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(71) Applicant: **FIBER INNOVATION TECHNOLOGY, INC.** [US/US]; 398 Innovation Drive, Johnson City, TN 37604 (US).

(72) Inventor: **KAPSALI, Veronika**; 231 Stanstead Road, Bishops Stortford, Hertforshire CM23 2BT (GB).

(74) Agent: **NESBITT, Daniel F.**; Hasse & Nesbitt LLC, 8837 Chapel Square Drive, Suite C, Cincinnati, OH 45249 (US).

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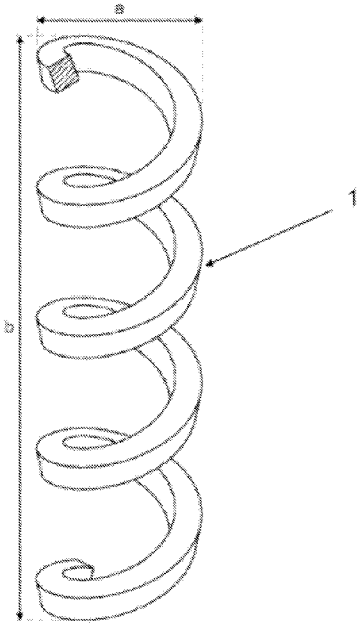


Fig. 1a

(57) Abstract: A non-woven fabric contains one or more webs, and one or more partial or complete incisions in at least one of the webs. Each of the one or more webs containing a plurality of shape-changing fibres activatable by an external stimulus and being orientated within the plane of the one or more webs. In response to activation by the external stimulus, the shape-changing fibres change shape such that the one or more partial or complete incisions widens. Also described herein is a method for making such a non-woven fabric and a non- woven fabric where in response to activation by the external stimulus the shape-changing fibres are configured to respond such that the thickness of the one or more webs decreases

Adaptive fabrics

Field of the Invention

[0001] This disclosure relates generally to fabrics, and in particular to fabrics with autonomous, adaptive ventilation and insulation.

Background of the Invention

[0002] Textiles comprise any manufacture from fibres, filaments, or yarns and are characterized by flexibility, fineness, and a high ratio of length to thickness. A fabric is a flexible material consisting of a network of natural or artificial fibres and may be made through weaving, knitting, spreading, crocheting, or bonding that may be used in production of further goods, such as clothing/garments, for example footwear and apparel. Fabrics for industrial uses in fields such as medical, filtration and insulation, are also gaining importance.

[0003] The many types of modern textile fabrics, produced from both traditional and man-made materials, are often classified according to structure and generally fall into two categories: fabrics formed through a mechanical manipulation and interlacing of yarn, which includes woven and knitted types, lace, nets, and braid; and fabrics produced from fibre masses including those produced by bonding, felting, fusing or interlocking to construct non-woven fabrics and felts. A yarn is a long continuous length of interlocked fibres, suitable for use in the production of textiles, sewing, crocheting, knitting, weaving, embroidery and ropemaking.

[0004] Fibres are units of matter having length at least 100 times their diameter or width. Fibres suitable for textile use possess adequate length, fineness, strength, and flexibility for yarn formation and fabric construction and for withstanding the intended use of the completed fabric. Conventional natural fibres that are used in yarns, such as cotton, wool and flax and also man-made regenerated fibres, such as rayon, swell as they absorb moisture. This causes the yarn to swell which in turn reduces the air permeability of the textile structure. In recent times, addition to mechanical improvements in yarn and fabric manufacture, there have been rapid advances in development of new fibres, as well as in processes to improve textile characteristics.

[0005] Clothing may incorporate fabrics/materials that are specifically selected for particular environmental conditions. Examples of various types of articles of clothing include shirts,

headwear, coats, jackets, trousers, underwear, gloves, socks, and footwear. The characteristics of the fabrics that are incorporated into clothing are generally selected based upon the specific activity for which the clothing is intended to be used. One of the primary purposes of fabrics in the clothing industry is to keep the wearer of the clothing warm, although clothing is also worn as a fashion accessory. As a result, clothing is often designed and worn to provide a desired level of insulation for a wearer.

[0006] Within the textile industry there are many applications where a humidity responsive material would be useful. For example, in the modern urban environment people are constantly moving between hot and humid environments to air-conditioned buildings. With such a lifestyle it is difficult to remain comfortable in all conditions, as different clothes will be suitable for different environments. It is known that people feel particularly uncomfortable when they are hot and sweaty from walking. The level of discomfort is more closely related to a feeling of damp clothing than it is to temperature. It is therefore desirable to be able to alter the insulation and/or ventilation properties of the fabric according to the moisture levels in the environment.

[0007] For clothing designed for a purpose such as sports, where a wearer may overheat, breathable fabrics are sometimes used. Known breathable fabrics include those made from thinner materials and finer yarns, moisture-wicking and quick-drying materials that evaporate moisture away from the skin, loose fitting clothing and clothing that includes web panels. For example, a fabric that reduces the quantity of perspiration that accumulates adjacent to the skin may be most appropriate for athletic activities commonly associated with a relatively high degree of exertion. Accordingly, fabric may be selected to enhance the performance or comfort of individuals engaged in specific activities.

[0008] Other garments designed to help manage the level of insulation include those with inserts that can inflate and deflate with air. Inflation and deflation are controlled by mini pumps and microcontrollers. Goretex has also launched a non-mechanical inflatable version of a garment that inflates and deflates called AirVantage. Other garments designed to help manage the level of insulation include include those made with a nonwoven material made of fibres coated with a special material that expands and contracts in response to temperature. However, the shape change in relation to the change in temperature is minimal, making this an ineffective mechanism.

[0009] Other active insulation products include: Thermobal, Octa® Loft, Patagonia Nano-

puff, Arcteryx Proton, which are engineered non-wovens designed to either stay warm when wet, be superlight, or be breathable. None of these materials are adaptive, which is to say that they cannot change their insulation properties during use. North Face Vantrix is a non-woven insulation fabric with perforations designed to open when stretched during movement. However, this relies on movement of the user and is found to be ineffective during use.

[0010] An alternative, known approach, incorporates flaps in the fabric that are designed to curl upwards to create holes in the fabric in damp conditions. This mechanism is based on a flap curling away from the plane of the fabric in the z direction, which is vertical in relation to the plane of the fabric which lies in the x,y plane). This approach is limited because, where the insulation material is used as a component within a garment, the pressure exerted by any adjoining or adjacent fabric or body part will prevent the flap from opening, which makes them ineffective for adaptively managing the level of insulation of a garment under these and other circumstances.

[0011] The present invention seeks to address these and other disadvantages encountered in the prior art by providing an improved fabric with adaptive insulation properties that can function in a wide variety of applications.

Summary of the Invention

[0012] In an embodiment of the present invention relates to a non-woven fabric contains one or more webs, and one or more partial or complete incisions in at least one of the webs. Each of the one or more webs containing a plurality of shape-changing fibres activatable by an external stimulus and being orientated within the plane of the one or more webs. In response to activation by the external stimulus, the shape-changing fibres change shape such that the one or more partial or complete incisions widens.

[0013] Another embodiment of the present invention relates to a method for producing a fabric as described herein, having the steps of: spinning a plurality of shape-changing fibres into a web, and making one or more partial or complete incisions in the web. The plurality of shape-changing fibres are activatable by an external stimulus and orientated within the plane of the web. In addition, the shape-changing fibres change shape such that the one or more partial or complete incisions widens.

[0014] Another embodiment of the present invention relates to a non-woven fabric for

adaptive insulation having one or more webs having a plurality of shape-changing fibres. Each one of the plurality of shape-changing fibres is activatable by an external stimulus and the plurality of shape-changing fibres are predominantly orientated parallel to an axis perpendicular to the plane of the web, defining a web thickness. Also, in response to activation by the external stimulus the shape-changing fibres are configured to respond such that the thickness of the one or more webs decreases.

Figures

[0015] Specific embodiments are now described, by way of example only, with reference to the drawings, in which:

[0016] Fig. 1a depicts an example of a shape-changing fibre in an unactivated state;

[0017] Fig. 1b depicts an example of a shape-changing fiber in an activated state;

[0018] Fig. 2 depicts an example of a web comprising a plurality of shape-changing fibres shown from three different angles;

[0019] Fig. 3a depicts an example of a fabric comprising a plurality of partial incisions from three different perspectives;

[0020] Fig. 3b depicts an example of a fabric comprising a plurality of complete incisions from two different perspectives;

[0021] Fig. 4 depicts a magnified view of an example of a fabric comprising a complete incision;

[0022] Fig. 5a depicts a fabric comprising a plurality of shape-changing fibres orientated in an unactivated and activated state;

[0023] Fig. 5b depicts a fabric comprising a plurality of shape-changing fibres that are substantially orientated/aligned in the z direction;

[0024] Fig. 6a depicts a magnified cross-sectional view of an example of a typical VLap textile structure;

[0025] Fig. 6b depicts a cross-sectional view of a fabric comprising a plurality of shape-changing fibres that are substantially orientated/aligned in the z direction after a wet/dry activation cycle;

[0026] Fig. 7a depicts a graph illustrating the heat transfer properties of damp and dry fabrics;

[0027] Fig. 7b depicts a table that presents, clo and tog values in relation to fabric thickness

between wet and dry fabrics;

[0028] Fig. 8 depicts a table that provides some examples of shape-changing fibre to binder fibre ratios that may be used to produce the non-woven fabrics described herein.

[0029] The figures herein are for illustrative purposes only and are not necessarily drawn to scale.

Overview

[0030] By providing a non-woven fabric 2 comprising: one or more webs 3, each of the one or more webs 3 comprising a plurality of shape-changing fibres 1 activatable by an external stimulus and being orientated within the plane of the one or more webs 1; and one or more partial or complete incisions 4 in the one or more webs 3, wherein in response to activation by the external stimulus, the shape changing fibres 1 change shape such that the one or more partial or complete incisions 4 widens, a number of benefits are provided.

[0031] By providing a non-woven fabric 6 for adaptive insulation comprising: one or more webs 7 comprising/consisting of a plurality of shape-changing fibres 1, wherein each one of the plurality of shape-changing fibres 1 is activatable by an external stimulus and the plurality of shape-changing fibres 1 are predominantly orientated parallel to an axis perpendicular to the plane of the web 7, defining a web thickness and, wherein in response to activation by the external stimulus the shape-changing fibres 1 are configured to respond such that the thickness of the one or more webs 7 decreases, a number of benefits are provided.

[0032] In overview, according to embodiments disclosed herein, the properties of a fabric 2, 6 may be engineered such that the material has a particular behaviour when exposed to an external predetermined stimulus or trigger. This provides a number of benefits. For example, using the system disclosed herein, it is possible to alter the insulation and/or ventilation properties of the fabric 2, 6 according to the environment it is in.

[0033] For example, the present disclosure provides a fabric 2 as shown for example in Figs. 2 to 4 that increases its permeability when damp, and decreases its permeability when dry. In other words, the disclosure provides a fabric 2 that is breathable when damp, and warm when dry. This is contrary to how most fabrics react. For example, natural fibres tend to swell when damp, making them more bulky. This in turn makes fabrics made from such fibres less breathable than when they are dry, as they swell into the spaces between the yarns,

making the space smaller and therefore making it more difficult for moisture to pass through the fabric.

[0034] The present disclosure also provides a fabric 6 as shown for example in Fig. 5a and 5b that alters its thermal resistance in response to changes in environmental moisture. In damp conditions, this fabric 6 allows more heat to pass through the textile system.

[0035] The present disclosure relates to fabrics 2, 6 that utilise shape-changing fibres 1 (also referred to interchangeably as active fibres), which are activatable by an external stimulus. These shape-changing fibres 1 may be engineered such that, responsive to exposure to the external stimulus, the shape-changing fibres 1 are configured to reduce in length. This reduction in length may refer to the one-dimensional length of the space that a shape-changing fibre 1 takes up (the effective length), as opposed to the absolute length of the shape-changing fibre 1. Alternatively, this may refer to the absolute length of the shape-changing fibre 1. In one example, the external stimulus is moisture (which may also be referred to as humidity, wetness or the quantity of water present).

