is a flow chart of the method for providing an embossed nonwoven fabric according to embodiments of the present invention;
- Figure 2 is a block diagram of a system for providing an embossed nonwoven fabric according to embodiments of the present invention;
- Figure 3a shows schematically an embossing apparatus comprising a calender for performing the embossing step of the method for providing an embossed nonwoven fabric according to embodiments of the present invention;
- Figures 3b, 3c and 3d show schematically an embossing apparatus comprising two calenders according to other embodiments of the present invention;
- Figure 4 shows schematically a portion of fibers of a bonded substrate before and after the embossing at a temperature near the melting temperature of the fibers;
- Figure 5 shows two images of a portion of a nonwoven fabric after the embossing; and
- Figure 6 shows schematically an example embossing pattern.

Detailed disclosure of embodiments of the invention

[0035] Figure 1 is a flow chart of the method for providing an embossed nonwoven fabric according to embodiments of the present invention. Figure 2 is a block diagram of an example system for providing an embossed nonwoven fabric according to the method of the present invention. The method shown in Figure 1 will be described below, by way of non-limiting example, with reference to the system shown schematically in Figure 2.

[0036] According to embodiments of the present invention, the method for providing an embossed nonwoven fabric is a method performed in line, which consists of different steps carried out continuously one after the other (namely, without interruption of the manufacturing process of the embossed nonwoven fabric), which comprises:

- a first step of preparing or forming the unbonded substrate of the nonwoven fabric (step 101);
- a second bonding step of the substrate fibers (indicated also as substrate bonding step, step 102); and
- a third step, following the second bonding step of the substrate, which comprises embossing of the substrate obtained at the end of the bonding step (step 103) to obtain the nonwoven fabric with a given three-dimensional embossing pattern imprinted.

[0037] According to the present invention, the above-mentioned steps are performed in a continuous sequential manner, namely one after the other. This does not rule out the method comprising one or more further steps between any two of the steps mentioned, which are also performed continuously with respect to the preceding step and following step, as will be described below.

[0038] The flow chart of Figure 1 also shows a fourth step of winding the embossed nonwoven fabric in rolls (step 104).

[0039] The example system of Figure 2 comprises:

- at least one mixing device 21 configured to mix the fibers that compose the nonwoven fabric substrate. In particular, the system of Figure 2 comprises a mixing device 21 configured to provide a mixture of fibers;
- a substrate forming apparatus 22 configured to form, from the blends of fibers produced by the at least one mixing device 21, an unbonded substrate of the nonwoven fabric;
- a bonding apparatus 23 configured to implement a bonding process to bond the fibers of the unbonded substrate of the nonwoven fabric. Preferably, it is a thermal bonding process. The bonding apparatus 23 is in particular configured to cause bonding of the nonwoven fabric substrate at a certain bonding temperature Tc. The expression "bonding temperature" indicates the temperature at which bonding of the unbonded substrate occurs. As known, said temperature depends on numerous factors and process parameters, including the material of the fibers of which the unbonded substrate is composed, the basis weight, the linear density or thread count of the fibers, the speed of the line, etc. In particular, according to embodiments of the present invention, the bonding temperature Tc corresponds to the maximum temperature reached in the bonding apparatus 23. According to embodiments of the present invention, the bonding temperature Tc is near the melting temperature of the fibers. According to some embodiments of the present invention, the difference between the bonding temperature Tc and the melting temperature of the fibers can be between -6°C and +6 °C. According to other embodiments, the bonding temperature Tc can be much higher than the melting temperature of the fibers, as will be described in further detail below; and
- an embossing apparatus 24 configured to emboss the nonwoven fabric provided by the bonding apparatus. The embossing apparatus 24 is in particular configured to perform the embossing at an operating temperature that allows softening of the substrate and the deformation thereof along the nonwoven fabric production line, after bonding of the substrate. According to the present invention, the operating temperature of the embossing apparatus 24 (also called embossing temperature Te) is below the bonding temperature Tc of the bonding apparatus. According to embodiments of the present invention, in particular, the difference between the bonding temperature Tc and the embossing temperature Te is between 10°C and 80°C, more preferably between 13°C and 45°C.

[0040] Lastly, the system of Figure 2 comprises a winding device 25 configured to wind in rolls the embossed nonwoven fabric provided by the embossing device 24, and a cutting apparatus 26 configured to cut said rolls.

[0041] The first step 101 of the method shown in Figure 1 comprises forming the substrate of the nonwoven fabric from a certain type of fiber or from one or more blends of fibers. The fibers can be:

- synthetic fibers such as, for example, bicomponent polyolefin and/or polyester fibers like the already mentioned PET/PE bicomponent fibers, or PET/CoPET or PP/PE (namely, polypropylene/polyethylene bicomponent fibers), or PET/PP (namely, polyethylene terephtalate/polypropylene bicomponent fibers);
- natural fibers such as, for example, cotton, linen, hemp, etc.; and
- artificial fibers of other type such as, for example, viscose, lyocell, etc.

