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(54) ELECTRICALLY CONDUCTIVE TEXTILE ASSEMBLIES AND MANUFACTURE THEREOF

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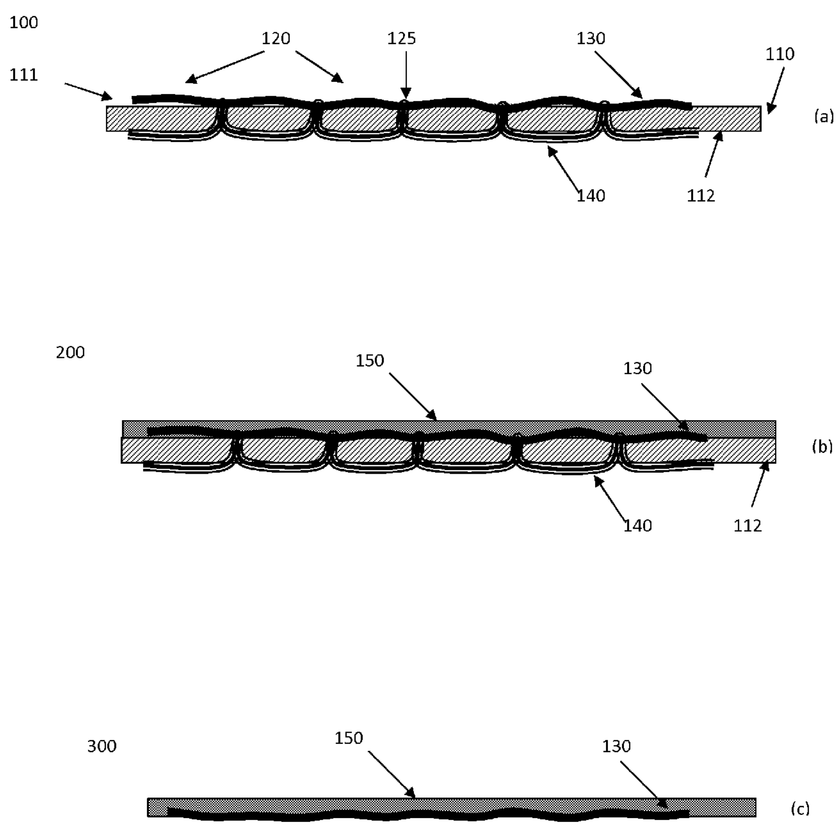
(57) ABSTRACT

There is provided a method of making a conductive assembly for use in textiles, the method comprising providing a composite material comprising: a temporary substrate having a first surface and a second surface opposite the first surface; a stitching pattern comprising a plurality of lockstitches on the temporary substrate, such that a conductive thread is disposed at the first surface of the temporary substrate and a thermo-fusible thread is disposed at the second surface; and an insulating layer comprising an adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread; and heating the insulating layer and thermo-fusible thread to the activation temperature and curing the adhesive in the insulating layer of the composite material, thereby securing the conductive thread to the insulating layer. Articles according to the process are also provided.



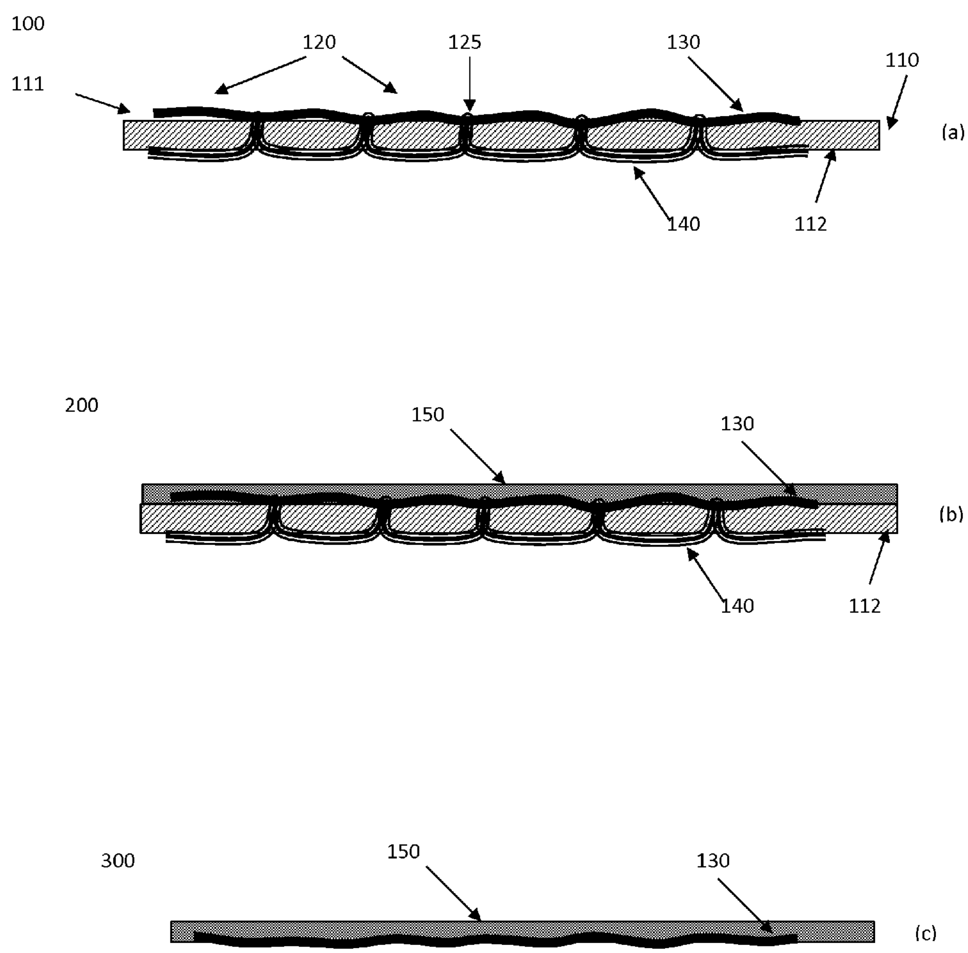

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FIG. 1

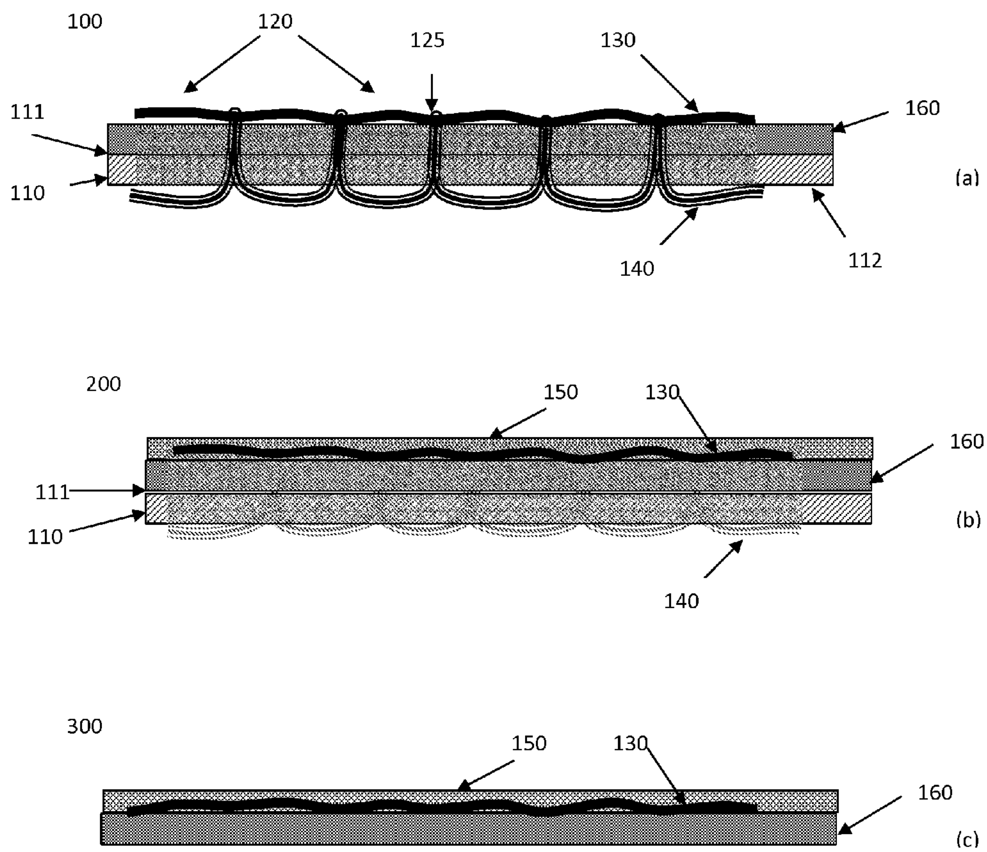
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FIG. 2