[0036] One example of a shape-changing fibre 1 that may be used in the disclosed embodiments is illustrated in Figs. 1a and 1b. Fig. 1a shows a shape-changing fibre 1, which may be a staple fibre, in a dry environment in which it has an inactivated configuration. The shape-changing fibre 1 has a production imposed crimp which results in a shape-changing fibre 1 with a helix shape and a generally oblong form factor, shown in Fig. 1a by dimensions a and b. A helix may be described as a three-dimensional curve around an axis. The pitch of a helix is the length of one complete turn measured along the axis of the helix. A circular helix has a constant curvature and constant torsion. On exposure to increased humidity, the crimp of the shape-changing fibre 1 increases, such that the number of bends per length increases and the radius of the bends decreases i.e. the helix becomes tighter, the radius and pitch of the helix decreases, and the fibre is more compact. In other words, the effective length, shown as dimension b in Figs. 1a and 1b of the shape-changing fibre 1, is reduced when the fibre 1 is in its activated state. Selecting components of the bi-component fibre with differing properties gives rise to the helix structure. The hygroscopic component is selected to have less thermal shrinkage and to be less stiff than the non-hygroscopic polymer. When co-extruded then heat shrunk, the hygroscopic component wants to elongate. However, this is restricted by the non-hygroscopic component resulting in the helix structure. On exposure to humidity, the hygroscopic component wants to further elongate. Again, this action is resisted

by the non-hygroscopic component and the stiffer non-hygroscopic component causes the helix angle to tighten. This results in the activated configuration shown in Fig. 1b. Compared with the shape-changing fibre 1 in relatively dry conditions, the width a is reduced and the length b is reduced. On removal of the trigger, the active shape-changing fibre 1 returns to its inactivated configuration shown in Fig. 1a. Typically, the length b may be reduced by 20% and the width a reduced by 10% in 100% humid conditions compared with dry conditions.

[0037] The shape-changing fibres 1 are formed together into a web 3, 7, and the fabric 2, 6 comprises one or more of these webs 3, 7. By controlling the orientation of the shape-changing fibres 1 within the web 3, 7, it is possible to tailor how the resulting fabric 2, 6 will respond to the external stimulus by taking advantage of the properties of the shape-changing fibres 1. Different properties can be achieved by orientating the shape-changing fibres 1 in different directions, as well as by additional processes, such as the introduction of incisions 4 into the web 3.

Detailed Description of the Invention

[0038] Examples of specific linkages and structures will now be described.

[0039] One embodiment is shown from different perspectives in Figs. 2, 3a, 3b and 4. Fig. 2 shows the orientation of a plurality of shape-changing fibres 1 within a web 3. The web 3 may be thought of as a plane of material with a particular thickness. In some examples, the fabric 2 may comprise more than one web 3 (a plurality of webs 3). The plurality of webs 3 may also be thought of as a plane of material with a particular thickness. Where a web 3 is referred to, it should also be understood that this may also refer to a plurality of webs 3. In some examples, the web 3 may also be thought of as comprising a plurality of webs 3. The plane of the web 3 is along the xy direction, and the thickness of the web 3 is in the z direction. The web 3 has a length (y) and a width (x) that are significantly greater than the depth (z). As can be seen from looking down the y and x axes, the plurality of shape-changing fibres 1 are substantially orientated within the xy plane, which is to say that they are substantially orientated away from/not in the z direction. As can be seen from looking down the z axis, in one example, the plurality of shape-changing fibres 1 are orientated in different, random, directions to one another, within the xy plane. In another example, the orientation of the shape-changing fibres 1 is evenly distributed within the xy plane of the web 3. In another example, the orientation of a portion of the shape-changing fibres 1 is either

predominantly in the x direction or in the y direction, or another direction parallel to one another. In another example, the orientation of a first portion of the shape-changing fibres 1 is in the x direction and the orientation of a second portion of the shape-changing fibres 1 is in the y direction, for example so that the web 3 has a cross configuration of shape-changing fibers 1 within the plane of the web 2. In other words, such that the plurality of shape-changing fibres 1 are perpendicular to one another within the xy plane of the web 3.

[0040] Fig. 3a shows an example of a fabric 2 from three different perspectives and, for each perspective, the fabric 2 is shown in a damp (activated) state on the left, and in a dry (inactivated) state on the right. In one example, the fabric 2 is a non-woven fabric 2. The first perspective shows the top face of a web 3, the second perspective shows the bottom face of the web 3, and the third perspective shows a side angle (cross section) view of the web 3. The web 3 is similar to the web 3 illustrated in Fig. 2, however it has been modified to introduce a plurality of incisions 4 into the web 3. In some examples the incisions are partial incisions and in some examples the incisions 4 may pass all the way through the web, wherein they may be referred to as complete incisions or slits. Where the fabric 2 comprises a single web 3, the incision 4 may pass all the way through the web 3 or partially through the web 3. Where the fabric 2 comprises more than one web 3, an incision 4 may pass all the way through all of the webs 3 as a full incision 4 or may be a partial incision 4 which may be thought of as comprising a complete incision 4 through some but not all of the webs 3. The incisions 4 may also be referred to as cuts, partial cuts, complete cuts, slits, partial slits or complete slits or by other appropriate terms as appropriate. First, looking at the fabric 2 in its dry state, which corresponds to its inactivated state, it can be seen that the bottom face of the web 3 comprises a plurality of incisions 4, whereas the top face of the web 3 does not. An incision 4 is a cut in the surface of the web 3, which may be introduced after the web 3 has been formed, as described in more detail below. For an incision 4 to be made, a portion of the web 3 (that has a thickness that is less than the total thickness of the web 3), is cut in two, and so that portion is separated into two portions 12. When the web 3 is in its inactivated state and there are no other external forces being applied, the two portions 12 of the web 3 that are separated by the cut (incision) will remain substantially together, because there is no force biasing them apart. Nonetheless, there will exist a width to the incision, even if this width is small, or zero when the web 3 is in its inactivated state. The side angle view shows that the plurality of incisions 4 do not pass all the way through the thickness of

the web 3. These could also be described as partial incisions 4, as opposed to, for example, slits that pass through the fabric 2. For an incision 4 to pass all the way through the thickness of the web 3, the portion of the web 3 that is cut must have a thickness that is equal to the thickness of the web 3.

[0041] When the fabric 2 is exposed to moisture, the plurality of shape-changing fibres 1 within the web 3 are activated and this causes them to adopt a second, activated configuration. As explained previously in relation to the example shown in Fig. 1a and 1b, in the activated configuration (in the presence of the external stimulus), the shape-changing fibres 1 undergo a dimensional transformation. In particular, the length of each of the plurality of shape-changing fibres 1 is reduced. This reduction in length of the shape-changing fibres 1, together with the orientation of the fibres, is what causes the width of the incision to increase when the fabric 2 is activated. In other words, the reduction of length of the shape-changing fibres 1 modifies the structure of the web 3, which in turn modifies the structure of the fabric 2. In one example, the fabric 2 is constrained at one or more edges or borders of the fabric, for example by connection to another fabric or material. Modifying the structure of the fabric 2 changes the properties of the fabric 2.

[0042] This can be seen when looking at the fabric 2 of Fig. 3a in its wet state, which corresponds to its activated state, it can be seen that the width of the incision 4 has increased. In other words, the two portions 12 of the web 3 that were separated by the incision 4 move further apart from one another. The width of the incision 4 increases by a greater amount at the center of the length of the incision, when compared to at the ends of the incision 4. This is because at the ends of the incision 4, the shape-changing fibres 1 are still entangled. The amount by which the incision 4 increases in width is greater closer to the bottom face. However, because the incision 4 does not pass all the way through the web 3, at the end of the incision 4 that is closer to the top face of the web 3, the incision 4 is constrained from widening because the shape-changing fibres 1 are still connected to one another.

[0043] In the top section 5 of the web 3 that the plurality of incisions 4 has not reached, a plurality of shape-changing fibres 1 that are in this top section will also become activated when the fabric 2 is wet. However, because no incision has been made in this section of the web 3 the effect of this is that, when the plurality of shape-changing fibres 1 become activated and reduce in length, this section of the web 3 contracts, predominantly within the

xy plane. This section of the web 3 therefore reduces in permeability due to a reduction in the space between the fibres. This section of the web 3 therefore increases in density. This section of the web 3 therefore increases its resistance to airflow in damp conditions.

[0044] As a result, the fabric 2 shown in Fig. 3a can be thought of as a hybrid fabric 2 in which partial slits (incisions 4) are introduced into the fabric 2 in the z direction but without fully cutting through the fabric 2 all the way. This example delivers a functional nonwoven fabric 2 with dual functionality. Exposing the fabric 2 to the external stimulus, in this case water, has an effect of changing the properties of the fabric 2. This in turn changes the properties of any garments made from such a fabric 2 when they exposed to the external stimulus. On one side, (without the incisions 4) exposure to moisture would reduce the permeability of the textile, which makes the fabric 2 ideal for applications next to the outer layer of a garment that could be exposed to rain. The other side (with incisions 4) would, when exposed to moisture, create pores into the structure of the textile that would increase air permeability, making it ideal for application closer to the skin and sweaty microclimate. Such a fabric 2 would therefore be well suited for items of clothing such as coats for outdoor exploration.

[0045] Fig. 3b shows an example of a fabric 2 of another embodiment from one perspective but in two different states. The fabric 2 is shown in a damp (activated) state on the left, and in a dry (inactivated) state on the right. The web 3, from which the fabric 2 is made, is similar to the web 3 illustrated in Fig. 2, which is to say that it comprises a plurality of shape-changing fibres 1, all predominantly orientated within the xy plane of the web 3. The web 3 shown in Fig. 3b also comprises a plurality of incisions 4 that, in this example, pass all the way through the web 3.

[0046] As described previously, when the web 3 is in its inactivated state and there are no other external forces being applied, the two portions 12 of the web 3 that are separated by the cut (incision 4) will remain substantially together, because there is no force biasing them apart. Nonetheless, there will exist a width to the incision 4, even if this width is small, or zero, or even negative when the web 3 is in its inactivated state.

[0047] When the web 3 is in its activated state, it can be seen that the width of the incision 4 has increased. In other words, the two portions 12 of the web 3 that were separated by the incision 4 move further apart from one another. Because the incision 4 passes all the way through the web 3, the incision 4 widens by an equal (or nearly equal) amount, across the

thickness of the web 3. In other words, the incision 4 becomes a perforation/hole/pore. As can be seen in Fig. 3b, the width of the incision 4 increases by a greater amount at the center of the length of the incision 4, when compared to at the ends of the incision 4. This is because at the ends of the incision 4, the shape-changing fibres 1 are still entangled.

[0048] As described previously, when the fabric 2 is exposed to moisture, the plurality of shape-changing fibres 1 within the web 3 are activated and this causes them to adopt a second, activated configuration. In particular, the length of each of the plurality of shape-changing fibres 1 is reduced. This reduction in length of the shape-changing fibres 1, together with the orientation of the shape-changing fibres 1, is what causes the width of the incision 4 to increase when the fabric 2 is activated. The reduction of length of the shape-changing fibres 1 modifies the structure of the web 3, which in turn modifies the structure of the fabric 2. Modifying the structure of the fabric 2 changes the properties of the fabric 2.

[0049] In this example, in the presence of moisture, the incisions 4 open up (widen) in such a way that they may be thought of as becoming perforations, or slits in the fabric 2. The presence of these widened incisions 4 (slits) in the fabric 2 decreases airflow resistance, which increases the breathability of the fabric 2. This is useful, for example, in garments because, when a wearer is at rest, the fabric 2 provides insulation and when the wearer is active and sweat builds up in the microclimate, the incisions 4 widen/open up to create pores and increase airflow through the fabric 2, which helps to cool the wearer down.