[0042] In the example system schematically shown in Figure 2, the fibers to be mixed are fed to the mixing device 21 by means of respective feeders. The mixing device is of known type and therefore will not be further described below. According to embodiments of the present invention, the mixture of fibers contains synthetic bicomponent fibers, for example PET/PE. For example, the mixing device 21 can receive PET/PE synthetic bicomponent fibers and artificial fibers such as, for example, viscose from respective feeders and mix said fibers in a proportion of 70/30 (namely, the resulting blend comprises 70% of bicomponent fibers and 30% of viscose).

[0043] According to other embodiments of the present invention, several fiber mixtures can be obtained, for example two, having different fiber compositions or the same fiber composition but in different percentages, according to the type of application for which the resulting nonwoven fabric is intended.

[0044] Once the fibers have been mixed, the one or more fiber blends are sent, for example through a pneumatic system of centrifugal fans not shown in Figure 2, to the substrate forming apparatus 22.

[0045] According to embodiments of the present invention, the substrate forming apparatus 22 comprises at least a carder, to which the fiber mixtures are supplied to form the nonwoven fabric substrate. The carder 22 is preferably a known carder, and for this reason further details will not be provided here. As known, a carder forms an unbonded substrate, also called web, ordering the fibers mainly in the longitudinal direction with respect to the carder line (namely, the so-called machine direction or MD). The carder 22 can, for example, produce webs having a basis weight between 14 g/m^2 and 120 g/m^2.

[0046] The web provided by the carder 22 is then conveyed to the bonding apparatus 23 for example via conveyor belts (not shown in Figure 2). In the bonding apparatus 23 the bonding step 102 of the method according to the present invention is then carried out.

[0047] According to the present invention, the bonding occurs by means of a thermal process. In particular, according to embodiments of the present invention, the bonding apparatus 23 comprises an oven configured to implement an "Air Through Bonding" (ATB) type process to bond the unbonded substrate provided by the carder 22. This advantageously allows a nonwoven fabric to be obtained with a high level of softness and fluffiness. In particular, for example, the oven 23 can be a horizontal oven with several sections (for example, five sections). More in particular, it can be, for example, a horizontal oven of the RegulAirHS "Speedliner" type produced by Schott & Meissner Maschinen- und Anlagenbau GmbH, Blaufelden, Germany. According to alternative embodiments of the present invention, the oven 23 can be a vertical oven or a circular oven. The operation of an oven of the above-mentioned type is known and will therefore not be further described below.

[0048] As already anticipated above, according to embodiments of the present invention, at least one of the fiber blends supplied to the carder 22 contains bicomponent fibers (for example, PET/PE), namely fibers with a low melting point or low-melting component. In this case, in the oven 23, due to the action of the air temperature and the forced convection produced in the oven, the low-melting material of the coating of the bicomponent fibers (e.g. PE) melts and creates fixing points between the cores of the fibers (in PET, for example).

[0049] The following Table 1 shows some examples of substrates comprising bicomponent fibers or blends with bicomponent fibers used to provide an embossed nonwoven fabric according to the present invention. The first column shows the type of synthetic fibers used or the blend of synthetic fibers used and the features of the substrate in terms of basis weight (in gsm, namely grams per square meter) and linear density or thread count (in dtex). The second column shows the low-melting component of the fibers considered and the third column shows the melting temperature range of the low-melting component.

Table 1

	Substrate	**Low-melting component**	**Melting temperature range**
1	PET/PE bicomponent 35 gsm; 2.2 dtex	PE	130°C-138°C
2	PP/PE bicomponent 30 gsm; 2.0 dtex	PE	130°C-138°C
3	PET/PP bicomponent 35 gsm; 5.8 dtex	PP	160°C-170°C
4	blend with: 50% PET/CoPET 50% PET 35 gsm; 4.4 dtex	CoPET	110°C-130°C

[0050] During the bonding step 102, the oven 23 is preferably operated at a temperature that causes bonding of the substrate. This operating temperature of the oven 23 is the bonding temperature Tc. In particular, according to embodiments of the present invention, the bonding temperature Tc is the maximum temperature reached in the oven 23. According to embodiments of the present invention, the bonding temperature Tc is between approximately 120°C and approximately 200°C. Furthermore, inside the oven, the hot air is blown onto the unbonded substrate by means of blowers (the speed of which will be indicated in rpm). According to the embodiments indicated above, the blower speed can vary between 500 rpm and 1600 rpm.

[0051] The following Table 2 shows some parameters relative to the bonding operation of the example substrates shown in Table 1. In Table 2, from the second to the sixth column, the temperatures reached in the sections of the example oven cited above and the relative blower speeds are shown. Furthermore, Table 2 shows the mean speed of the process line feed (indicated in m/min) relative to the production of an embossed nonwoven fabric from the above-mentioned example substrates.