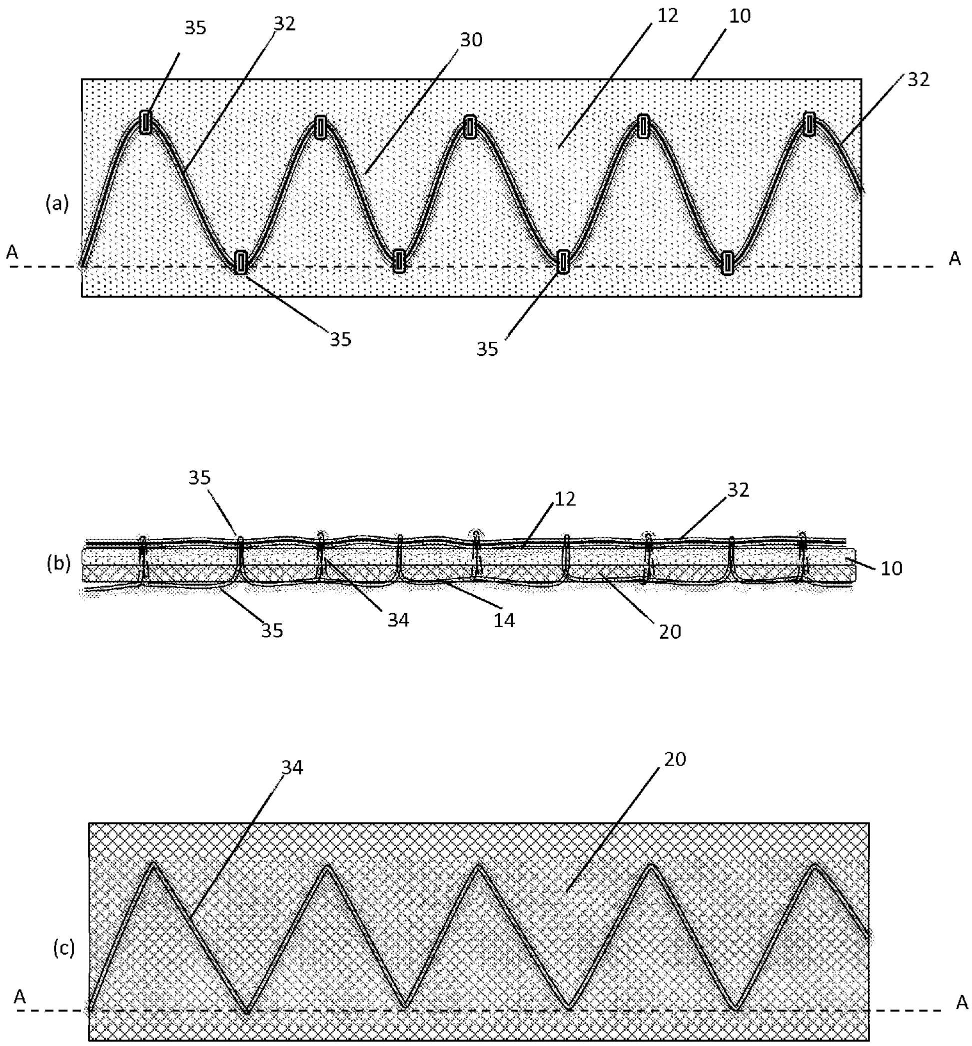


FIG. 3

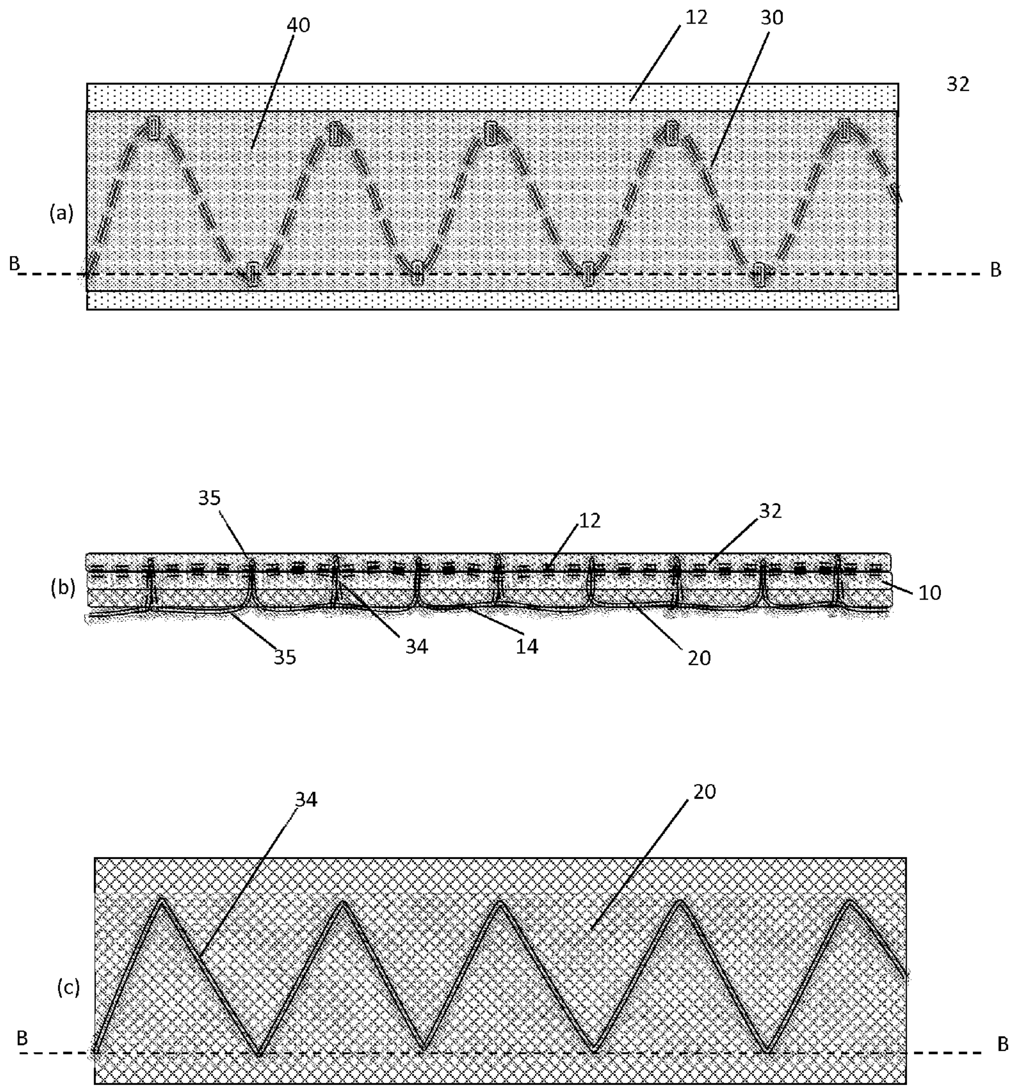


FIG. 4

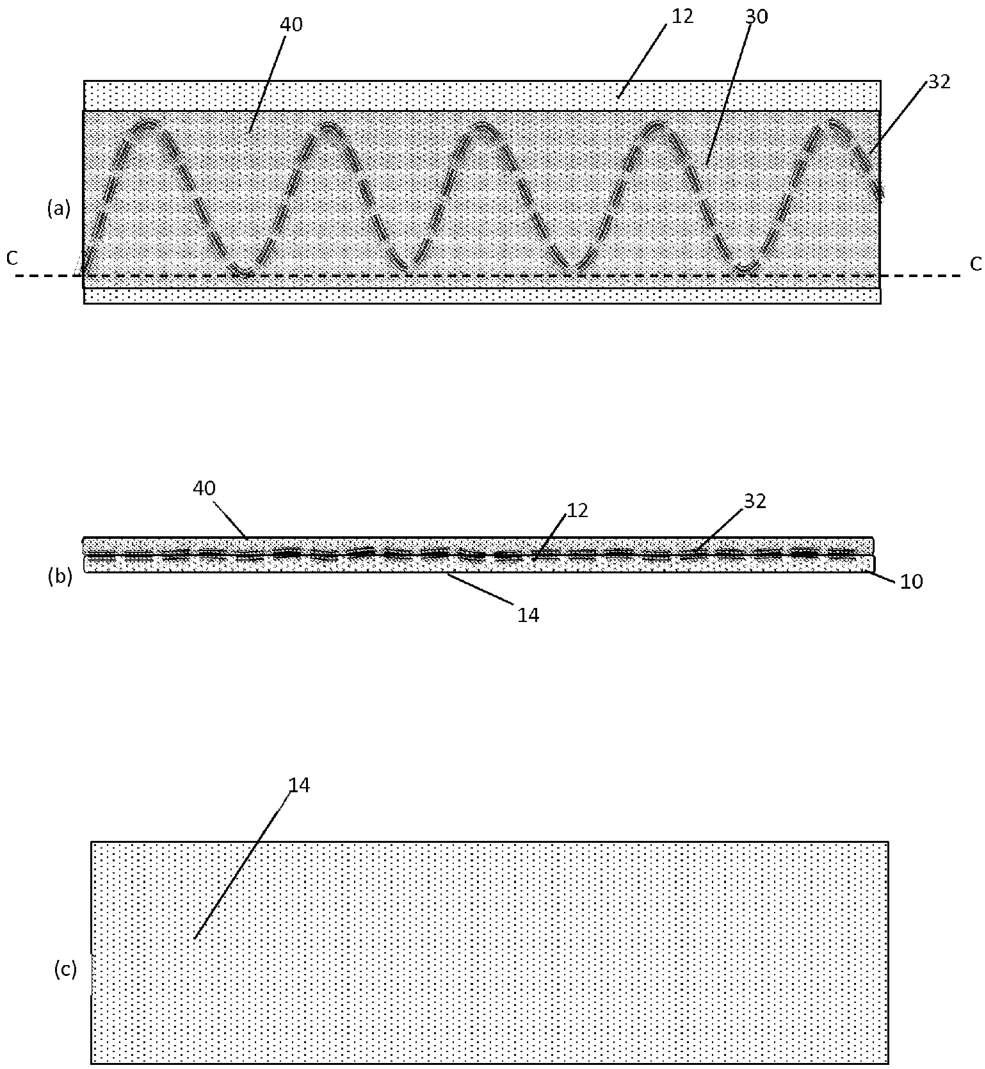


FIG. 5

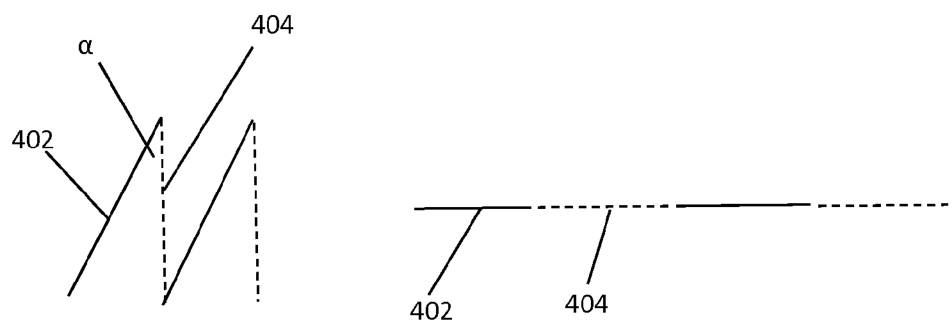
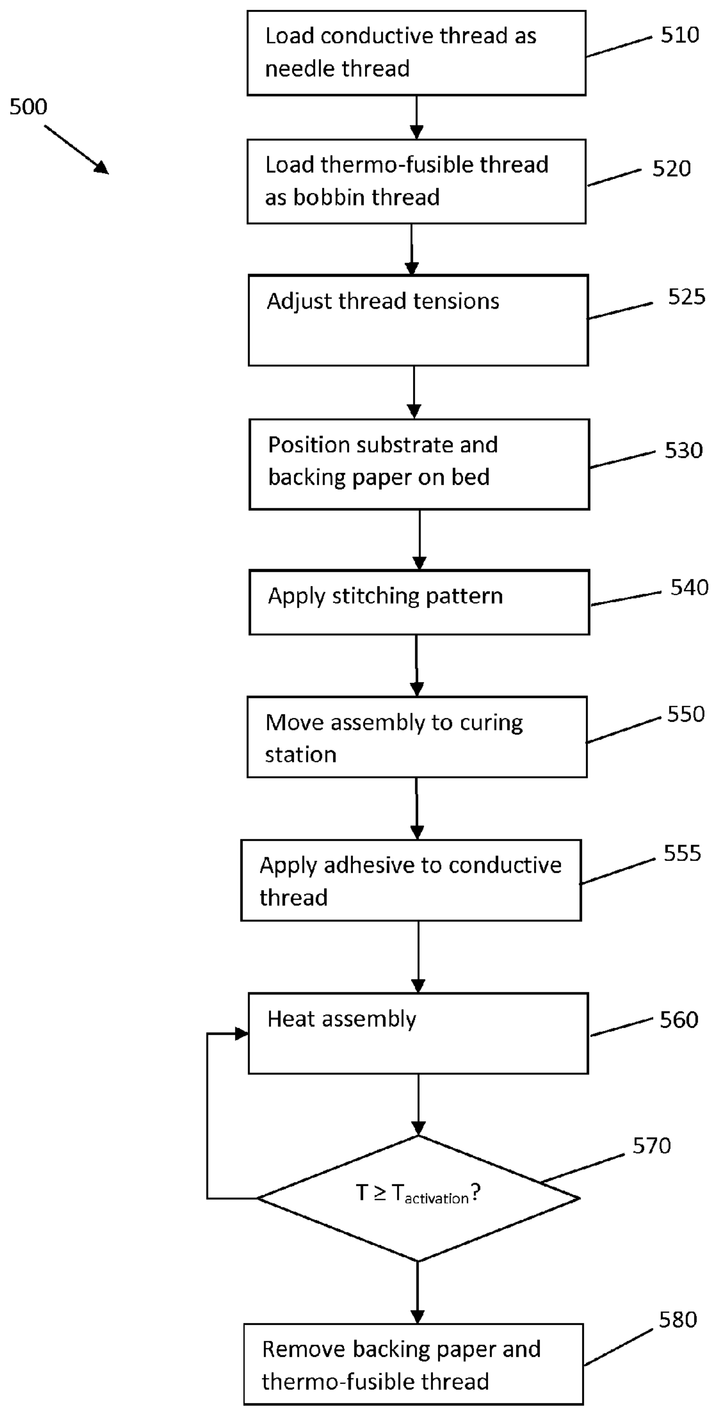


Figure 6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Load conductive thread as needle thread
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Load thermo-fusible thread as bobbin thread
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Adjust thread tensions
525
Position substrate and backing paper on bed
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Apply stitching pattern
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Move assembly to curing station
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Apply adhesive to conductive thread
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Heat assembly
560
T ≥ T activation ?
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Remove backing paper and thermo-fusible thread
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FIG. 7