[0050] The textile (fabric 2) thus becomes more permeable to air in damp conditions by opening and closing structural pores along the xy plane of the textile. To achieve this effect the shape-change properties of certain shape-changing fibres 1, such as Inotek™ fibres, which contract when exposed to moisture, are used to open and close pores as they expand and contract in dry/ damp conditions and by ensuring fibres are orientated along the x/y planes of the nonwoven. The incisions 4 may be introduced at the end of the production process. For example, one or more incisions 4 can be made using a rotary blade, die cutting apparatus, laser or sonic cutting apparatus. These processes can be used to introduce partial incisions 4 or full incisions 4 that pass all the way through the web.

[0051] Fig. 4 shows a magnified view of an example of a fabric 2 comprising a plurality of shape-changing fibres 1 predominantly orientated within the xy plane of the web 3 and comprising an incision 4 that passes through the web 3 it has been made in. On the left, the fabric 2 is in a dry (inactivated) state, on the right the fabric 2 is in a damp (activated) state.

The web 3 from which the fabric2 is made is similar to the web 3 illustrated in Fig. 2, which is to say that it comprises a plurality of shape-changing fibres 1, all predominantly orientated within the xy plane of the web 3. It can be seen that when the fabric 2 is dry, the incision 4 is closed (it is a narrow width) and, when the fabric 2 is wet, the Inotek™ fibres have contracted to open up the incision 4 (it increases in width). This figure demonstrates the effect of fibre shape-change to the incision 4.

[0052] In another embodiment, the web 3 from which the fabric 2 is made is similar to the web 3 illustrated in Fig. 2, which is to say that it comprises a plurality of shape-changing fibres 1, all predominantly orientated within the xy plane of the web 3. In this example however, the web 3 does not comprise any incisions 4. In the case where there are no incisions 4, the fabric 2 increases its resistance to airflow in damp conditions, thus preventing the flow of air though the fabric 2. This would be beneficial in some garments because when the wearer is at rest and it begins to rain, if positioned within the outer shell of the garment system, the fabric 2 would adapt its structure to help prevent cold, wet wind penetrating the garment.

[0053] The fabrics 2 described above alter their insulation and/or ventilation properties in relation to the moisture levels in the environment by focusing the orientation of shape-changing fibres and thus shape-change in the x,y direction. Throughout this application, the examples refer to humidity activated shape-changing fibres 1 by way. However, it is envisaged that other stimuli may be used to activate the shape-changing fibres 1. Where humidity is the external stimulus, which acts as a trigger, in an active state the shape-changing fibres are in a humid environment and an active configuration, in an unactive state the shape-changing fibres are in a dry environment and an unactive configuration.

[0054] Table 1 below provides test data obtained using two different fabric 2 samples that both incorporated a plurality of incisions 4 passing through the web 3 of the fabric 2. For both samples (Inotek 14 (180 gr/m2) and Inotek (15 80 gr/m2)), by incorporating the incision 4 (slit) feature, the fabrics 2 (textiles) increases their air permeability in damp conditions significantly. The air permeability of each sample was also tested without the incision 4 design in damp conditions and discovered that the air permeability decreased when damp. Accordingly, in one example, a fabric 2 similar to that described with reference to Fig. 2 and without any incisions 4 has the ability to restrict airflow in damp conditions. Similarly, a hybrid fabric 2 as described in relation to Fig. 3a has the ability to increase air

permeability following exposure to damp conditions on one side of the fabric 2, whilst reducing air permeability following exposure to damp conditions on the other side of the fabric 2.

[0055] TABLE 1

In14	air perm [l*m-2*s-1] 10cm2 100Pa pressure drop	StDev
carded no slits	1106	47
carded no slit damp	1018	36
carded with slits dry	1166	42
carded with slits damp	1458	44
In15	air perm [l*m-2*s-1] 10cm2 100Pa pressure drop	StDev
carded no slits	2074	34
carded no slit damp	1968	36
carded with slits dry	2130	69
carded with slits damp	2438	55

[0056] The fabrics 2 described above provide autonomous, adaptive breathability and insulation. Furthermore these fabrics 2 are suitable for use in a garment wherein, in use, pressure may be exerted onto the fabric 2 by adjoining different fabrics 2 or by a human body. As a result of the incisions 4 widening within the plane of the web 3, as opposed to, for example, lifting away from the plane of the web 3, these adaptable fabrics 2 can be reliably used in a greater variety of situations.

[0057] The properties of the fabrics 2, 6 disclosed in the embodiments herein may be engineered such that the material has a particular behaviour when exposed to an external predetermined stimulus or trigger. The activating external stimulus or trigger for the shape-changing fibres 1 is determined during the manufacturing of the shape-changing fibres 1 and fabric 2 and, at least in part, are determined by the chemistry of the components of the shape-changing fibres 1 (fibres). For example, fibres with two chemically differing components may be activated by moisture/humidity, temperature, light, pH, electrical current, force field, microbes, or biological matter. The effect between the activated and inactivated state is reversible.

[0058] Whilst the web 3 has been disclosed as comprising a plurality of shape-changing fibres 1, in some examples, these fibres may be provided in the form of one or more yarns.

For example, a bundle of spun fibres twisted together may provide the body of a yarn. The yarn may be spun with 100% staple shape-changing fibres 1 or a blend of neutral and shape-changing fibres 1 may be used. Further, the yarn may include filament fibres. The shape-changing fibres 1 are arranged in the yarn so that they are exposed to the external trigger. The yarn may have a relatively loose twist and the yarn dimension is relatively broad. As discussed in more detail below, on exposure to humid conditions, the shape-changing fibres 1 shrink, becoming shorter with a narrow cross-section. The yarn therefore becomes more tightly twisted in the activated configuration compared with dry conditions and the yarn dimension becomes narrower. Hence, active yarns may be comprised in the fabrics 2 disclosed herein so that the fabrics 2 becomes more breathable when exposed to humidity.

[0059] The mechanical structure of the shape-changing fibres 1, yarns, and fabric 2 may also lead to differing properties. Shape-changing fibres 1 may use that have been extruded with different cross-sections such as rectangular, oval, round or demonstrate groves (i.e. tri-lobal). In a bi-component fibre, the components may not be evenly distributed and may be in a range of proportions. Indeed, an asymmetric arrangement may be desirable.

[0060] In one example, the shape-changing fibre 1, comprising material activated by an external stimulus, has a first configuration in an inactivated state, and in response to activation by the external stimulus the shape-changing fibre 1 twists to adopt a second, increased twist, configuration, relative to the first configuration.

[0061] A shape-changing fibre 1 may be made from a shape-memory material. Preferably the shape-changing fibre 1 is arranged in a helix and in the second configuration the shape-changing fibre 1 is arranged in a helix with relatively decreased radius and pitch. This allows for a shape-changing fibre 1 that is relatively long and wide when inactivated and relatively short and narrow when activated. The fibre may move between an active state and an inactivated state in proportion to the external stimulus, that is to say it can adopt a range of configurations between fully inactivated and fully activated (twisted) configurations, with a corresponding range of dimensions and consequent thermal properties.

[0062] In one example, the shape-memory material comprises at least two components having differing physical reaction to the external stimulus. The components may be in a ratio range of 50:50 to 20:80 and may be arranged in side-by-side, sea island or eccentric configuration. In one example, the shape-changing fibres 1 have an asymmetric configuration. In one example, the first material component is 70% Nylon 6 and a second

component is 30% polypropylene where the polypropylene provides an off-centre core and the shape-changing fibre 1 is crimped.

[0063] Filament fibres may be cut into staple fibres of any appropriate the length which will depend on the use.

[0064] The effect described above in relation to the shape-changing fibres 1 can be achieved with a twisted shape-memory fibre. Shape-memory materials are able to retain two or more shapes and transition between those shapes when triggered by an external or environmental stimulus. In the examples described herein, the external stimulus is humidity. It is preferable that the shape-memory material has a relatively quick rate of reacting to the trigger so that it quickly changes from a first shape to a second shape. One way of achieving a shape-memory fibre (shape-changing fibre 1) is to use at least two polymers to make a bi-component fibre.

[0065] Further, the shape-changing fibres 1 may go through a range of transitional shapes. With the example of humidity as a trigger, the humidity may be increased from 0% relative humidity to 100% relative humidity. At 0% humidity the shape-changing fibre 1 would have a first configuration. A 100% humidity the shape-changing fibre would adopt a second configuration. In conditions where humidity is between these two extremes the shape-changing fibre 1 could adopt a number of transitional configurations.

[0066] The disclosure also relates to a method of production of fabrics 2 comprising shape-changing fibres 1 and/or yarns, textiles and other materials.

[0067] In overview of the fabrication process, manufactured fibres are often produced in a continuous filament fibre process. Extrusion processes for making multi-component fibres are known and need not be described here in detail. Generally though, to form a multi-component fibre, at least two polymers are extruded separately and fed into a polymer distribution system wherein the polymers are introduced into a spinneret plate or die. The polymers follow separate paths to the fibre spinneret and are combined in a spinneret hole. The spinneret is configured so that the extrudant has the desired overall fibre cross section (e.g., round, tri-lobal, etc.). The spinneret may be configured to produce single or multiple filament fibres. Following extrusion through the die, the resulting thin fluid strands, or filaments, remain in the molten state for some distance before they are solidified by cooling in a surrounding fluid medium, which may be chilled air blown through the strands. This is one example of a method of producing a shape-changing fibre, such as may be used in the fabrics 2 disclosed herein.

[0068] The shape-changing fibres 1 may then be melt spun as a direct laid, non-woven web 3, 7 via a jet process, to produce a non-woven fabric 2. For example, in a spunbonding process, the strands are collected in a jet following extrusion through the die, such as for example, an air attenuator. The strands are then blown onto a take-up surface, such as a roller or a moving belt, to form a spunbond web 3, 7. Alternatively, in a meltblown process, air is ejected at the surface of a spinneret to simultaneously draw down and cool the thin fluid polymer streams. The streams are subsequently deposited on a take-up surface in the path of cooling air to form a fibre web 3, 7.

[0069] Regardless of the type of melt spinning procedure which is used, the thin fluid streams are typically melt drawn in a molten state (i.e., before solidification occurs) to orient the polymer molecules for good tenacity. Typical melt draw down ratios known in the art may be utilized. The skilled artisan will appreciate that specific melt draw down is not required for meltblowing processes.

[0070] When a continuous filament or staple process is employed, it may be desirable to subject the strands to a draw process. In the draw process, the strands are typically heated past their glass transition point and stretched to several times their original length using conventional drawing equipment, such as, for example, sequential godet rolls operating at differential speeds. Typical draw ratios can depend upon polymer type. For example, draw ratios of about 2 to about 5 times are typical for polyolefin fibres. Optionally, the drawn strands may be heat set to reduce any latent shrinkage imparted to the fibre during processing.

[0071] Optionally, the fibres may additionally be subjected to a crimping process prior to the formation of staple.

[0072] Yarns may be made from 100% shape-changing fibres 1 or may be blended with other fibres. Each of the products is arranged to increase air permeability in an active state. Yarns may be spun using any appropriate approach, for example, air jet, Murata Jet, Ring or core spun methods. Fabrics may be knitted, woven, non-woven, glued, stitched, or bonded. Fabrics 2 disclosed herein may be suitable for use as agricultural textiles, building textiles, geo-textiles, domestic or industrial interior textiles, domestic or industrial cover textiles, filters, medical textiles, medial dressing textiles, packaging, or vehicle interior/exterior textiles.

[0073] The shape-changing fibres 1 may be bonded together to form the web 3, 7 in various

ways. For example, the shape-changing fibres 1 may be lapped together by a lapping process. In one example, the shape-changing fibres 1 may be bonded together using a low melt binder.