Table 2

Substrate	Sec. 1	Sec. 2	Sec. 3	Sec. 4	Sec. 5	Speed [m/min]
1	128°C 500 rpm	134°C 800 rpm	136°C 1150 rpm	138°C 1250 rpm	138°C 1250 rpm	100
2	128°C 600 rpm	134°C 800 rpm	136°C 1000 rpm	137°C 1150 rpm	137°C 1150 rpm	130
3	154°C 700 rpm	158°C 1150 rpm	160°C 1150 rpm	164°C 1400 rpm	164°C 1400 rpm	130
4	196°C 1400 rpm	196°C 1450 rpm	198°C 1500 rpm	198°C 1550 rpm	200°C 1600 rpm	160

[0052] As is clear from the parameters shown in Table 2, in the example cases of the substrates 1, 2 and 3 the bonding temperature Tc (namely, in these examples, the maximum temperature reached in the oven) is near to the melting temperature of the low-melting component of the bicomponent fibers, whereas if the blend comprising 50% of PET/CoPET bicomponent fibers and 50% PET fibers is used, the bonding temperature Tc is much higher than the melting temperature of the PET/CoPET bicomponent fibers comprised in the blend. In this case, it should be noted that, in the substrate considered, the overall PET part (for which the melting temperature range is between 260°C and 280°C) is approximately 75% and the remaining material is CoPET. In the example case considered here, the line speed is increased up to 160 m/min to increase productivity. With this line speed and with the composition indicated in Table 1 (thick fibers at 4.4 dtex), the bonding temperature Tc must be increased to 200°C to allow bonding of the substrate by melting of the CoPET. From the above, it is clear that the fine setting of the bonding temperature Tc and, in the specific case described above, of the temperatures of the various oven sections, and of the blowers' speed is closely linked to the characteristics of the substrate considered and the line feed rate.

[0053] At the end of the bonding step 102, the oven 23 provides a substrate of bonded fibers (bonded substrate).

[0054] At this point, the method comprises an embossing step 103 of the product provided by the oven 23 to obtain the nonwoven fabric according to the present invention. In particular, the embossing step 103 is performed by means of the embossing apparatus 24, which will be described below.

[0055] According to some embodiments of the present invention not shown in the drawings, the method can comprise a cooling step, between the bonding step 102 and the embossing step 103. The cooling step can be performed partly in the bonding apparatus. For example, the oven of the bonding apparatus can comprise a cooling cylinder through which the bonded substrate is passed if said cooling step is envisaged. Additionally or alternatively, the system, according to these embodiments of the present invention, can comprise a cooling device such as, for example, a cooling suction belt configured to cool the bonded substrate by the passage of air at ambient temperature. The optional cooling apparatus can be configured to bring the bonded substrate to ambient temperature (for example, approximately 25°C) or to maintain the bonded substrate at a temperature higher than the ambient temperature by, for example, approximately 10°C. The cooling step allows control of the bonded substrate temperature before it undergoes the embossing step. In particular, maintaining the bonded substrate at the embossing apparatus inlet at a temperature higher than the ambient temperature constitutes a pre-heating which can facilitate the subsequent embossing step.

[0056] According to preferred embodiments of the present invention, the embossing apparatus 24 comprises one or more calenders each consisting of a pair of rollers, in particular a pair of counter-rotating rollers. Figure 3a shows schematically the embossing apparatus 24 according to some embodiments of the present invention, comprising a single calender (also indicated in Figure 3a by the reference number 24). The calender 24 comprises a first roller 31 and a second roller 32.

[0057] The first roller 31 preferably comprises a cylinder made of a thermally conductive material. In particular, preferably, the material of the first roller 31 has thermal conductivity greater than 5 $W \cdot m^{-1} \cdot K^{-1}$. Preferably, the material of the first roller 31 is made of metal or metal alloy, for example iron or steel. The first roller 31 preferably comprises, at the external surface thereof, an embossing artwork or pattern corresponding to a three-dimensional design to be imprinted on the nonwoven fabric. In particular, preferably, the embossing pattern is engraved on the first roller 31 in low relief, namely such that the nonwoven fabric is negatively embossed; in this case the contact points with the nonwoven fabric are defined by the contour of the pattern. This advantageously reduces the risk of alteration of the properties of the nonwoven fabric. The first roller 31 is preferably engraved in low relief with a percentage between 40% and 90%, more preferably between 60% and 80%. The engraving depth is preferably between approximately 0.5 mm and 2.5 mm.

[0058] The first roller 31 has preferably a height between 3 m and 5 m, for example 3.7 m, and a diameter preferably between 20 cm and 120 cm, for example 50 cm.

[0059] According to embodiments of the present invention, the first roller 31 is configured to perform also a perforation of the bonded substrate of the nonwoven fabric. In particular, according to these embodiments, the first roller 31 can comprise, on the external surface thereof, protuberances or positive reliefs with height between approximately 0.2 mm and approximately 4 mm in order to provide holes in the bonded substrate having variable dimension and shape, with density of the holes between 4 holes/cm^2 and 25 holes/cm^2.