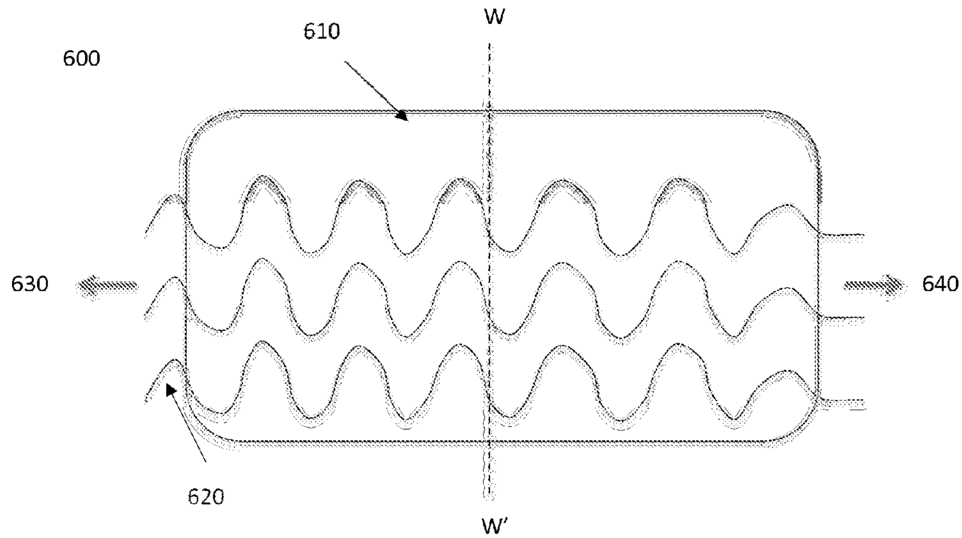

FIG. 8

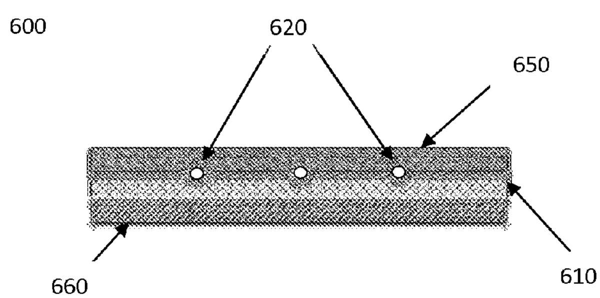

FIG. 9

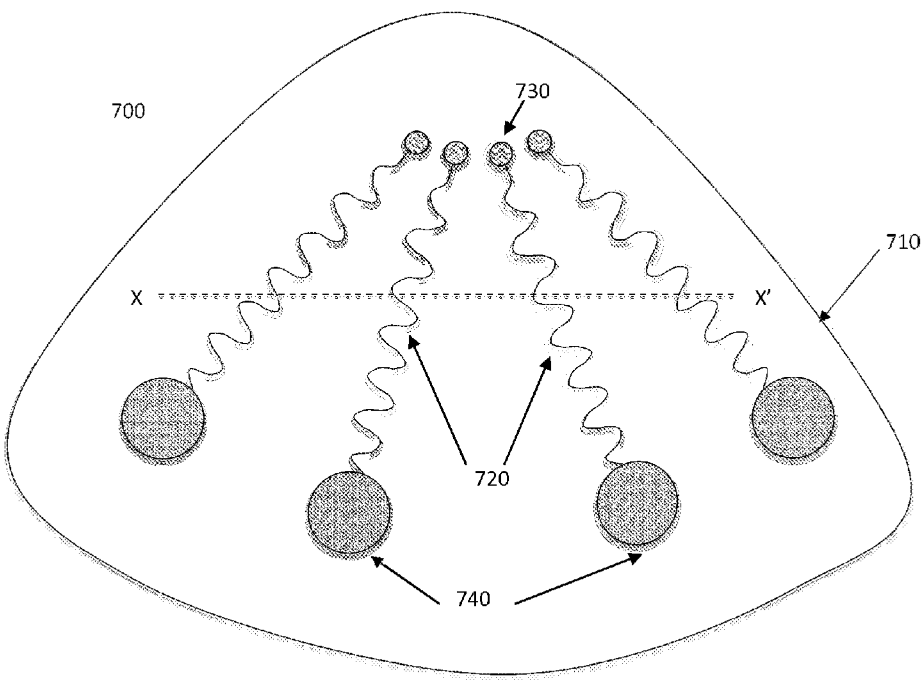

Fig. 10

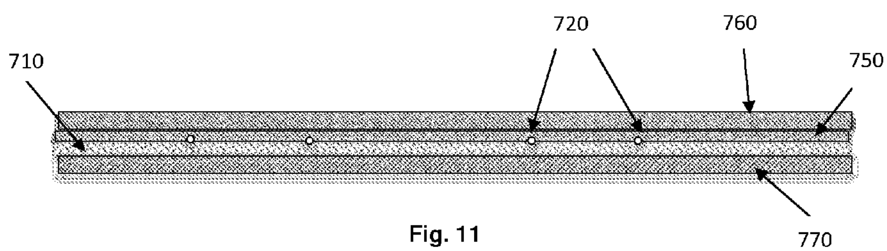

Fig. 11

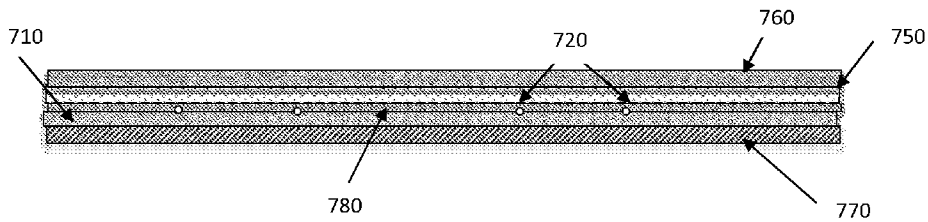

Fig. 12

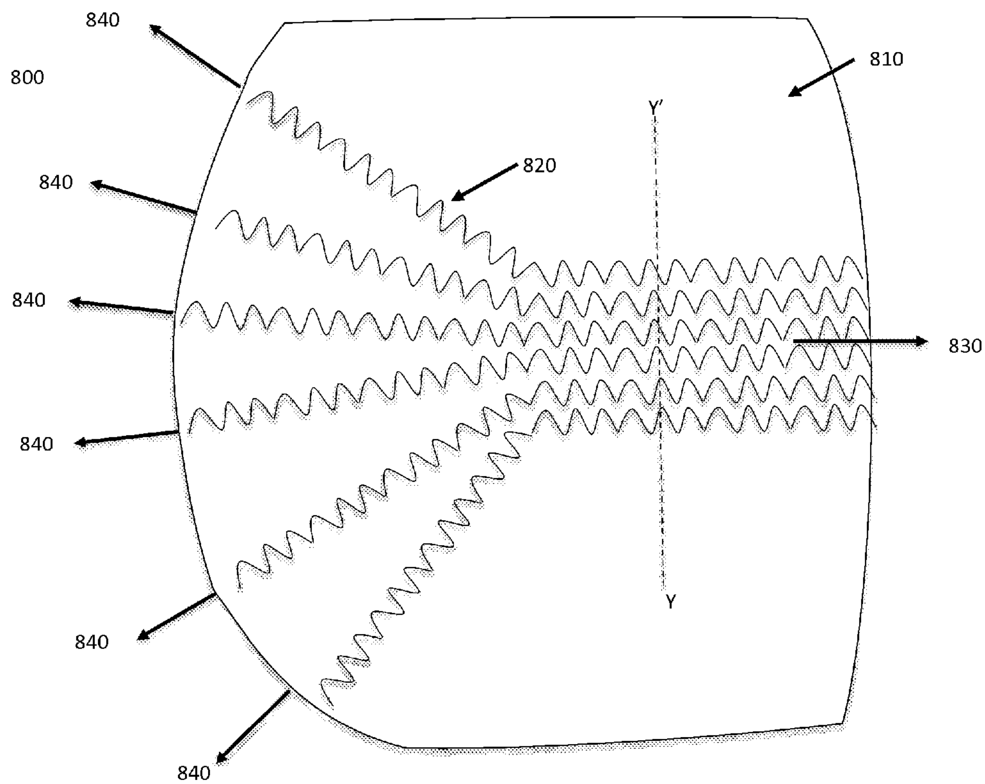

FIG. 13

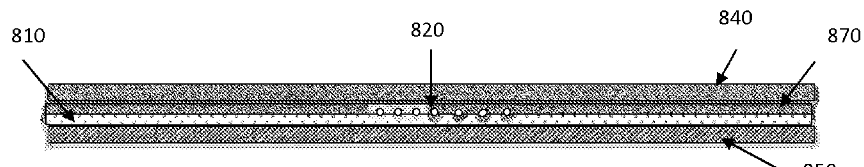

FIG. 14

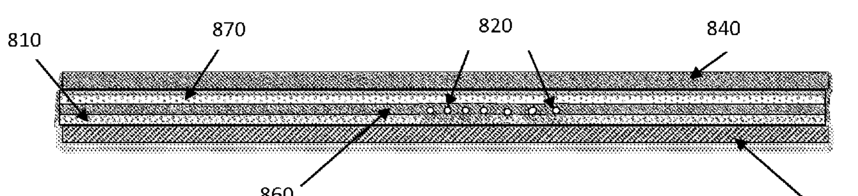

FIG. 15

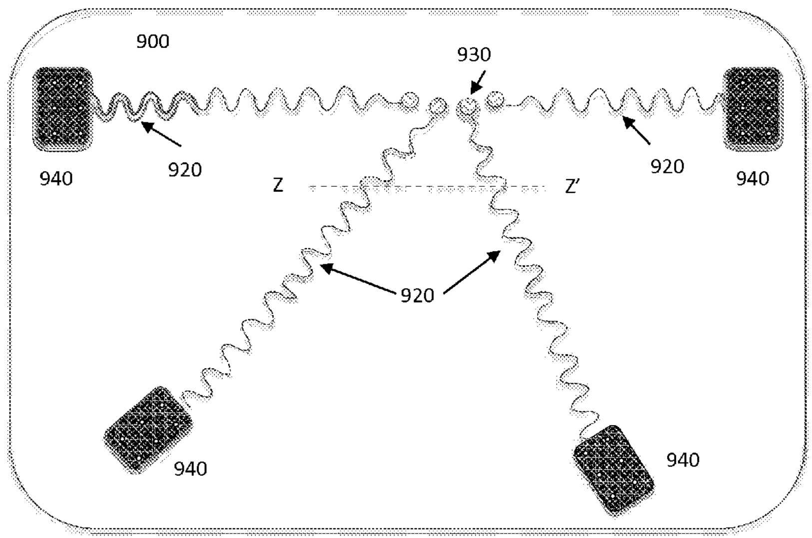

FIG. 16

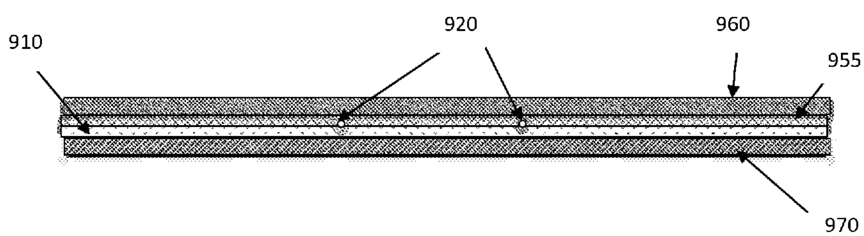

FIG. 17

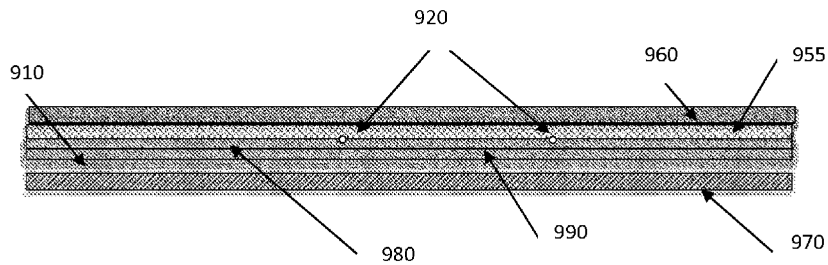
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FIG. 18

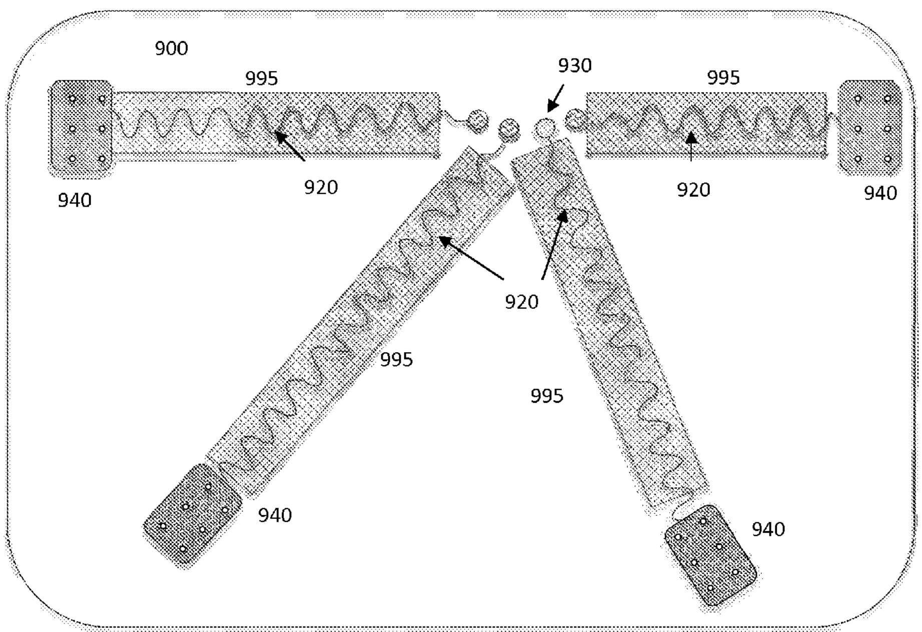
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FIG. 19

ELECTRICALLY CONDUCTIVE TEXTILE ASSEMBLIES AND MANUFACTURE THEREOF

BACKGROUND

[0001] In the field of e-textiles, one application of which is wearable electronics, electrical and electronic circuitry can be created in or on textiles and apparel by several different methods.