[0074] In one example, the non-woven fabric 2 is made in three stages. Firstly, a fine web 3 of shape-changing fibres 1 is created using well known laying or other processes which will be familiar to the skilled person such as drylaid (carded or airlaid), wetlaid, spunlaid, meltblown or submicron spinning processes. For example, the shape-changing fibres 1, which may be Inotek™ fibres, may be carded together with binder fibres to form a web 3 that comprises a plurality of shape-changing fibres 1 and a plurality of binder fibres. In one example, drylaid (or other) webs 3 may then be used to form thicker one or more thicker webs 3 by layering (drylaid) webs 3 on top of each other in parallel, at a particular angle or at a random orientation. Secondly, the web(s) 3 may be bonded together using thermal, mechanical or chemical processes. For example, the more than one web 3 may be layered for a particular thickness and then bonded together by passing through an oven. Thirdly, finishing treatments can optionally be applied such as (but not limited to) coatings, mechanical treatments or surface modifications.

[0075] Another embodiment is shown in Figs. 5a, 5b and 6b. Fig 5a shows a fabric 6 and the orientation of a plurality of shape-changing fibres 1 within a web 7 comprised within the fabric 6. In some examples, the fabric 6 may comprise more than one web 7 (a plurality of webs 7). The plurality of webs 7 may also be thought of as a plane of material with a particular thickness. Where a web 7 is referred to, it should also be understood that this may also refer to a plurality of webs 7. In some examples, the web 7 may also be thought of as comprising a plurality of webs 7. The plane of the web 7 is along the xy direction, and the thickness of the web 7 is in the z direction. The web 7 has a length (y) and a width (x) that are significantly greater than the depth (z). As can be seen from Fig. 5a and 5b, the plurality of shape-changing fibres 1 are substantially orientated in the vertical, z, direction, i.e. as substantially orientated parallel to an axis perpendicular to the xy plane of a web 7 comprised in the fabric 6. Fig. 5a also shows the fabric 6 in a dry (inactivated) state on the right, and a wet (activated) state on the left. It can be seen that, when the fabric 6 is in an activated state, the thickness of the web 7/fabric 6 is reduced compared to when they fabric 6 is in an inactivated state.

[0076] This is similarly illustrated in Fig. 5b, which also shows a fabric 6 comprising a plurality

of shape-changing fibres 1 that are substantially orientated/aligned in the z direction. By changing the thickness of the fabric 6, the thermal resistance is also altered.

[0077] This reduction in thickness occurs because, when the fabric 6 is exposed to moisture, the plurality of shape-changing fibres 1 within the web 7/fabric 6 are activated and this causes them to adopt a second, activated configuration. As explained previously in relation to the example shown in Fig. 1a and 1b, in the activated configuration (in the presence of the external stimulus), the shape-changing fibres 1 undergo a dimensional transformation. In particular, the length of each of the plurality of shape-changing fibres 1 is reduced. The shape-changing fibres 1 are substantially orientated in the z direction and as a result, when these shape-changing fibres 1 contract, this results in a reduction in thickness of the web 7 and fabric in which they are comprised. The reduction of the thickness of the web 7 alters the thermal resistance of the web 7/fabric 6 which allows more heat to pass through the textile system.

[0078] Fig. 6a shows a magnified cross-sectional view of an example of a VLap textile structure, from which it can be seen that the fibres are orientated in the z direction.

[0079] Fig. 6b shows a cross sectional view of an Inotek^{TM} V-lap sample after a first wet/dry activation cycle. This is an example of a fabric 6 made up of a web 7 that comprises a plurality of shape-changing fibres 1 predominantly orientated along an axis perpendicular to the xy plane of the web 7, wherein on the left, the fabric 6 is in a dry (inactivated) state and on the right, the fabric 6 is in a damp (activated) state. This shows that the thickness of the fabric 6 is reduced when the fabric 6 is exposed to the external stimulus, which in this case is water.

[0080] The shape-changing fibres 1 in the fabrics 6 depicted in Figs. 5a, 5b and 6b are substantially orientated in the z direction and, as a result, when these shape-changing fibres 1 contract, this results in a reduction in thickness of the web 7 and fabric 6 in which they are comprised. In other words, the reduction of length of the shape-changing fibres 1 modifies the structure of the web 7, which in turn modifies the structure of the fabric 6. Modifying the structure of the fabric 6 changes the properties of the fabric 6. In one example, the shape-change fibres 1 are Inotek^{TM} fibres, which contract when exposed to moisture.

[0081] As explained above, when fabrics 6 such as those depicted in Figs. 5a, 5b and 6b experience moist conditions, a hygroscopic shape change occurs. In particular, the thickness of the fabric 6 is reduced. This induces changes in volume of air within textile matrix which

impacts the thermal resistance of the fabric 6. One example of some calculations of thermal resistance is set out below. If thermal conductivity k is constant for damp and dry state where T = Temperature (K), l = Thickness of Specimen and q = Heat flow rate (W/m2) of material, then:

$$k = q\frac{l}{\Delta T} \qquad \text{(I)}$$

$$R = \frac{\Delta T}{q} = \frac{L}{k} \qquad \text{(II)}$$

[0082] Thus, thermal resistance, R, is proportional to difference in textile/fabric 6 thickness. The thermal conductivity (k) for each sample was calculated as shown in Table 2 below.

[0083] TABLE 2

	k1 component	k1	v1	k2 component	k2	v2	K
Inotek bico	PA	0.25	.7	PP	0.12	0.3	0.196119
Bonding bico	PE	0.34	0.4	PP	0.12	0.6	0.17727
Blend inotek+bico	Inotek	0.196119	0.75	bonding bico	0.17727	0.24	0.19196
Fibres+air	Blend inotek+bico	0.19196	0.01	Air	0.0264	0.99	0.027105
Fibres+water	Blend inotek+bico	0.19196	0.036	water	0.5918	0.964	0.559481

Tabe 3 below shows

TABLE 3

	thickness	RSI [m2KW-1	tog	clo
INOTEK 14v dry	16	0.590297409	5.902974	3.80837
INOTEK 14v wet	6	0.010724222	0.107242	0.069189
INOTEK15vdry	11	0.405829469	4.058295	2.618255
INOTEK15v wet	4	0.007149481	0.071495	0.046126

Rf = d(mm)*10^-13/k(Wm-1K-1)
1tog=0.1Rf
1clo=0.155 Rf

[0084] This was demonstrated experimentally. Thermal resistance of the fabric 6 was measured experimentally by placing a damp sample on a heated mat with known

temperature and periodically taking the temperature of the top face of the fabric 6. The results of this are illustrated in Fig. 7a, which shows the heat transfer properties of damp to dry fabrics 6 as described above, with a V-lap sample made using Inotek™ shape-changing fibres 1.

[0085] The line 8 and line 9 indicate the temperature of the heated mat, line 10 illustrates the temperature on the surface of the dry fabric 6, line 11 illustrates temperature on surface of damp fabric 6. It can be seen that the temperature of the surface of the damp fabric 6 rises quickly, demonstrating rapid heat transfer from the heated mat, through the fabric 6 and onto the surface of the fabric 6/textile. However, temperature on the surface of the dry state textile raises gradually, demonstrating that heat transfer through the dry fabric 6 is slower.

[0086] Calculations of thermal resistance, clo and tog values in relation to fabric thickness between wet and dry are presented in Fig. 7b. This shows that the thickness of the wet fabric 6 is less than half the thickness of the dry fabric 6. This also shows that the thermal resistance, tog and clo value of the wet fabric 6 is substantially lower than the thermal resistance of the dry fabric 6.

[0087] This fabric 6 therefore alters its thermal resistance in response to changes in environmental moisture. In damp conditions, this fabric 6 allows more heat to pass through the textile system. This adaptable property is useful in a number of applications. For example, in jacket linings this fabric 6 provides warmth when the wearer is at rest and then, when they begin to sweat, they become less insulating, thus helping to prevent the wearer from overheating.

[0088] In one example, adaptive insulation (as illustrated in Figs. 5a, 5b and 6b) is made using a vertical lapping (V-Lap) machine to vertically lap a plurality of shape-changing fibres 1 (such as Inotek™ fibres) to vertically orient the plurality of shape-changing fibres 1 within the resulting web 7. In one example, the method of production involves uses an air bonding technique, which may be performed using an airlay system, which may also be used to randomly orient the shape-changing fibres 1 relative to one another within the plane of the web 3. In another example, the method of production comprises carding, which may be used to orient the shape-changing fibres 1 in a particular direction, for example, parallel to one another within the plane of the web 3, 7. In one example the method of production comprises including a plurality of bonding fibres in the mix that is used to produce one or

more webs 7, such that the one or more webs 7 comprise bonding fibres and shape-changing fibres 1. In one example, a low melt binder is used. The method may further comprise vlapping the plurality of shape-changing fibres 1 (and, optionally, bonding fiber) into a desired shape. In one example, the process uses thermal bonding. For example, the plurality of shape-changing fibres 1 (and, optionally, bonding fibre) may be heated in an oven so that the plurality of bonding fibres melts to bond to the plurality of shape-changing fibres 1 (such as Inotek™ fibres). In another example, the method comprises stitch or knit bonding to orient the plurality of shape-changing fibres 1 in the z direction. After the shape-changing fibres 1 have been formed or bound into a web 7, the web 7 may be subjected to an activation cycle. The activation cycle involves wetting and then drying the web 7/fabric 6. The activation cycle enables the shape-changing fibres 1 to relax into their final position following the carding and textile production processes that straighten the shape-changing fibres 1. This is one example of a process that orientates the shape-changing fibres 1 in the z direction, as shown in, for example, Figs. 5a, 5b and 6b.

[0089] The table illustrated in Fig. 8 provides some examples of shape-changing fibre 1 (Inotek™) to binder fibre ratios that may be used to produce the non-woven fabrics 2, 6.

[0090] Whilst the fabrics 2, 6 provided in this disclosure and the advantages that they offer have been discussed in the context of the clothing industry and their use in garments, there are also applications for in non- apparel sectors such as in filtration, geotextiles and construction.

[0091] The above implementations have been described by way of example only, and the described implementations and arrangements are to be considered in all respects only as illustrative and not restrictive. It will be appreciated that equivalent variations of the described implementations and arrangements may be made without departing from the scope of the invention. For example, whilst the examples given in relation to the embodiments described above have referred to water or moisture as being the external activator, it will be appreciated by the skilled artisan that other types of shape-changing fibres 1 that, may be responsive to one or more different external stimuli may also be implemented.

[0092] It should also be understood that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention which

are, for brevity, described in the context of a single embodiment, may also be provided separately, or in any suitable subcombination.

[0093] All references specifically cited herein are hereby incorporated by reference in their entireties. However, the citation or incorporation of such a reference is not necessarily an admission as to its appropriateness, citability, and/or availability as prior art to/against the present invention.

[0094] Further aspects of the invention are set out in the following items:

[0095] 1. A non-woven fabric comprising:

one or more webs, each of the one or more webs comprising a plurality of shape-changing fibres activatable by an external stimulus and being orientated within the plane of the one or more webs; and

one or more partial or complete incisions in at least one of the webs,

wherein in response to activation by the external stimulus, the shape changing fibres change shape such that the one or more partial or complete incisions widens.

[0096] 2. A non-woven fabric for adaptive insulation comprising:

one or more webs comprising/consisting of a plurality of shape-changing fibres, wherein each one of the plurality of shape-changing fibres is activatable by an external stimulus and the plurality of shape-changing fibres are predominantly orientated parallel to an axis perpendicular to the plane of the web, defining a web thickness and,

wherein in response to activation by the external stimulus the shape-changing fibres are configured to respond such that the thickness of the one or more webs decreases.