[0060] According to the present invention, the second roller 32 comprises, at the external surface thereof, a material having a lower hardness than the material of the first roller 31. Preferably, the material of the second roller 32 (in particular, the material present at the external surface thereof) is a polymer material. In particular, according to embodiments of the present invention, the second roller 32 comprises a hollow cylinder, for example made of a metallic material, coated by a sheath comprising one or more layers of polymer material. Alternatively, the second roller 32 can comprise a solid cylinder made of a polymer material. The external surface of the second roller 32 is preferably smooth. Alternatively, it can comprise bristles. The polymer material is preferably selected from: rubber, EVA (ethylene vinyl acetate), TPU (thermoplastic polyurethane), TPE (thermoplastic elastomer), PTFE (polytetrafluoroethylene), D3O (elastomeric expansion polymer), or is a mixture of one or more of the above-mentioned materials (for example a mixture of rubber and EVA). According to embodiments of the present invention, the second roller 32 comprises a polymer material which has a hardness preferably between 35 and 75 on the Shore A scale, more preferably between 50 and 60. Advantageously, the presence of a sheath with several layers of different materials allows the characteristics of the second roller to be modified according to the process: for example, the second roller can be provided with an antifriction external layer, for example made of PTFE, to improve resistance to abrasion, particularly useful if the first roller comprises positive reliefs for providing holes in the bonded substrate.

[0061] According to embodiments of the present invention, the sheath of the second roller 32 can have a thickness between 2 mm and 30 mm.

[0062] The second roller 32 preferably has a height between 3 m and 5 m, for example 3.7 m, and an overall diameter between 30 cm and 120 cm.

[0063] The distance between the external surface of the first roller 31 and the surface of the second roller 32 in the calender 24 can be between 0 mm (namely, the rollers can be in contact) and 7 mm depending on the pattern to be transferred and the thickness of the substrate to be processed.

[0064] The first roller 31 and the second roller 32 of the calender 24 rotate preferably at a speed between 80 m/min and 140 m/min.

[0065] The pressure between the first roller 31 and the second roller 32 (namely, the pressure along the contact line, indicated also as crushing pressure or calendering pressure) can be between approximately 7.5 kN/m and approximately 100 kN/m, in particular between approximately 25 kN/m and approximately 70 kN/m.

[0066] The first roller 31 is preferably heated so that its surface temperature (which corresponds to the temperature transferred to the bonded substrate from this embossing apparatus 24 during the embossing step 103, namely the embossing temperature Te) is lower than the bonding temperature Tc. The surface temperature of the first roller 31 is the temperature of the external surface of the roller. According to embodiments of the present invention, in particular, the difference between the bonding temperature Tc and the embossing temperature Te is between 10°C and 80°C, more preferably between 13°C and 45°C.

[0067] Table 3 shows the embossing temperature Te (second column) and the calendering pressure (third column) for the example substrates mentioned above. Both for the embossing temperature and for the calendering pressure, possible value ranges are shown for the examples considered.

Table 3

Substrate	Temperature Te	Pressure [kN/m]
1	115°C - 120°C	25 - 40
2	115°C - 120°C	25 - 40
3	120°C - 150°C	25 - 50
4	120°C - 150°C	25 - 50

[0068] The first roller 31 can be heated by means of a diathermic oil circuit or by means of electric resistances (not shown in the drawings), which provide a constant temperature over the whole external surface of the first roller 31. Due to the thermal dissipation of the cylinder (which also depends on the embossing pattern engraved in it), the heating temperature of the diathermic oil is preferably set to a value higher than the desired value of the surface temperature of the first roller 31; for example, the value set for the heating temperature of the oil can be approximately 20°C higher than the desired surface temperature value to be reached.

[0069] The second roller 32 is preferably at ambient temperature and can undergo induction heating by the first roller 31. The second roller 32 can be provided with an external cooling system, by means of air, or internal cooling system, by water, to counter the deterioration of the polymer material due to the heating thereof.

[0070] As already anticipated above, according to the present invention, the embossing temperature Te is lower than that obtained during the bonding with melting of the fibers. In particular, the embossing temperature Te is preferably selected so as not to re-induce a bonding effect in the nonwoven fabric substrate, namely so as not to induce new melting of the material of the fibers that would tend to stick together. This would cause a deterioration of the properties of the nonwoven fabric in terms of softness to touch and "visual" fluffiness. As is clear from Table 3, for the processes that involve the substrates 1, 2 and 3, the embossing temperature Te is lower than the bonding temperature Tc and the melting temperature of the substrate fibers. In the case of the substrate 4, the embossing temperature Te is lower than the bonding temperature Tc (200°C) but can be higher than the melting temperature of the bicomponent fibers of the blend. This depends on the other process parameters. In this case, in fact, given the conditions of the substrate considered (which has thick fibers at 4.4 dtex) and the speed of the line, the embossing temperature selected in the range indicated does not cause further bonding of the fibers.

[0071] The second roller 32, having a lower hardness inferior than the first roller 31, allows transfer onto the substrate of the negative pattern engraved on the first roller 31, because it allows indentation and therefore penetration of the substrate by the first roller 31, which would not be possible if it were also made of metal or of equal hardness.