[0002] For example, conductive paths may be printed on textile substrates, using screen printing or template printing. Here the screen or the template will be made with open areas for the required conductive regions. The screen or template is placed precisely on the substrate at the desired position for the conductive circuit traces. The print paste or ink used in these methods generally consists of a conductive powder of suitable particle size such as silver, copper, or carbon, and a binder such as acrylic, epoxy, or silicone. The paste or ink is applied on to the textile substrate by the appropriate printing method and is cured under suitable curing conditions to produce a conductive textile product.

[0003] The conductivity of the conductive path depends on the width and thickness of the path and the composition of the print paste. Since printing methods may employ screens or templates, not only can products in which conductive paths appear on only one side of the textile substrate be made, but it is also possible to apply relatively complex patterns of conductive paths on the substrate. However, in most instances the applied conductive paths cannot stretch with the substrate without cracking, and printing methods are thus generally unsuitable for products where stretchability is important.

[0004] Some proposed printing methods use silicone based conductive inks to provide some level of stretchability. A problem with these inks is that the conductivity decreases when the printed conduction paths are stretched. This makes them unsuitable for applications such as analog signal transfer, where constant conductivity during stretch is essential.

[0005] Other template-based conductive material deposition techniques are also known. In general these techniques have the same disadvantages as printing-based methods, in that the conductive material may break (thereby interrupting the conduction path) or the conductivity may change when the substrate is stretched.

[0006] In relation to electronic garments, particularly those incorporating sensors and the like, it is highly desirable to have stretchable circuits given that the sensors etc. that are to be used should generally touch the wearer's body at all times. Stretchable circuits typically require stretchable fabric substrates. Presently known methods of achieving stretchable conductive paths on garments have many flaws, in particular being susceptible to reduced conductivity (which is difficult to predict as it is a nonlinear effect).

[0007] Alternative methods produce conductive textiles using conductive yarns or thread in the fabric manufacturing process. The conductive threads or yarns may be made of 100% conductive materials, or a combination of standard textile yarn material and conductive material. Additionally the yarn or thread may have a dielectric layer as the outermost layer to provide electrical insulation. When conductive threads are used in fabric manufacturing, for example in a weaving or knitting process, they are interlaced or interlooped in the machine direction or the cross direction. Weaving or knitting therefore, in general, cannot create non-linear and complex patterns for the conduction path, and cannot accommodate significant levels of stretching of the substrate, so may be of limited use for advanced wearable electronic apparel applications. Although woven and knitted fabrics can be cut to the shape of the desired conductive paths for use as an appliqué on a substrate, their use is generally limited to applications where only a few conductive paths are required and a low level of stretch is permitted. In addition, cutting and re-application of the cut conductive paths onto the substrate is a manual and cumbersome process, and leads to the wastage of costly conductive materials.

[0008] In order to address the above problem associated with woven or knitted conductive threads, sewing or embroidery machinery can be used instead. This has previously been done in order to create conductive paths on textile substrates which can accommodate some degree of stretch. Several examples of conductive embroidery threads and embroidered circuits are known; see, for example, U.S. patent application Ser. Nos. 09/160,540 and 11/409,243, U.S. Pat. Nos. 7,025,596 and 8,505,474, and European Patent Publication EP 1633429 A1. Embroidered or sewn circuits can address some of the disadvantages of the methods described above.

[0009] In most embroidered circuits, the conductive thread is used as the needle thread and a non-conductive (e.g., cotton) thread is used as the bobbin thread. As such, a disadvantage of embroidered circuitry is that the embroidery undesirably changes the appearance and tactility of both surfaces of the garment. To overcome this, it is necessary to use masking in the form of an additional substrate applied to the non-conductive thread, producing a multilayer composite which is heavy and bulky and thus unsuitable for applications such as sportswear, or apparel requiring high flexibility and stretchability and adaptation to body contours during use. Further, additional process steps are required, increasing the cost of manufacture.

[0010] Embodiments of the present invention seek to solve or alleviate one or more of the above problems, or at least to provide a useful alternative.

SUMMARY OF THE INVENTION

[0011] Aspects of the invention may relate to the manufacture of complete or intermediate products, as well as said products. Accordingly, in a first aspect, the present invention provides a method of making a conductive assembly for use in textiles, the method comprising:

- **[0012]** (a) providing a composite material comprising:
  - **[0013]** a temporary substrate having a first surface and a second surface opposite the first surface;
  - **[0014]** a stitching pattern comprising a plurality of lockstitches on the temporary substrate, such that a conductive thread is disposed at the first surface of the temporary substrate and a thermo-fusible thread is disposed at the second surface; and
  - **[0015]** an insulating layer comprising an adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread; and
- **[0016]** (b) heating the insulating layer and thermo-fusible thread to the activation temperature and curing the adhesive in the insulating layer of the composite material, thereby securing the conductive thread to the insulating layer.

[0017] Advantageously, the use of conductive and thermo-fusible threads on opposite sides of the temporary substrate allows the conductive thread to be temporarily anchored to the temporary substrate until the adhesive of the insulating layer is applied to fix it in place.

[0018] This process provides an intermediate product where the temporary substrate and thermo-fusible thread remain attached. The resulting intermediate product may then be used in additional processes to provide an intermediate/final product. Thus, in certain embodiments of the first aspect of the invention, the temporary substrate may be removed, along with the thermo-fusible thread, concomitantly with the curing step. Alternatively, the temporary substrate may be removed in a separate step, such that the product obtained in step (b) above may subsequently be reheated to a temperature sufficient to soften the thermo-fusible thread to enable it to be removed along with the temporary substrate.

[0019] It will be appreciated that the temporary substrate may be removed as part of the heating and curing step. Accordingly, in a second aspect of the invention, there is provided a method of making a conductive assembly for use in textiles, the method comprising:

[0020] (a) providing a composite material comprising:

[0021] a temporary substrate having a first surface and a second surface opposite the first surface,

[0022] a stitching pattern comprising a plurality of lockstitches on the temporary substrate, such that a conductive thread is disposed at the first surface of the temporary substrate and a thermo-fusible thread is disposed at the second surface; and

[0023] an insulating layer comprising a cured adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread, where the cured adhesive secures the conductive thread to the insulating layer; and

[0024] (b) heating the insulating layer and thermo-fusible thread to a temperature at or below the activation temperature and removing the temporary substrate from the insulating layer to remove the thermo-fusible thread.

[0025] In certain embodiments of the invention, the heating and curing steps are carried out substantially simultaneously.

[0026] The temporary substrate may be particularly useful for the application of stitching. Given this, in certain embodiments, the temporary substrate may be formed from a non-stretchable material.

[0027] In certain embodiments when the insulating layer and conductive thread are bonded onto a surface of a textile substrate, the insulating layer has a stretchability that is higher than or equal to a stretchability of the textile substrate.

[0028] In certain embodiments, the composite material may further comprise an adhesive film on at least part of the first surface of the temporary substrate, such that it is disposed between the first surface of the temporary substrate and the conductive thread. The adhesive film is intended to form part of the resulting conductive assembly, such that it is removable from the temporary substrate when the temporary substrate is removed along with the thermo-fusible thread. For example, the adhesive film may be an insulating adhesive, a stabilisation adhesive or a layered laminate having an insulating adhesive layer in contact with the first surface and a stabilisation adhesive layer in contact with the conductive thread.

[0029] In alternative embodiments to those further comprising an adhesive film on at least part of the first surface of the temporary substrate, the composite material may further comprise a textile substrate having a first face and a second face opposite the first face, where the second face of the textile substrate is disposed towards the first surface of the temporary substrate and the first face is disposed towards the conductive thread. For example, the first surface of the temporary substrate may be temporarily laminated to the second face of the textile substrate with a bonding film.

[0030] In certain embodiments, the insulating layer has a stretchability that is higher than or equal to a stretchability of the textile substrate.

[0031] In certain embodiment of the invention, the composite material may further comprise one or more of the following on the first face and/or the second face of the textile substrate: a support adhesive; a mesh fabric; an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

[0032] In embodiments of the invention disclosed herein, the stitching pattern may comprise a plurality of lockstitches, that are applied to the temporary substrate using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread.

[0033] In yet further embodiments, the insulating layer may further comprise a fibrous substrate. For example, the fibrous substrate may be permanently laminated to the insulating material by a bonding means or apparatus (e.g. a bonding film, or through the insulating adhesive, such that the insulating adhesive bonds both the fibrous material and the conductive thread (or intermediate layers if present)). It will be appreciated that the fibrous material is opposite the surface of the insulating adhesive that bonds to the conductive thread or to any intermediate layers between the conductive thread and the insulating adhesive (e.g. a mesh, or a fabric and a further adhesive layer as described directly below).