[0097] 3. A method of producing a fabric for adaptation insulation according to item 2, the method comprising:

using a spinning process predominantly orientating a plurality of shape-changing fibres in a particular direction,

wherein each one of the plurality of shape-changing fibres is activatable by an external stimulus; and

vertically lapping the plurality of orientated shape-changing fibres to produce a web, the web comprising the plurality of shape-changing fibres predominantly orientated perpendicular to the plane of the web.

[0098] 4. The method of item 1, further comprising:

activating the plurality of shape-changing fibres by exposing the plurality of shape-changing fibres to the external stimulus; and

after exposing the plurality of shape-changing fibres to the external stimulus, removing the external stimulus.

[0099] 5. The method of either of items 3 or 4, wherein the spinning process comprises air bonding.

[00100] 6. The method of any of items 3 to 5, wherein the spinning comprises carding the plurality of shape-changing fibres with a plurality of binder fibres.

[00101] 7. The method of item 6, further comprising thermally bonding the plurality of shape-changing fibres with the plurality of binder fibres.

[00102] 8. The method of any previous items further comprising:

layering the web with one or more further webs to form a plurality of webs; and

bonding the plurality of webs.

[00103] 9. The non-woven fabric of any preceding item, wherein each shape-changing fibre has a first configuration in an inactivated state and,

in response to activation by the external stimulus, each shape-changing fibre is arranged to adopt a second, increased twist, active state configuration, relative to the first configuration.

[00104] 10. The non-woven fabric of item any preceding item, wherein each shape-changing fibre is arranged to reversibly move between the active state and the inactivated state.

[00105] 11. The non-woven fabric of items 9 or 10, wherein in the first configuration each shape-changing fibre is arranged in a first helix geometry and in the second configuration each shape-changing fibre is arranged in a second helix geometry with relatively decreased radius and pitch.

[00106] 12. The non-woven fabric of any of items 9 to 11, wherein in the first configuration the shape-changing fibre is relatively long and wide and in the second configuration the shape-changing fibre is relatively narrow and the effective length is relatively short.

[00107] 13. The non-woven fabric of any preceding item, wherein the shape changing fibres comprise a shape-memory material.

[00108] 14. The non-woven fabric of any of any preceding item, wherein one or more of the shape changing fibres comprises at least two components.

[00109] 15. The non-woven fabric of item 14, wherein the at least two components are selected to have differing physical reaction to the external stimulus.

[00110] 16. The non-woven fabric of item any preceding item, wherein one or more of the plurality of shape changing fibres has two components in a ratio range of 50:50 to 20:80.

[00111] 17. The non-woven fabric of any of items 14 to 15, wherein the at least two components arranged in side-by-side, sea island or eccentric configuration.

[00112] 18. The non-woven fabric of any of items 14 to 17, wherein the first material component is 70% Nylon 6 and a second component is 30% polyethylene where the polyethylene provides an off-centre core and the fibre is crimped.

[00113] 19. The non-woven fabric of item any preceding item, wherein one or more of the plurality of shape changing fibres has a rectangular, oval, circular or tri-lobal cross section.

[00114] 20. The non-woven fabric of item any preceding item, wherein one or more of the plurality of shape changing fibres is a staple fibre.

[00115] 21. The non-woven fabric of any preceding item, wherein the non-woven fabric comprises one or more binder fibres.

[00116] 22. A non-woven fabric comprising:

one or more webs comprising a plurality of shape-changing fibres activatable by an external stimulus and being orientated within the plane of the web.

Claims

1. A non-woven fabric comprising:
   A. one or more webs, each of the one or more webs comprising a plurality of shape-changing fibres activatable by an external stimulus and being orientated within the plane of the one or more webs; and
   B. one or more partial or complete incisions in at least one of the webs,
   wherein in response to activation by the external stimulus, the shape changing fibres change shape such that the one or more partial or complete incisions widens.

2. The non-woven fabric of claim 1, wherein the shape changing fibres are configured to respond such that the one or more partial or complete incisions widens in proportion to the external stimulus.

3. The non-woven fabric of claim 1, wherein in response to activation by the external stimulus, each one of the plurality of shape-changing fibres is configured to reduce in length to widen the one or more partial or complete incisions.

4. The non-woven fabric of any previous claim, wherein there is more than one incision and wherein the more than one incisions are predominantly aligned along more than one axis.

5. The non-woven fabric of any previous claim, wherein the one or more webs has a thickness and the one or more incisions are partial incisions that do not pass through the thickness of the one or more webs.

6. The non-woven fabric of claim 5, wherein the shape changing fibers comprised within a portion of the thickness of the one or more webs through which the one or more partial incisions does not pass, in response to activation by the external stimulus, are configured to respond such that the portion of the one or more webs increases in density.

7. The non-woven fabric of any of claims 1 to 4, wherein the one or more webs has a thickness and one or more of the one or more incisions are complete incisions that pass through the thickness of the web one or more webs.

8. The non-woven fabric of any previous claim, wherein the non-woven fabric comprises a single web.

9. The non-woven fabric of any previous claim, wherein the non-woven fabric comprises more than one web.

10. The non-woven fabric of any preceding claim, wherein the plurality of shape-changing fibres are orientated perpendicular to one another within the plane of the one or more webs.

11. The non-woven fabric of any preceding claim, wherein the plurality of shape-changing fibres are orientated parallel to one another within the plane of the one or more webs.

12. The non-woven fabric of any preceding claim, wherein the plurality of shape-changing fibres are orientated randomly to one another within the plane of the one or more webs.

13. A garment comprising the non-woven fabric of any of claims 1 to 12.

14. A method of producing a fabric according to claim 1, the method comprising:
    A. spinning a plurality of shape-changing fibres into a web, wherein the plurality of shape-changing fibres are activatable by an external stimulus and orientated within the plane of the web; and
    B. making one or more partial or complete incisions in the web, wherein in response to activation by the external stimulus, the shape changing fibres change shape such that the one or more partial or complete incisions widens.

15. The method of claim 14 further comprising:
    layering the web with one or more further webs to form a plurality of webs;
    bonding the plurality of webs; and
    making the one or more partial or complete incisions in the plurality of webs.

16. The method of either of claims 14 or 15 further comprising:

applying a finishing treatment.

17. The method of any of claims 14 to 16, wherein the spinning comprises one of a drylaid, wetlaid, spunlaid, meltblown or submicron spinning process.

18. The method of any of claims 14 to 17, wherein the spinning comprises carding the plurality of shape-changing fibres with a plurality of binder fibres.

19. The method of any of claims 14 to 18, wherein the one or more incisions are made using rotary blade, a die cutting apparatus, a laser cutting apparatus or a sonic cutting apparatus.

20. A non-woven fabric for adaptive insulation comprising:

A. one or more webs comprising/consisting of a plurality of shape-changing fibres, wherein each one of the plurality of shape-changing fibres is activatable by an external stimulus and the plurality of shape-changing fibres are predominantly orientated parallel to an axis perpendicular to the plane of the web, defining a web thickness and,
wherein in response to activation by the external stimulus the shape-changing fibres are configured to respond such that the thickness of the one or more webs decreases.

21. The non-woven fabric of claim 20, wherein each shape-changing fibre is arranged to reversibly respond.

22. The non-woven fabric of either of claims 20 or 21, wherein the shape changing fibres are configured to respond such that the thickness of the one or more webs decreases in proportion to the external stimulus.

23. The non-woven fabric of any of claims 20 to 22, wherein in response to activation by the external stimulus, each one of the plurality of shape-changing fibres is configured to reduce in length to reduce the thickness of the one or more webs.

24. The non-woven fabric of any of claims 20 to 23, wherein the one or more webs comprises a low melt binder and is produced using a vertical lapping air bonding construction technique.