[0072] As is clear from the preceding description, during the process described so far, the nonwoven fabric substrate undergoes two different thermal actions in which it is heated to a certain temperature transferred by convection by means of blowers into the oven 23 and then by conduction by means of cylinder pressure into the calender 24, and the temperature transfer occurs as a function of the feed rate of the substrate along the production line. The heating of the unbonded substrate during the bonding step allows the fibers to be bonded while the subsequent heating during the embossing step allows the material to be softened and deformed. The different process parameters can vary according to the thermal conductivity of the materials and the specific heat of the component fibers. For example, a material with a high specific heat can absorb a large quantity of heat without a significant increase in temperature. This means that, if a substrate has a high specific heat, it could take longer to heat up when exposed to a heat source, compared to a substrate with a low specific heat.

[0073] Consequently, the composition of the substrate, its basis weight, the temperature, together with the pressure and feed rate of the line, are all parameters that determine the conditions necessary for reaching first the melting temperature of the fibers involved in the bonding and subsequently the temperature that allows deformation for the three-dimensional embossing.

[0074] Returning to what is shown schematically in Figure 3a, during the embossing step 103 the nonwoven fabric provided by the oven 23 is conveyed towards the calender 24 by means of intermediate rollers, for example. The reference letters A and B indicate the two sides of the nonwoven fabric.

[0075] As it passes through the calender 24, the product provided by the oven 23, due to the crushing pressure of the two rollers 31, 32 and the surface temperature of the first roller 31, is embossed and the embossing pattern is imprinted on side A, so that the bonded substrate acquires the three-dimensional design defined by said pattern. After passing through the calender 24, the side indicated in the Figure by the letter A' comprises the three-dimensional design imprinted in positive relief by the calender 24; the side indicated by the letter B' comprises a negative design.

[0076] Advantageously, as already mentioned, thanks to the combined action of the first roller 31 and the second roller 32 which, due to the presence of the polymer material, yields to the penetration of the engraving present on the first roller 31, the nonwoven fabric is imprinted with a three-dimensional design without compromising the softness and fluffiness guaranteed by the thermally bonded substrate.

[0077] Figures 3b, 3c and 3d show an embossing apparatus 24 according to other embodiments of the present invention, comprising a first calender 24a and a second calender 24b. Each calender comprises a first roller, engraved with an embossing pattern, and a second roller and is identical to the one described with reference to Figure 3a. The addition of a second calender means that the side on which to perform the embossing can be selected or embossing effects can be conferred to the bonded substrate on both sides. The embossing pattern of the rollers of the two calenders can be different, thus obtaining a nonwoven fabric embossed with different patterns on the two opposite sides.

[0078] In particular, Figure 3b shows an embossing apparatus 24 comprising a first calender 24a comprising a first roller 31 and a second roller 32 and a second calender 24b comprising a first roller 31' and a second roller 32'. The first roller 31' of the second calender 24b is engraved with an embossing pattern which can be the same as or different from the embossing pattern engraved on the first roller 31 of the first calender 24a. According to this configuration schematized in Figure 3b, the first calender 24a, which is configured to perform the embossing on side A of the bonded substrate, is not in contact with the bonded substrate and therefore does not carry out any embossing. The second calender 24b is configured to carry out embossing on side B of the bonded substrate and is brought into contact with the bonded substrate (after passing through the calender 24b, the letter B' indicates the side of the nonwoven fabric on which the embossing pattern is imprinted, and the letter A' indicates the opposite side). According to these embodiments of the present invention, therefore, the embossing apparatus 24 can be configured to carry out alternate embossing of side A or side B of the bonded substrate.

[0079] Figure 3c shows an embossing apparatus comprising a first calender 24a and a second calender 24b similar to those shown schematically in Figure 3b, configured to carry out the embossing (with the same pattern or with different patterns) of both sides A and B of the nonwoven fabric. Figure 3d shows an embossing apparatus comprising a first calender 24a and a second calender 24b similar to those shown schematically in Figure 3b and in Figure 3c, configured to carry out a first and a second embossing of the same side A of the nonwoven fabric.

[0080] As is clear, the presence of a pair of calenders in the embossing apparatus allows combinations like those schematized in Figure 3b-3d via which different effects can be obtained on the two sides of the nonwoven fabric.

[0081] Figure 4 shows schematically a portion of the fibers of a bonded substrate and the effect that would be obtained by carrying out an embossing step at a temperature near the one that allows bonding of the fibers of the substrate considered. On the left some fibers of the bonded substrate are shown and on the right the same fibers in the condition they would assume after an embossing step in which the temperature is brought to a value near the one reached for the bonding. As is clear, in some points the fibers tend to stick together causing deterioration of the properties of the nonwoven fabric which, at the points where the fibers have stuck together, feels harder to the touch.

[0082] Figure 5 shows two images obtained by scanning electron microscope (SEM) which show a portion of a bonded substrate comprising PP/PE bicomponent fibers with a basis weight of 20 g/m^2 which has undergone a bonding step in an example oven of the type described above, at a maximum temperature of approximately 135°C at 1200 r.p.m. with a feed rate of 110 m/min. The image on the left to scale 20:1 and the one on the right enlarged to scale 100:1 show the portion of the bonded substrate at the end of an embossing step performed at an operating temperature of 130°C, namely a value near the melting temperature of the PE fiber coating. As is clear, if during the embossing step the fibers are subject to a temperature near the temperature that allowed bonding of the substrate, namely, in this case, a temperature near the melting temperature, they tend to lose their circular section and stick to one another, as shown in detail in the enlarged image on the right.