[0034] In embodiments of the invention comprising a textile substrate:

[0035] (a) the composite material may further comprise an insulating adhesive layer on the first face of the textile substrate and a non-mesh fabric on top of the insulating adhesive layer; or

[0036] (b) the composite material may further comprise a mesh fabric on the first face of the textile substrate. For example, the composite material may further comprise an insulating adhesive layer disposed between the mesh fabric and the first face of the textile substrate.

[0037] In certain embodiments of the invention, textile substrate may be a mesh.

[0038] The additional layers of materials introduced in the above embodiments may provide additional strength, flexibility and/or stability to the resulting intermediate and final products. For example, the additional strength, flexibility and/or stability may be beneficial with respect to one or more stages of the lifetime of the resulting products (e.g. during manufacture, during use of the final product, or during washing/drying of the final products).

[0039] In a third aspect of the invention, there is provided a method of making a conductive assembly for use in textiles, the method comprising:

[0040] (a) providing a composite material comprising:

[0041] a stabilisation substrate having a first surface and a second surface opposite the first surface,

[0042] a patterned conductive thread is disposed at the first surface of the stabilisation substrate; and

[0043] an insulating layer comprising a cured adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread, where the cured adhesive secures the conductive thread to the insulating layer;

[0044] (b) providing a textile fabric; and

[0045] (c) bonding the textile fabric to the stabilisation substrate.

[0046] In certain embodiments of the third aspect of the invention, the textile fabric may further comprise an insulating adhesive layer that is bonded to the stabilisation substrate. For example, the stabilisation substrate may be a mesh fabric or a stabilisation adhesive.

[0047] In certain embodiments of the invention, the stitching pattern may have a geometry configured to accommodate stretching of the textile substrate. In other embodiments of the invention, the patterned conductive thread may have a geometry configured to accommodate stretching of the textile substrate. For example:

[0048] (a) the stitching pattern or the patterned conductive thread comprises one or more of: a triangle wave pattern; a sawtooth pattern; a sinusoidal pattern; an omega-shaped pattern; a square wave pattern, and an irregular wave pattern; and/or

[0049] (b) the stitching pattern or the patterned conductive thread comprises at least some irregularly spaced portions.

[0050] In certain embodiments, the activation temperature of the adhesive of the insulating layer may be at least 10° C. higher than the Vicat softening point of the thermo-fusible thread, preferably at least 30° C. higher, more preferably at least 70° C. higher, and even more preferably at least 80° C. higher.

[0051] In embodiments of the invention, the conductive thread may comprise one or more conductive filaments or fibre bundles having a resultant thread count in the range from about 25 dtex to 2500 dtex. For example, the resultant thread count may be in the range from about 125 dtex to 1250 dtex, such as about 250 dtex.

[0052] In embodiments of the invention, the thermo-fusible thread may have a Vicat softening point in the range from about 50° C. to about 150° C.

[0053] In certain embodiments of the invention, the thermo-fusible thread may comprise a mono-filament or multifilament strand of polymer fibres.

[0054] In yet further embodiments, the insulating layer may comprise a barrier layer.

[0055] In yet further embodiments of the invention, the composite material may further comprises short staple fibres flocked on the adhesive whilst uncured. Advantageously, the flocking may provide extra comfort to a wearer of a garment made using the assembly prepared according to the processes described herein. Additionally or alternatively, the flocking may provide electrostatic or electromagnetic shielding.

[0056] In yet further embodiments, the stitching pattern may be applied using a sewing machine or an embroidery machine.

[0057] In yet further embodiments of the invention, the conductive thread may comprise one or more fibre(s) and/or filament(s) with: a linear density of from 0.05 to 50.0 dtex; and/or a diameter of from 0.05 μm to 50 μm.

[0058] Unless explicitly stated herein, the embodiments of the invention mentioned hereinbefore apply to the first to third embodiments of the invention. In addition, said embodiments may be combined in any technically sensible manner with said aspects of the invention.

[0059] In a fourth aspect of the invention, there is provided a conductive assembly for use in textiles comprising:

[0060] a temporary substrate having a first surface and a second surface opposite the first surface;

[0061] a stitching pattern, comprising a plurality of lockstitches, the lockstitches being formed using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread, such that the conductive thread is disposed at the first surface of the temporary substrate and the thermo-fusible thread is disposed on the second surface; and

[0062] an insulating layer comprising an adhesive applied to at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread.

[0063] Said conductive assembly may be an intermediate product.

[0064] In certain embodiments of the fourth aspect of the invention:

[0065] (a) the adhesive of the insulating layer is a cured thermoplastic insulation adhesive; and/or

[0066] (b) the temporary substrate is formed from a non-stretchable material; and/or

[0067] (c) the insulating layer has a stretchability that is higher than or equal to a stretchability of a textile substrate.

[0068] In further embodiments of the fourth aspect of the invention, the conductive assembly may further comprise an adhesive film on at least part of the first surface of the temporary substrate, such that it is disposed between the first surface of the temporary substrate and the conductive thread, optionally wherein the adhesive film is an insulating adhesive, a stabilisation adhesive or a layered laminate having an insulating adhesive layer in contact with the first surface and a stabilisation adhesive layer in contact with the conductive thread.

[0069] In alternate embodiments of the fourth aspect of the invention, the conductive assembly may further comprise a textile substrate having a first face and a second face opposite the first face, where the second face of the textile substrate is disposed towards the first surface of the temporary substrate and the first face is disposed towards the conductive thread. For example:

[0070] (a) the first surface of the temporary substrate may be laminated to the second face of the textile substrate with a bonding film; and/or

[0071] (b) the insulating layer may have a stretchability that is higher than or equal to a stretchability of the textile substrate; and/or

[0072] (c) the conductive assembly may further comprise one or more of the following on the first face and/or the second face of the textile substrate: a support adhesive; a mesh fabric; or more particularly, an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

[0073] In certain embodiments of the fourth aspect of the invention, the insulating layer may further comprise a fibrous substrate. For example:

[0074] (a) the fibrous substrate is permanently laminated to the insulating layer by a bonding means or apparatus (e.g. a bonding film); and/or

[0075] (b) the composite material may further comprise an insulating adhesive layer on the first face of the textile substrate and a non-mesh fabric on top of the insulating adhesive layer.

[0076] In further embodiments of the fourth aspect of the invention, the composite material may further comprise a mesh fabric on the first face of the textile substrate. In certain embodiments, the composite material comprising a mesh fabric may further comprise an insulating adhesive layer disposed between the mesh fabric and the first face of the textile substrate.

[0077] In yet further embodiments of the fourth aspect of the invention, the textile substrate may be a mesh.

[0078] In a fifth aspect of the invention, there is provided a conductive assembly for use in textiles, comprising:

[0079] a stabilisation substrate having a first surface and a second surface opposite the first surface,

[0080] a patterned conductive thread is disposed at the first surface of the stabilisation substrate; and

[0081] an insulating layer comprising a cured adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermofusible thread, where the cured adhesive secures the conductive thread to the insulating layer; and

[0082] a textile fabric bonded to the stabilisation substrate.

[0083] Said conductive assembly may be an intermediate product.

[0084] In embodiments of the fifth aspect of the invention, the textile fabric may further comprise an insulating adhesive layer and the insulating adhesive layer is bonded to the stabilisation substrate. For example, the stabilisation substrate may be a mesh fabric or a stabilisation adhesive.

[0085] In embodiments of the first to fifth aspects of the invention, the adhesive layers that may be mentioned therein (optionally excluding the stabilisation adhesive) may be made of a thermoplastic material. Advantageously, the use of thermoplastic adhesives may enable the conductive assemblies of the current invention to be thin and not cause discomfort to a wearer. In addition, the use of such thermoplastic materials may enable the conductive assemblies to be easily reshaped with heat. This property may be particularly useful in the construction of pre-fabricated narrow-width conductive assembly films that can be laid down on a textile substrate (e.g. a garment) in a desired pattern/design, thereby providing freedom and flexibility to construct customised conductive pathways in a garment with ease. Such customised pathways may be in the form of straight lines, curves or combinations thereof.

[0086] In a sixth aspect of the invention, there is provided a conductive assembly for use in textiles, comprising:

[0087] an insulating layer having a first surface and a second surface opposite the first surface;

[0088] a conductive thread disposed at the first surface of the insulating layer and having a pattern, wherein

[0089] wherein the insulating layer comprises a cured thermoplastic insulation adhesive in contact with the conductive thread, which is held by the cured adhesive.

[0090] Said conductive assembly may be an intermediate or final product (e.g. bonded on both sides to a textile, as described hereinbelow).

[0091] In embodiments of the sixth aspect of the invention, the insulating layer may have a stretchability that is higher than or equal to a stretchability of a textile substrate.

[0092] In further embodiments of the sixth aspect of the invention, the conductive assembly may further comprise an adhesive film on at least part of the first surface of the insulating layer, such that the conductive thread is disposed between the first surface of the insulating layer and the adhesive layer. For example, the adhesive film may be an insulating adhesive, a stabilisation adhesive or a layered laminate having an insulating adhesive layer in contact with the first surface of the insulating layer and a stabilisation adhesive layer in contact with the conductive thread.

[0093] In embodiments of the sixth aspect of the invention, the conductive assembly may further comprise a textile substrate having a first face and a second face opposite the first face, where the first face of the textile substrate is disposed towards the first surface of the insulating layer, such that the conductive thread is disposed between the first surface of the insulating layer and the first face of the textile substrate. In embodiments where the textile substrate is present, the conductive thread may not protrude from the second surface such that the textile substrate retains the original visual and haptic properties of the second surface.