25. The non-woven fabric of any of claims 20 to 24, wherein the non-woven fabric comprises a single web.

26. The non-woven fabric of any of claims 20 to 25, wherein the non-woven fabric comprises more than one web.

27. A garment comprising the fabric of any of claims 20 to 26.

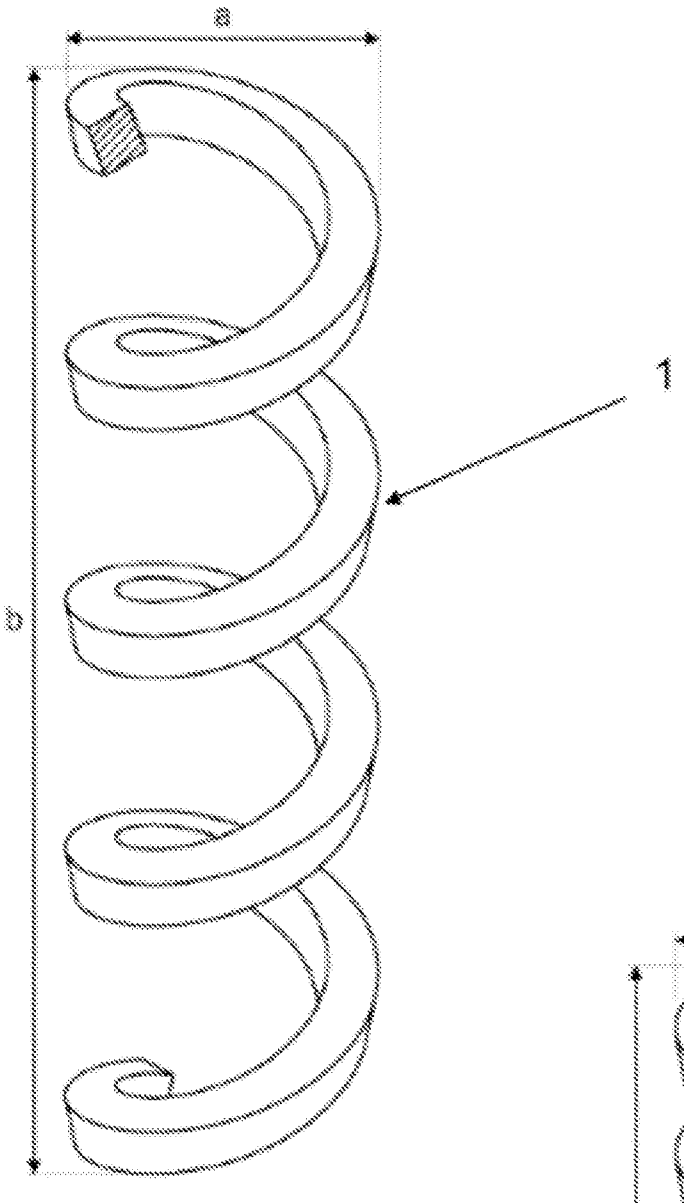


Fig. 1a

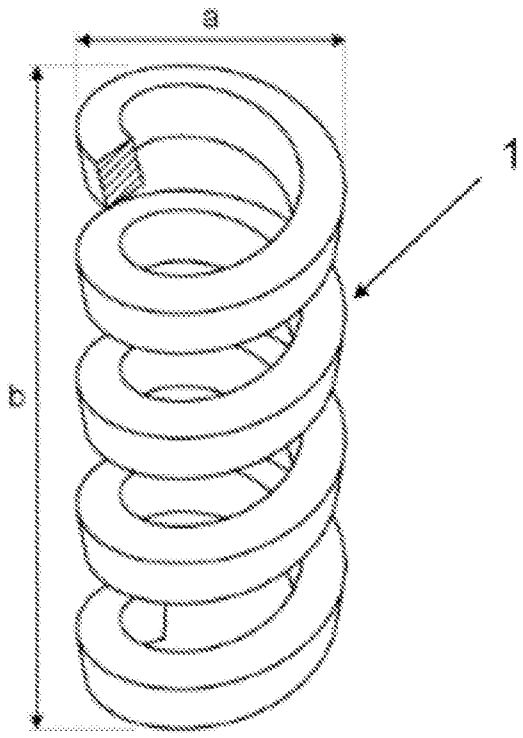


Fig. 1b

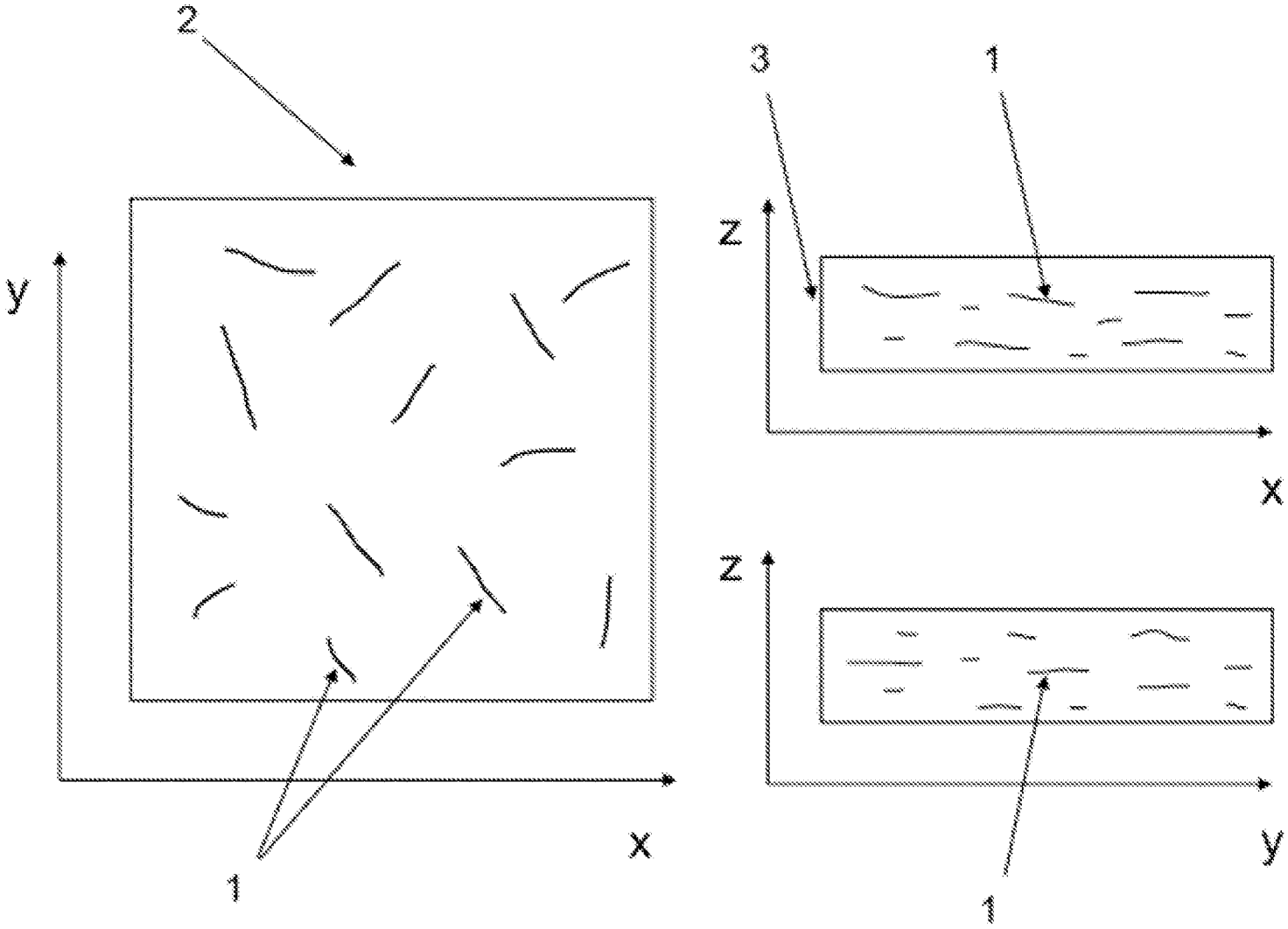


Fig. 2

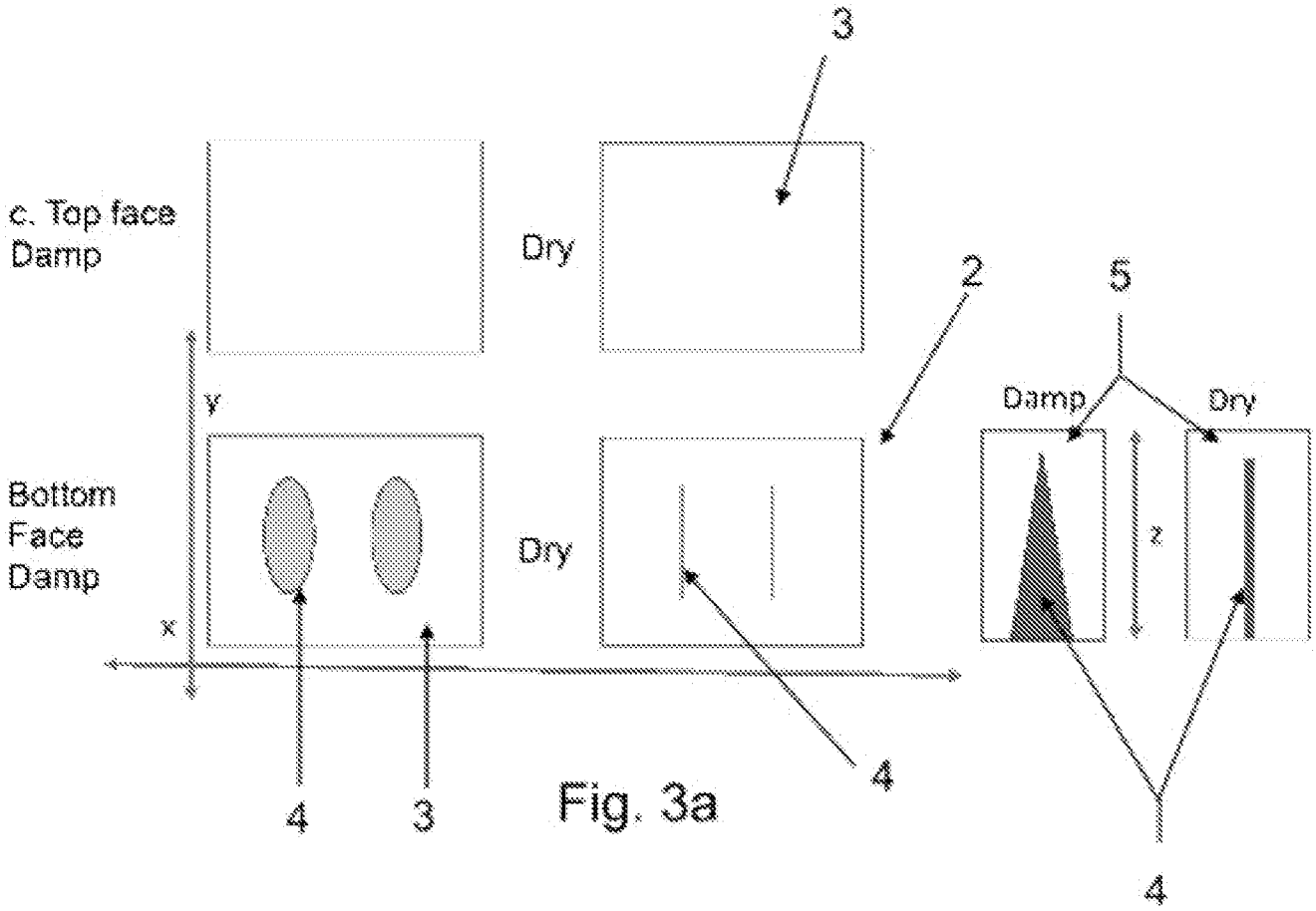

3
c. Top face
Damp
Dry
2
5
y
Damp
Dry
Bottom
Face
Damp
Dry
z
x
4
4
3
4

Fig. 3a

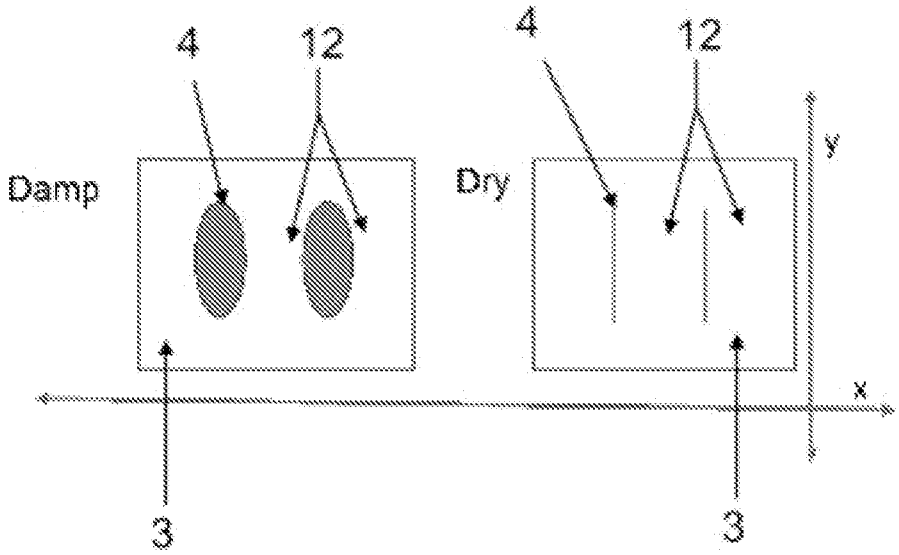

4
12
4
12
Damp
Dry
y
x
3
3

Fig. 3b

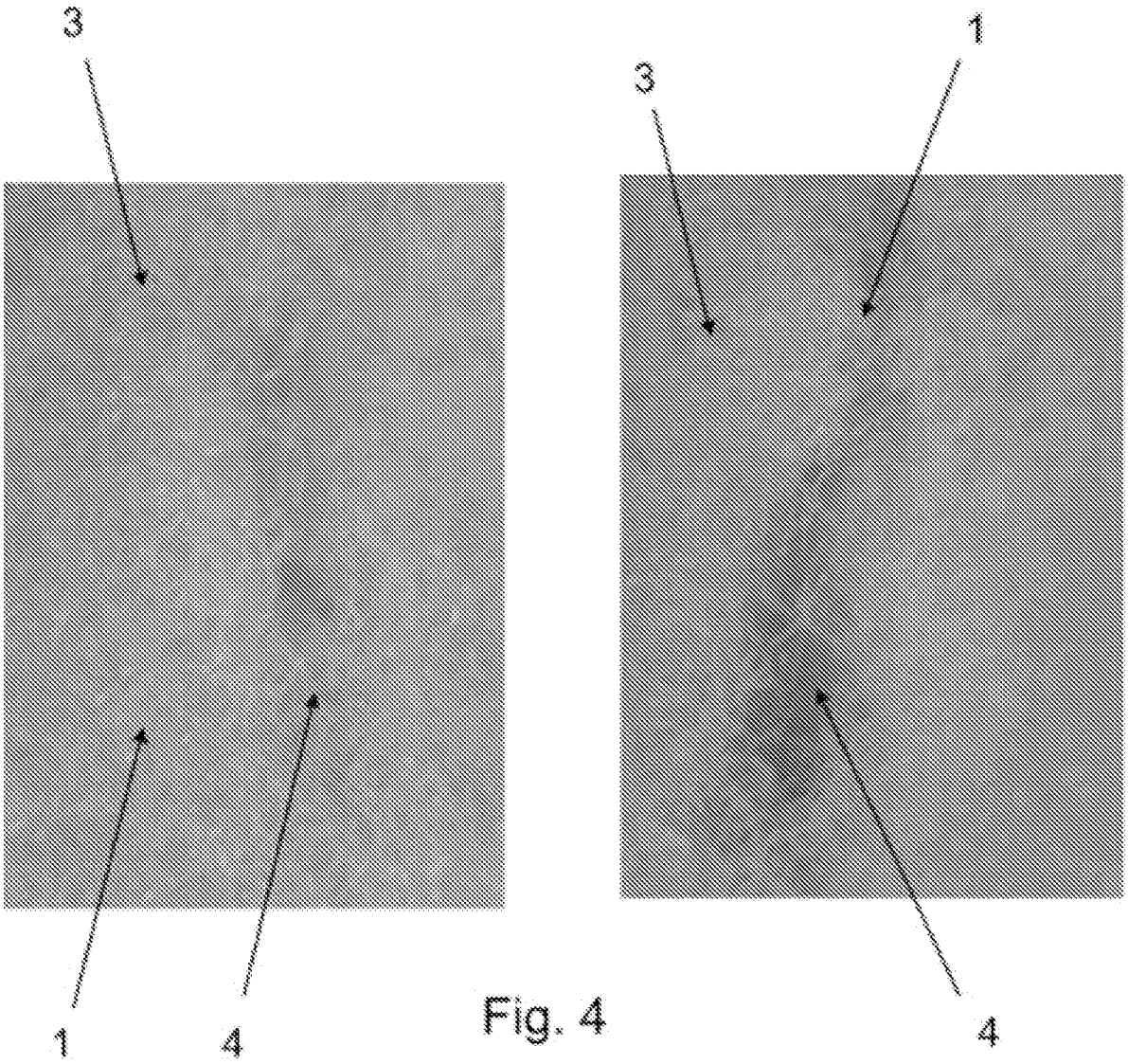


Fig. 4

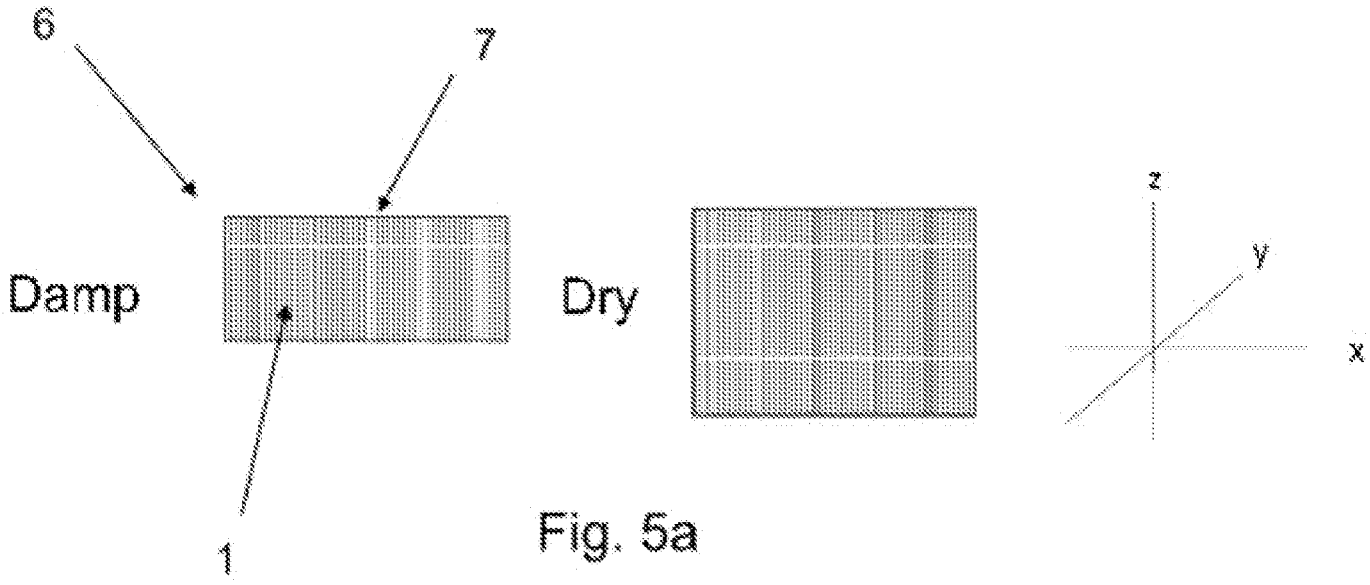


Fig. 5a

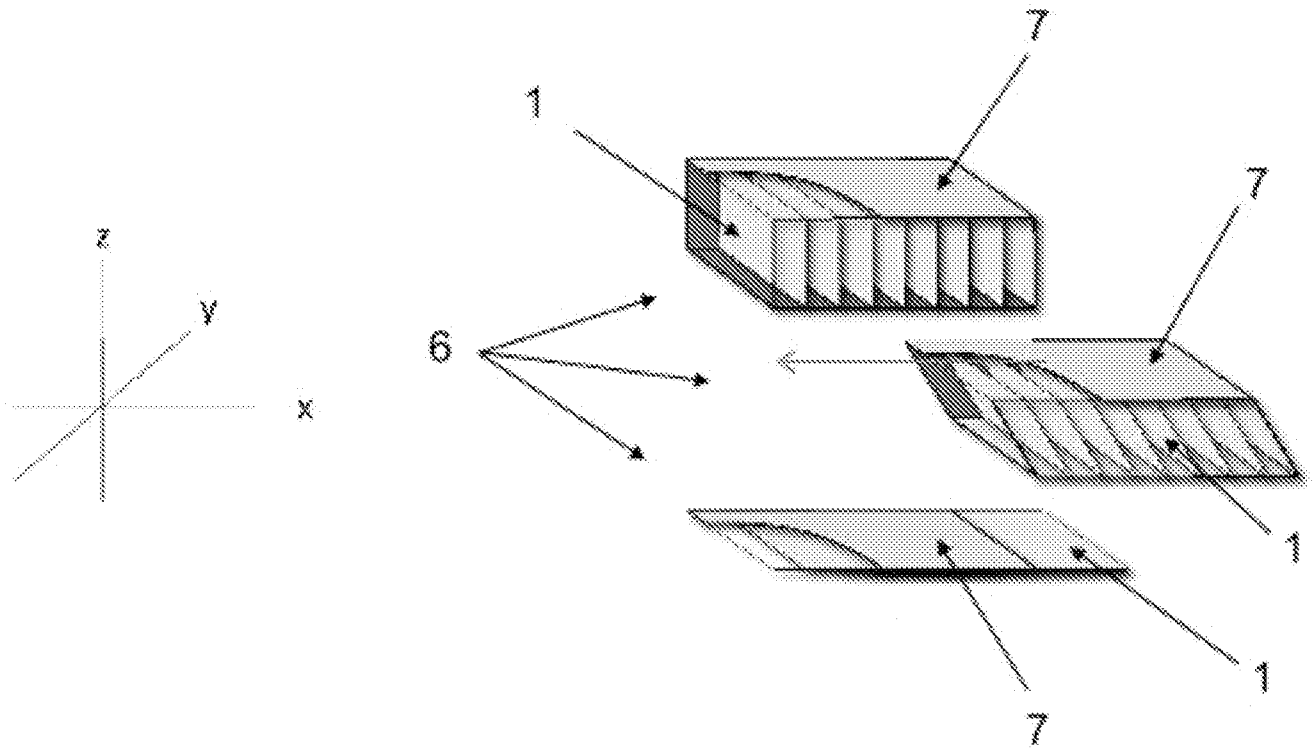


Fig. 5b

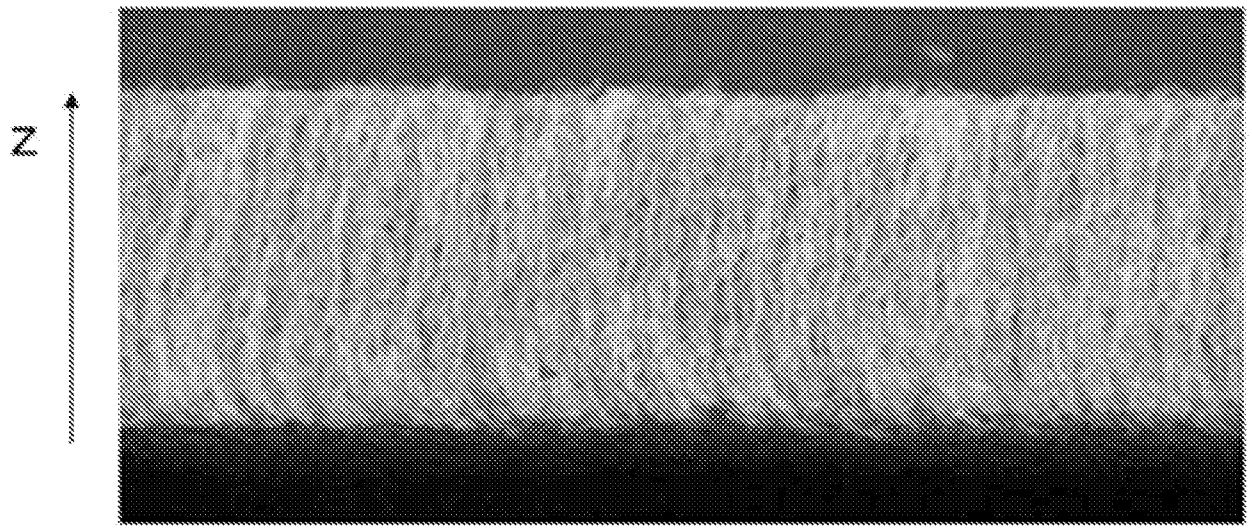


Fig. 6a

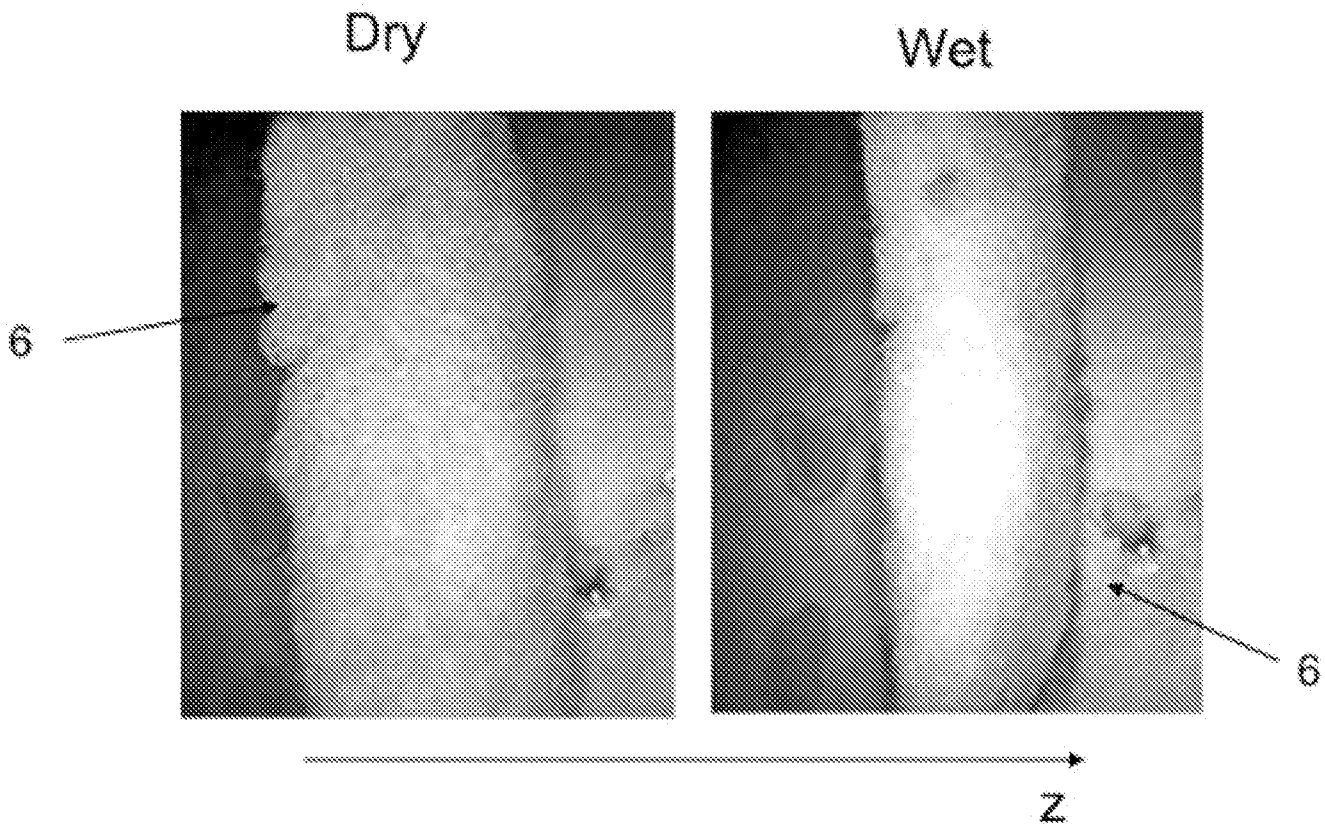


Fig. 6b

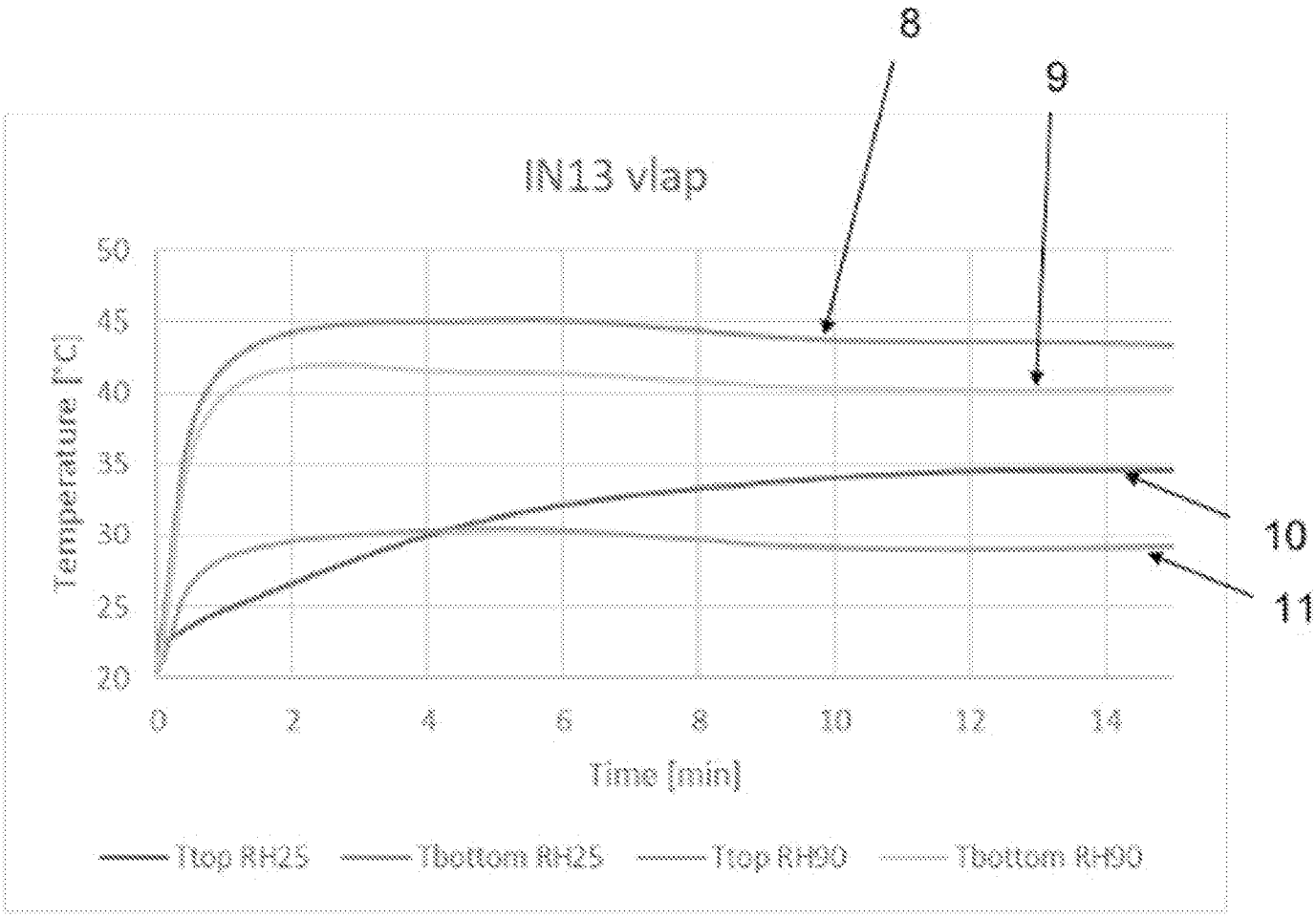


Fig. 7a

	Thickness [mm]	Decrease by	Rf [m²·K·W⁻¹]	Rtop [m²·K·W⁻¹]	Rbt [m²·K·W⁻¹]
IN14 vlap Dry	16.0	NA	0.59	5.90	3.81
IN14 vlap Wet	6.0	63%	0.01	0.11	0.07

$$Rf = \frac{d(mm)\cdot 10^{-3}}{k(Wm^{-1}K^{-1})} \qquad Rtop=0.1R_f \qquad Rbt=0.155R_f$$

d-thickness, k-conductivity

Fig. 7b

Sample code	Blend	Nonwoven technology	Base Weight (gsm)
IN 11	25% PE/PP bicomponent fibres 75% Inotek 3.3/60 fibres	Vertically lapped	180
		Carded	180
IN 12	25% PE/PP bicomponent fibres 75% Inotek 2.2/60 fibres	Vertically lapped	180
		Carded	180
IN 13	15% PE/PP bicomponent fibres 85% Inotek 3.3/60 fibres	Vertically lapped	180
		Carded	180
IN 14	15% PE/PP bicomponent fibres 85% Inotek 2.2/60 fibres	Vertically lapped	180
		Carded	180

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/47865

A. CLASSIFICATION OF SUBJECT MATTER

IPC - A41B 11/02; A41B 9/00; A41C 1/00; A41C 1/08 (2021.01)

CPC - A41B 11/02; A41B 9/001; A41C 1/003

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2020/0022436 A1 (Nike, Inc.) 23 January 2020 (23.01.2020) para [0142], [0150]-[0152], [0168], [0170]	1-4
A	US 2005/0208859 A1 (Baron et al.) 22 September 2005 (22.09.2005) entire document	1-4
A	WO 2017/165435 A2 (BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM) 28 September 2017 (28.09.2017) entire document	1-4
A	US 2017/0145602 A1 (Fiber Innovation Technology, Inc.) 25 May 2017 (25.05.2017) entire document	1-4

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 October 2021	JAN 31 2022
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Kari Rodriquez Telephone No. PCT Helpdesk: 571-272-4300

Form PCT/ISA/210 (second sheet) (July 2019)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/47865

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 5-10, 17-19, 23-27
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
(see supplemental box)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-4

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/47865

Continuation of:

-*- Box No. III Observations where unity of invention is lacking -*-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: Claims 1-4 is directed towards a non-woven fabric comprising: A. one or more webs, each of the one or more webs comprising a plurality of shape-changing fibres activatable by an external stimulus and being orientated within the plane of the one or more webs; and B. one or more partial or complete incisions in at least one of the webs, wherein in response to activation by the external stimulus, the shape changing fibres change shape such that the one or more partial or complete incisions widens.

Group II: Claims 14-16 is directed towards a method of producing a fabric according to claim 1, the method comprising: A. spinning a plurality of shape-changing fibres into a web, wherein the plurality of shape-changing fibres are activatable by an external stimulus and orientated within the plane of the web; and B. making one or more partial or complete incisions in the web, wherein in response to activation by the external stimulus, the shape changing fibres change shape such that the one or more partial or complete incisions widens.

Group III: Claims 20-22 is directed towards a non-woven fabric for adaptive insulation comprising: A. one or more webs comprising/consisting of a plurality of shape-changing fibres, wherein each one of the plurality of shape-changing fibres is activatable by an external stimulus and the plurality of shape-changing fibres are predominantly orientated parallel to an axis perpendicular to the plane of the web, defining a web thickness and, wherein in response to activation by the external stimulus the shape-changing fibres are configured to respond such that the thickness of the one or more webs decreases.

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features:

Group I requires towards a non-woven fabric: wherein the fibres are orientated within the plane of the one or more webs; B. one or more partial or complete incisions in at least one of the webs, wherein in response to activation by the external stimulus, the shape changing fibres change shape such that the one or more partial or complete incisions widens, not required by Group III.

Group II requires a method of producing a fabric according to claim 1, the method comprising: A. spinning a plurality of shape-changing fibres into a web and B. making one or more partial or complete incisions in the web, not required by Groups I or III.

Group III requires a non-woven fabric for adaptive insulation: wherein the plurality of shape-changing fibres are predominantly orientated parallel to an axis perpendicular to the plane of the web, defining a web thickness and, wherein in response to activation by the external stimulus the shape-changing fibres are configured to respond such that the thickness of the one or more webs decreases.

Shared Technical Features:

Groups I-III share the common feature of a non-woven fabric comprising: A. one or more webs, each of the one or more webs comprising a plurality of shape-changing fibres activatable by an external stimulus.