[0083] Figure 6 shows schematically an example of an embossing pattern that has a contact area of approximately 25%.

[0084] Downstream of the embossing step 103, the embossed nonwoven fabric can be conveyed to the winding device 25, where it can be wound in rolls (step 104) with height up to 3.6 m and diameter up to 2.5 m. The winding device 25 can comprise winding rollers. The rolls can be conveyed to the cutting apparatus 26 (for example a cutter) where they can be cut, before transportation, according to customer requirements.

[0085] The embossed nonwoven fabric provided according to the method of the present invention can be used for hygiene articles such as nappies, sanitary pads and adult incontinence products. An article of the type just mentioned, as known, typically comprises a top sheet which is in contact with the user's skin, a back sheet which is the outermost layer, coupled with a film made of PE, for example, and an acquisition distribution layer (ADL) positioned below the top sheet, which has the job of receiving and distributing the liquid particles over an absorbent core positioned between the ADL and the back sheet. The embossed nonwoven fabric provided via the method of the present invention has characteristics that make it advantageously usable both in the top sheet and in the back sheet, due to its softness and fluffiness to the touch and its visual appearance provided by the three-dimensional design imprinted. Furthermore, if used for the ADL, the nonwoven fabric of the present invention, when embossed with a pattern with at least partially continuous lines, channels the liquids and speeds up transpiration.

Claims

1. A method for providing an embossed nonwoven fabric, said method comprising the following steps, performed continuously one after the other:

a) providing a substrate of unbonded fibers of the nonwoven fabric;
b) performing a bonding of said fibers of said substrate with a thermal process reaching a bonding temperature at which said bonding of said fibers of said substrate occurs and obtaining a bonded substrate of said nonwoven fabric; and
c) after said step b), carrying out a three-dimensional embossing of said bonded substrate at an embossing temperature lower than said bonding temperature and obtaining said embossed nonwoven fabric,
wherein said step c) is performed by means of an embossing apparatus (24) comprising one or more calenders

(24; 24a, 24b), each calender consisting of a first roller (31) and a second roller (32),
wherein said first roller (31) comprises, at an external surface thereof, an embossing pattern,
wherein said first roller (31) is made of a thermally conductive material and is heated,
wherein said second roller (32) comprises, at an external surface thereof, a material with a lower hardness than the material of said first roller (31),
and wherein said embossing temperature corresponds to an external surface temperature of said first roller (31).

2. The method according to claim 1, wherein said bonding is carried out by means of an air through bonding type process.

3. The method according to claim 1 or 2, wherein said substrate of unbonded fibers comprises bicomponent fibers.

4. The method according to any one of the preceding claims, wherein the difference between said bonding temperature and said embossing temperature is between 10°C and 80°C.

5. The method according to any one of the previous claims, wherein said first roller (31) is configured to perform also a perforation of said bonded substrate.

6. The method according to any one of the preceding claims, wherein said material of said second roller (32) is a polymeric material selected from the following materials: rubber, EVA, TPU, TPE, PTFE, D3O.

7. The method according to any one of the preceding claims, wherein the first roller (31) is engraved, on said external surface thereof, with a negative embossing pattern and wherein the second roller (32) has a smooth external surface.

8. The method according to any one of the preceding claims, wherein the second roller (32) is equipped with a cooling system.

9. A system for providing an embossed nonwoven fabric, said system comprising:

- a substrate forming apparatus (22) configured to form a substrate of unbonded fibers of said nonwoven fabric;
- a bonding apparatus (23) configured to implement a process for bonding said fibers of said substrate, said bonding process being a thermal process reaching a bonding temperature at which said bonding of said fibers of said substrate occurs and obtain a bonded substrate of said nonwoven fabric; and
- an embossing apparatus (24) configured to emboss said bonded substrate provided by the bonding apparatus (23) at an embossing temperature lower than said bonding temperature and obtain said embossed nonwoven fabric, wherein said substrate forming apparatus (22), said bonding apparatus (23) and said embossing apparatus (24) are configured to perform the steps of, respectively, forming said substrate, implementing said bonding process and embossing said bonded substrate continuously one after the other,

wherein said embossing apparatus (24) comprises one or more calenders (24; 24a, 24b), each calender consisting of a first roller (31) and a second roller (32),
wherein said first roller (31) comprises, at an external surface thereof, an embossing pattern,
wherein said first roller (31) is made of a thermally conductive material and is heated,
wherein said second roller (32) comprises, at an external surface thereof, a material with a lower hardness than the material of said first roller (31),
and wherein said embossing temperature corresponds to an external surface temperature of said first roller (31).