[0094] In embodiments of the sixth aspect of the invention, where the textile substrate is present:

[0095] (a) the first surface of the temporary substrate may be laminated to the second face of the textile substrate with a bonding film; and/or

[0096] (b) the insulating layer may have a stretchability that is higher than or equal to a stretchability of the textile substrate; and/or

[0097] (c) the conductive assembly may further comprise one or more of the following on the first face and/or the second face of the textile substrate: a support adhesive; a mesh fabric; or more particularly, an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

[0098] In certain embodiments of the sixth aspect of the invention, the insulating layer may further comprise a fabric layer. For example, the fabric layer may be permanently laminated to the insulating layer by a bonding means or apparatus (e.g. a bonding film). For example, when the conductive assembly comprises a textile substrate and a fabric layer, the composite material may further comprise an insulating adhesive layer on the first face of the textile substrate and a non-mesh fabric on top of the insulating adhesive layer.

[0099] In certain embodiments of the sixth aspect of the invention, the insulating layer may further comprise a mesh fabric on the first face of the textile substrate. For example, the composite material may further comprise an insulating adhesive layer disposed between the mesh fabric and the first face of the textile substrate.

[0100] In further embodiments of the sixth aspect of the invention, the insulating layer may further comprise the textile substrate may be a mesh.

[0101] In embodiments of the fourth to sixth aspects of the invention:

[0102] (a) the pattern may have a geometry configured to accommodate stretching of a textile substrate (e.g. the pattern comprises one or more of: a triangle wave pattern; a sawtooth pattern; a sinusoidal pattern; an omega-shaped pattern; a square wave pattern, and an irregular wave pattern and/or the pattern comprises at least some irregularly spaced portions);

[0103] (b) the activation temperature of the adhesive of the insulating layer may be at least 10° C. higher than the Vicat softening point of the thermo-fusible thread, preferably at least 30° C. higher, more preferably at least 70° C. higher, and even more preferably at least 80° C. higher;

[0104] (c) the conductive thread may comprise one or more conductive filaments or fibre bundles having a resultant thread count in the range from about 25 dtex to 2500 dtex (e.g. from about 125 dtex to 1250 dtex, such as about 250 dtex);

[0105] (d) the thermo-fusible thread may have a Vicat softening point in the range from about 50° C. to about 150° C.;

[0106] (e) the thermo-fusible thread may comprise a mono-filament or multifilament strand of polymer fibres;

[0107] (f) the insulating layer may comprise a barrier layer;

[0108] (g) the composite material may further comprise short staple fibres flocked on the adhesive of the insulation layer;

[0109] (h) the conductive thread comprises one or more fibre and/or filament with one or more fibre(s) and/or filament(s) with: a linear density of from 0.05 to 50.0 dtex; and/or a diameter of from 0.05 μm to 50 μm.

[0110] In embodiments of the fourth and sixth aspects of the invention the conductive assembly may be in the form of a narrow-width tape.

[0111] Advantageously, the conductive threads used herein, such as the multifilament threads and textile-based metal coated threads provide excellent flexibility and durability (as the flexibility provides excellent resistance to fatigue failure even at high levels of deformation, and repeated deformation cycles undergone during use, washing and tumble drying), while providing added comfort to a wearer of a garment fitted with a conductive assembly of the current invention. In addition, the excellent properties of the conductive threads used herein enable garments fitted with said conductive assemblies to be washed without suffering from a subsequent loss of conductivity.

[0112] In a seventh aspect, the present invention provides a method of making a conductive textile assembly, the method comprising:

[0113] providing a textile substrate having a first surface and a second surface opposite the first surface;

[0114] positioning a backing layer on the second surface;

[0115] applying a stitching pattern, comprising a plurality of lockstitches, to the textile substrate using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread, such that the conductive thread is disposed at the first surface of the textile substrate and the thermo-fusible thread is disposed on the backing layer at the second surface;

[0116] applying an insulating layer comprising an adhesive to at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread;

[0117] heating the insulating layer and thermo-fusible thread to the activation temperature; and

[0118] curing the adhesive, thereby securing the conductive thread to the first surface.

[0119] In an eighth aspect, the invention provides a method of making a conductive textile assembly, the method comprising:

[0120] providing a textile substrate having a first surface and a second surface opposite the first surface;

[0121] positioning a backing layer on the second surface;

[0122] applying a stitching pattern, comprising a plurality of lockstitches, to the textile substrate using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread, such that the conductive thread is disposed at the first surface of the textile substrate and the thermo-fusible thread is disposed on the backing layer at the second surface;

[0123] applying an insulating layer comprising an adhesive to at least part of the conductive thread on the first surface;

[0124] heating the insulating layer and thermo-fusible thread to the activation temperature of the adhesive to cure the adhesive, thereby securing the conductive thread to the first surface;

[0125] whereby the thermo-fusible thread becomes sufficiently soft to be removed together with the backing layer.

[0126] Advantageously, the use of conductive and thermo-fusible threads on opposite sides of the textile substrate allows the conductive thread to be temporarily anchored to the substrate until the insulating layer can be applied to fix it in place. The thermo-fusible thread can then be removed such that the second surface of the substrate remains substantially free of undesirable visual or haptic features which would otherwise be the case if a normal thread was used in the stitching process. Assemblies produced by the inventive method may comprise conductive paths which are less intrusive to a wearer, as well as more durable under washing. Further, the method may be implemented using conventional sewing or embroidery machinery.

[0127] The method according to aspects and embodiments of the invention mentioned herein enables multiple conductive pathways to be applied to a substrate simultaneously with no short circuiting. Advantageously, conventional embroidery machines or sewing machines can be used, hence reducing the cost and increasing the accuracy of application of the conductive paths. Discrete conductive paths having high degree of complexity of path design may be applied. This is impossible with alternative methods such as knitting or weaving. Additionally, it is possible to apply conductive paths in a manner such that the circuits can accommodate high levels of stretch in one or more desired directions, with no (or at least very insignificant—less than 1%) changes in conductivity, and to achieve high path density (number of paths per unit width).

[0128] The method preferably further comprises removing the backing layer from the second surface while the thermo-fusible thread is molten.

[0129] In certain embodiments, the heating and curing steps are carried out substantially simultaneously. For example, heating the insulating layer to the activation temperature may act to cure the adhesive of the insulating layer, such that the heating and curing is a single step, thereby making the fabrication process more efficient.

[0130] The backing layer, also known in the art as a stabilizer layer, may be particularly useful for applying stitching to highly stretchable textile substrates. For this reason, the backing layer is preferably formed from a non-stretchable material.

[0131] The backing layer may be temporarily laminated to the second surface with a bonding film to further improve the stability of the assembly during stitching. Typically, bonding film manufacturers supply the films laid down on a rigid backing paper and this can be employed as the backing layer with convenience.

[0132] The stitching pattern may be applied using a sewing machine or an embroidery machine of conventional type.

[0133] The method may further comprise flocking short staple fibres on the adhesive whilst uncured. Advantageously, the flocking may provide extra comfort to a wearer of a garment made using the assembly, and/or may provide electrostatic or electromagnetic shielding.

[0134] In certain embodiments, the insulating layer has a stretchability which is higher than a stretchability of the textile substrate.

[0135] The method may further comprise applying one or more of the following to the first surface and/or the second surface: an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

[0136] In a ninth aspect, the present invention provides a conductive textile assembly, comprising:

- **[0137]** a textile substrate having a first surface and a second surface opposite the first surface;
- **[0138]** a stitched conductive thread disposed at the first surface of the textile substrate and having a stitching pattern; and
- **[0139]** an insulating layer comprising an adhesive and applied to at least part of the conductive thread to fix the conductive thread to the first surface;
- **[0140]** wherein the conductive thread does not protrude from the second surface.

[0141] In a tenth aspect, the present invention provides a conductive textile assembly comprising:

- **[0142]** a textile substrate having a first surface and a second surface opposite the first surface;
- **[0143]** a backing layer on the second surface;
- **[0144]** a stitching pattern, comprising a plurality of lockstitches, the lockstitches being formed using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread, such that the conductive thread is disposed at the first surface of the textile substrate and the thermo-fusible thread is disposed on the backing layer at the second surface; and
- **[0145]** an insulating layer comprising an adhesive applied to at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread.

[0146] In certain embodiments of the method and textile assembly of the invention, the stitching pattern has a geometry configured to accommodate stretching of the textile substrate. This allows for the provision of single sided conductive paths which may be highly stretchable without changes in conductivity resulting from stretching of the substrate. This is particularly advantageous for active apparel and the like incorporating circuit elements such as sensors which need to maintain constant contact with the wearer's skin. Allowing stretching in this way permits the wearer to move freely without compromising the electrical and electronic functions of the garment.

[0147] For example, the stitching pattern may comprise one or more of: a triangle wave pattern; a sawtooth pattern; a sinusoidal pattern; an omega-shaped pattern; and a square wave pattern. The stitching pattern may also, or alternatively, comprise one or more types of stretch stitch known in the art garment manufacture. The stitching pattern may comprise at least some irregularly spaced portions.