However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is anticipated by US 2020/0022436 A1 to Nike, Inc. (hereinafter 'Nike'). Nike discloses a non-woven fabric (para [0150] "With reference to FIG. 26 , a textile 80 having the configuration of a non-woven textile") comprising: A. one or more webs, each of the one or more webs comprising a plurality of shape-changing fibres activatable by an external stimulus (para [0152] "a textile may be formed that solely includes a layer of filaments 81"; para [0151] "filaments 81 are formed from a material that dimensionally - transforms in the presence of a physical stimulus"; see Fig 26 that shows a layer of filaments 81 as a web).

Group I and II share a non-woven fabric comprising: A. one or more webs, each of the one or more webs comprising a plurality of shape -changing fibres activatable by an external stimulus and being orientated within the plane of the one or more webs; and B. one or more partial or complete incisions in at least one of the webs, wherein in response to activation by the external stimulus, the shape changing fibres change shape such that the one or more partial or complete incisions widens.

However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is anticipated by Nike. Nike teaches a non-woven fabric (para [0150] "With reference to FIG. 26 , a textile 80 having the configuration of a non-woven textile") comprising: A. one or more webs, each of the one or more webs comprising a plurality of shape-changing fibres activatable by an external stimulus (para [0152] "a textile may be formed that solely includes a layer of filaments 81"; para [0151] "filaments 81 are formed from a material that dimensionally - transforms in the presence of a physical stimulus"; see Fig 26 that shows a layer of filaments 81 as a web) and being orientated within the plane of the one or more webs (see Fig 26 that shows the filaments oriented with the plane of the web); and B. one or more partial or complete incisions in at least one of the webs (para [0168] "A plurality of semi-circular incisions 74 extend through textile 74"; see Fig 36), wherein in response to activation by the external stimulus, the shape changing fibres change shape such that the one or more partial or complete incisions widens (para [0170] "When exposed to the physical stimulus , such as water or a change in temperature , for example , yarn transforms dimensionally and increases in size...Accordingly, the swelling of yarn causes the flaps formed by incisions 74 to curl upward...Each of textiles 80 and 90 may also exhibit similar properties due to the concentration of materials"; see Fig 37 that shows the incisions widening due to the external stimulus).

As the shared technical features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups. Therefore, Groups I-III lack unity under PCT Rule 13.

-*-Continued in Supplemental Box-*-

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/47865

Continuation of:

-*- Supplemental Box - Box No. III Observations where unity of invention is lacking -*-

NOTE: Claims 5-13, 17-19, and 23-27 have been found to be unsearchable under Article 17(2)(b) because they are dependent claims that are not drafted in accordance with the second and third sentences of Rule 6.4(a) and therefore have not been included with any invention.