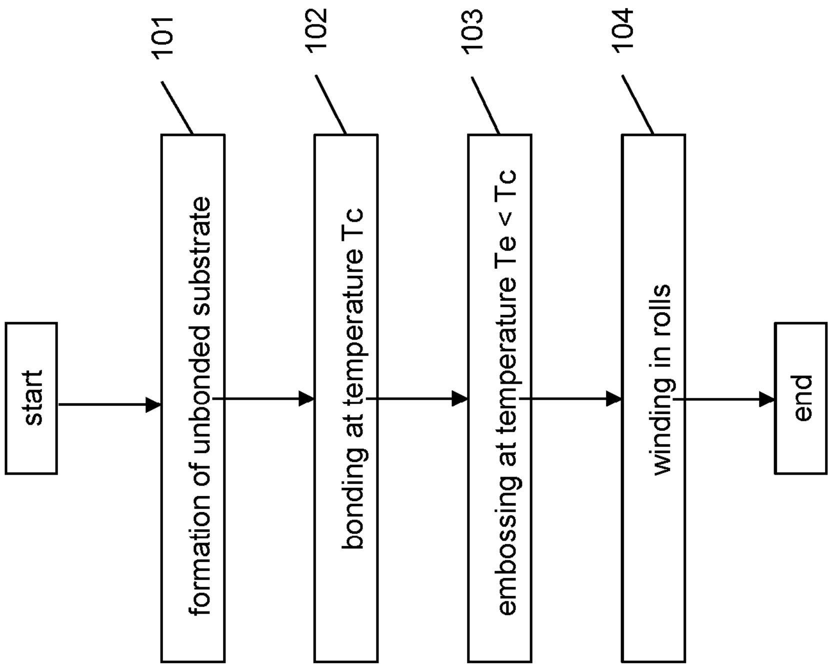
start
formation of unbonded substrate
101
bonding at temperature Tc
102
embossing at temperature Te < Tc
103
winding in rolls
104
end

Fig. 1

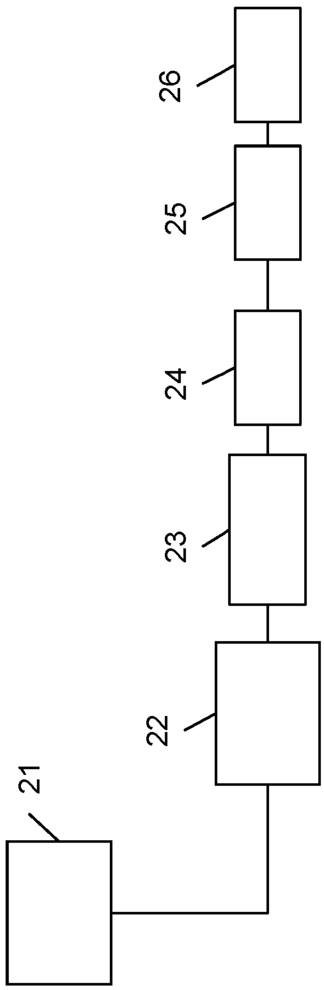

Fig. 2

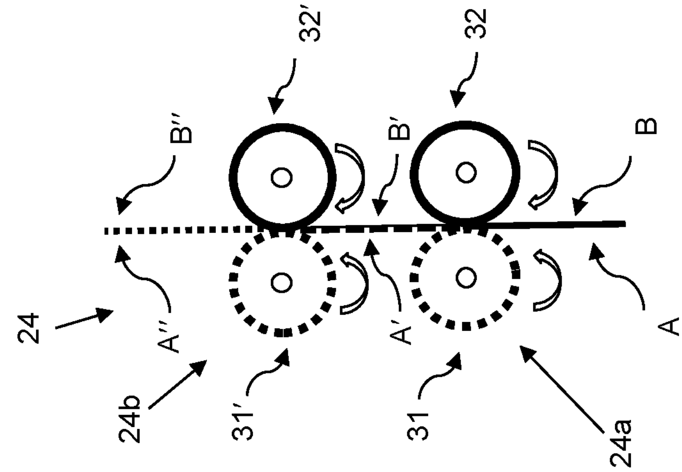

Fig. 3d

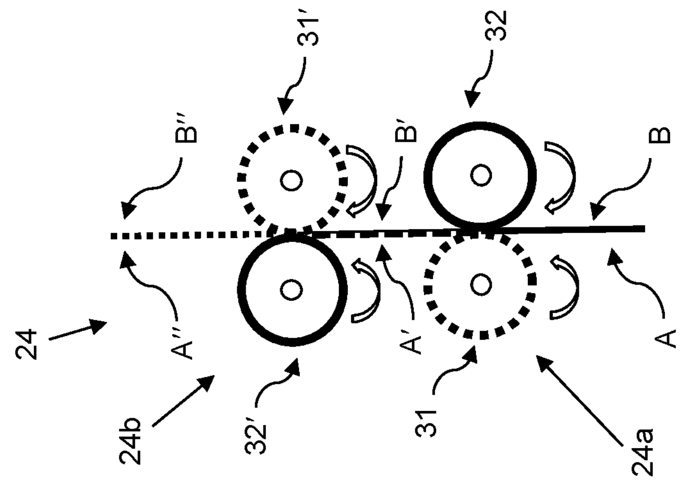

Fig. 3c

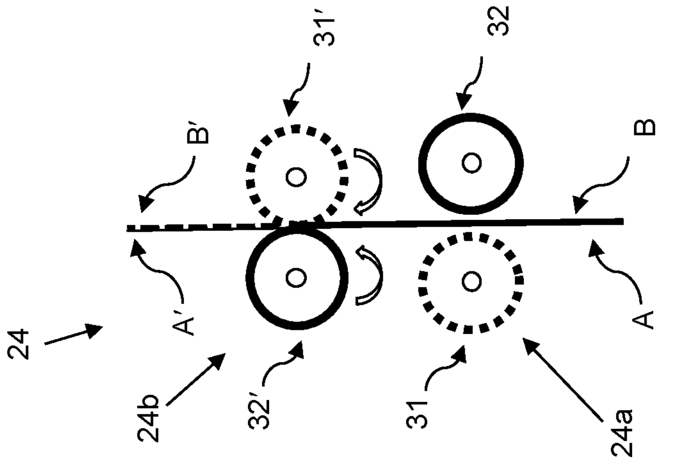

Fig. 3b

Fig. 4

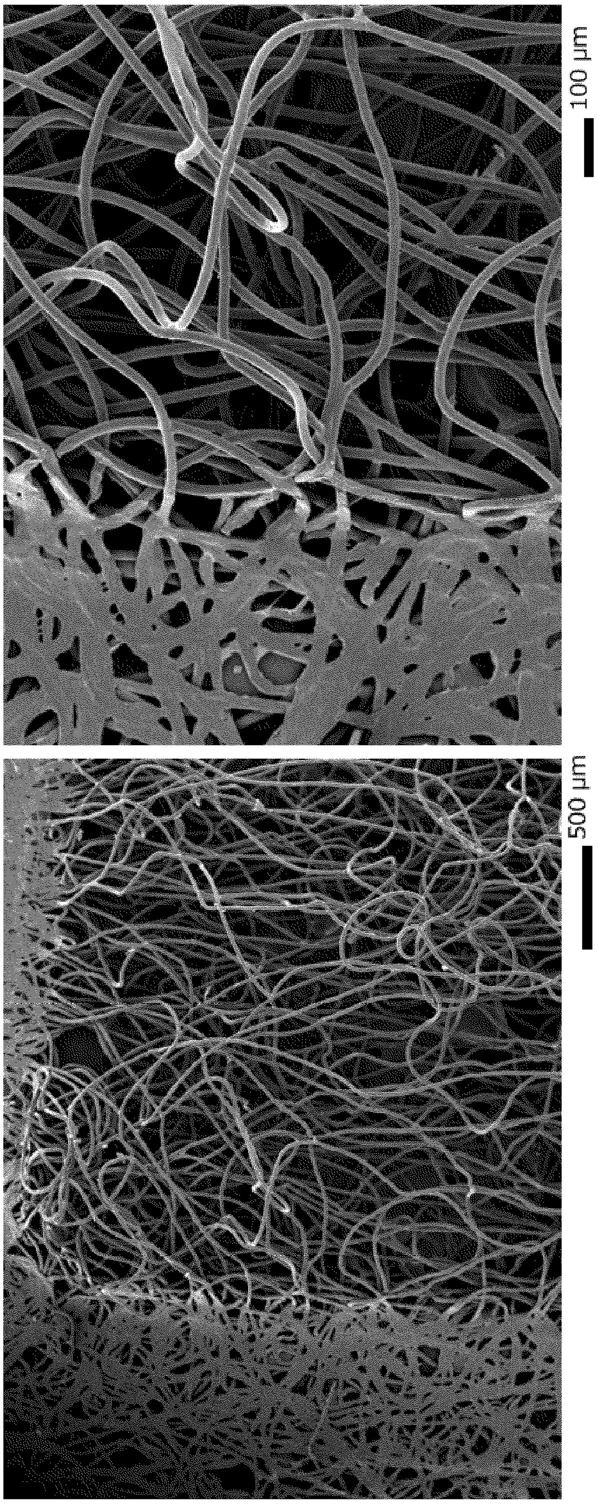

Fig. 5

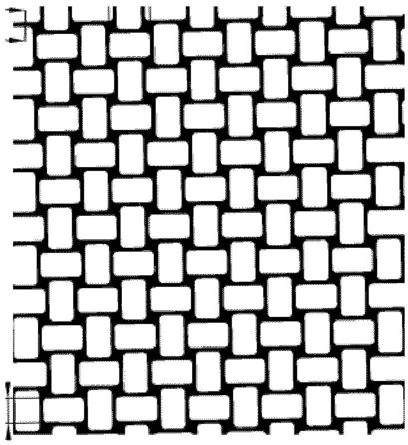

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 24 22 2786

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Y	* figure 2; examples 1-7; table 1 *	1-9	
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D04H

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	28 March 2025	Saunders, Thomas

CATEGORY OF CITED DOCUMENTS

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