[0148] In certain embodiments of the seventh to tenth aspects of the invention, the activation temperature of the adhesive is at least 10° C. higher than the Vicat softening point of the thermo-fusible thread. Preferably, the activation temperature is at least 30° C. higher than the Vicat softening point. More preferably, the activation temperature may be up to 70° higher than the Vicat softening point. Even more preferably, the activation temperature may be up to 80° higher than the Vicat softening point.

[0149] It has been found that a temperature differential of at least 10° C. allows efficient removal of the thermo-fusible thread before the thermo-fusible thread re-solidifies. The thermo-fusible thread may have a Vicat softening point in the range from about 50° C. to about 150° C.

[0150] The conductive thread may comprise conductive filaments or fibre bundles having a thread count in the range from about 25 dtex to 2500 dtex. More preferably, the thread count is in the range from about 125 dtex to 1250 dtex. Even more preferably, the thread count is about 250 dtex.

[0151] In certain embodiments, the thermo-fusible thread comprises a mono-filament or multifilament strand of polymer fibres.

[0152] The backing layer may be laminated to the second surface with a bonding film. The backing layer may be formed from a non-stretchable material.

[0153] The adhesive layer itself may provide an electrically insulating effect, thereby acting as an insulating layer. In some embodiments, the insulating layer may comprise a barrier layer which provides the insulating effect, or which adds to the insulating effect provided by the adhesive. For example, the insulating layer may comprise a barrier layer applied on top of the adhesive, optionally with a further adhesive layer applied on top of the barrier layer. The barrier layer may be effective in preventing ingress of conductive fluids such as sweat, thereby lowering the risk of short circuit.

[0154] The insulating layer may have a stretchability which is higher than a stretchability of the textile substrate.

[0155] In certain embodiments, the conductive textile assembly further comprises flocked short staple fibres in or on the adhesive.

[0156] The conductive textile assembly may further comprise one or more of the following on the first surface and/or the second surface: an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

[0157] Further aspects and embodiments of the invention are disclosed in the numbered clauses below.

1. A method of making a conductive textile assembly, the method comprising:

[0158] providing a textile substrate having a first surface and a second surface opposite the first surface;

[0159] positioning a backing layer on the second surface;

[0160] applying a stitching pattern, comprising a plurality of lockstitches, to the textile substrate using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread, such that the conductive thread is disposed at the first surface of the textile substrate and the thermo-fusible thread is disposed on the backing layer at the second surface;

[0161] applying an insulating layer comprising an adhesive to at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread;

[0162] heating the insulating layer and thermo-fusible thread to the activation temperature; and

[0163] curing the adhesive, thereby securing the conductive thread to the first surface.

2. A method according to clause 1, further comprising removing the backing layer from the second surface to remove the thermo-fusible thread.

3. A method according to clause 1 or clause 2, wherein the heating and curing steps are carried out substantially simultaneously.

4. A method according to any one of clauses 1 to 3, wherein the backing layer is temporarily laminated to the second surface with a bonding film.

5. A method according to any one of clauses 1 to 4, wherein the backing layer is formed from a non-stretchable material.

6. A method according to any one of the preceding clauses, wherein the stitching pattern has a geometry configured to accommodate stretching of the textile substrate.

7. A method according to clause 6, wherein the stitching pattern comprises one or more of: a triangle wave pattern; a sawtooth pattern; a sinusoidal pattern; an omega-shaped pattern; a square wave pattern, and an irregular wave pattern.

8. A method according to clause 6 or clause 7, wherein the stitching pattern comprises at least some irregularly spaced portions.

9. A method according to any one of the preceding clauses, wherein the stitching pattern is applied using a sewing machine.

10. A method according to any one of clauses 1 to 8, wherein the stitching pattern is applied using an embroidery machine.

11. A method according to any one of the preceding clauses, wherein the activation temperature of the adhesive is at least 10° C. higher than the Vicat softening point of the thermo-fusible thread, preferably at least 30° C. higher, more preferably at least 70° C. higher, and even more preferably at least 80° C. higher.

12. A method according to any one of the preceding clauses, wherein the conductive thread comprises conductive filaments or fibre bundles having a thread count in the range from about 25 dtex to 2500 dtex.

13. A method according to clause 13, wherein the thread count is in the range from about 125 dtex to 1250 dtex.

14. A method according to clause 13, wherein the thread count is about 250 dtex.

15. A method according to any one of the preceding clauses, wherein the thermo-fusible thread has a Vicat softening point in the range from about 50° C. to about 150° C.

16. A method according to any one of the preceding clauses, wherein the thermo-fusible thread comprises a mono-filament or multifilament strand of polymer fibres.

17. A method according to any one of the preceding clauses, wherein the insulating layer comprises a barrier layer.

18. A method according to any one of the preceding clauses, further comprising flocking short staple fibres on the adhesive whilst uncured.

19. A method according to any one of the preceding clauses, wherein the insulating layer has a stretchability which is higher than or equal to a stretchability of the textile substrate.

20. A method according to any one of the preceding clauses, further comprising applying one or more of the following to the first surface and/or the second surface: an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

21. A conductive textile assembly, comprising:

[0164] a textile substrate having a first surface and a second surface opposite the first surface;

[0165] a stitched conductive thread disposed at the first surface of the textile substrate and having a stitching pattern; and

[0166] an insulating layer comprising an adhesive and applied to at least part of the conductive thread to fix the conductive thread to the first surface;

[0167] wherein the conductive thread does not protrude from the second surface such that the textile substrate retains the original visual and haptic properties of the second surface.

22. A conductive textile assembly according to clause 21, wherein the stitching pattern has a geometry configured to accommodate stretching of the textile substrate.

23. A conductive textile assembly according to clause 22, wherein the stitching pattern comprises one or more of: a triangle wave pattern; a sawtooth pattern; a sinusoidal pattern; an omega-shaped pattern; a square wave pattern and an irregular wave pattern.

24. A conductive textile assembly according to clause 22 or clause 23, wherein the stitching pattern comprises at least some irregularly spaced portions.

25. A conductive textile assembly according to any one of clauses 21 to 24, wherein the conductive thread comprises conductive filaments or fibre bundles having a thread count in the range from about 25 dtex to 2500 dtex.

26. A conductive textile assembly according to clause 25, wherein the thread count is in the range from about 125 dtex to 1250 dtex.

27. A conductive textile assembly according to clause 25, wherein the thread count is about 250 dtex.

28. A conductive textile assembly according to any one of clauses 21 to 27, wherein the insulating layer comprises a barrier layer.

29. A conductive textile assembly according to any one of clauses 21 to 28, further comprising flocked short staple fibres in or on the adhesive.

30. A conductive textile assembly according to any one of clauses 21 to 29, wherein the insulating layer has a stretchability which is higher than or equal to a stretchability of the textile substrate.

31. A conductive textile assembly according to any one of clauses 21 to 30, further comprising one or more of the following on the first surface and/or the second surface: an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

32. A conductive textile assembly comprising:

[0168] a textile substrate having a first surface and a second surface opposite the first surface;

[0169] a backing layer on the second surface;

[0170] a stitching pattern, comprising a plurality of lockstitches, the lockstitches being formed using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread, such that the conductive thread is disposed at the first surface of the textile substrate and the thermo-fusible thread is disposed on the backing layer at the second surface; and

[0171] an insulating layer comprising an adhesive applied to at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread.

33. A conductive textile assembly according to clause 32, wherein the backing layer is laminated to the second surface with a bonding film.

34. A conductive textile assembly according to clause 32 or clause 33, wherein the backing layer is formed from a non-stretchable material.

35. A conductive textile assembly according to any one of clauses 32 to 34, wherein the stitching pattern has a geometry configured to accommodate stretching of the textile substrate.

36. A conductive textile assembly according to clause 35, wherein the stitching pattern comprises one or more of: a triangle wave pattern; a sawtooth pattern; a sinusoidal pattern; an omega-shaped pattern; a square wave pattern and an irregular wave pattern.

37. A conductive textile assembly according to clause 35 or clause 36, wherein the stitching pattern comprises at least some irregularly spaced portions.

38. A conductive textile assembly according to any one of clauses 32 to 37, wherein the activation temperature of the adhesive is at least 10° C. higher than the Vicat softening point of the thermo-fusible thread, preferably at least 30° C. higher, more preferably at least 70° C. higher, and even more preferably at least 80° C. higher.

39. A conductive textile assembly according to any one of clauses 32 to 38, wherein the conductive thread comprises conductive filaments or fibre bundles having a thread count in the range from about 25 dtex to 2500 dtex.

40. A conductive textile assembly according to clause 39, wherein the thread count is in the range from about 125 dtex to 1250 dtex.

41. A conductive textile assembly according to clause 39, wherein the thread count is about 250 dtex.

42. A conductive textile assembly according to any one of clauses 32 to 41, wherein the thermo-fusible thread has a Vicat softening point in the range from about 50° C. to about 150° C.

43. A conductive textile assembly according to any one of clauses 32 to 42, wherein the thermo-fusible thread comprises a mono-filament or multifilament strand of polymer fibres.

44. A conductive textile assembly according to any one of clauses 32 to 43, wherein the insulating layer comprises a barrier layer.

45. A conductive textile assembly according to any one of clauses 32 to 44, further comprising flocked short staple fibres on the adhesive.

46. A conductive textile assembly according to any one of clauses 32 to 45, wherein the insulating layer has a stretchability which is higher than or equal to a stretchability of the textile substrate.

47. A conductive textile assembly according to any one of clauses 32 to 46, further comprising one or more of the following on the first surface and/or the second surface: an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

48. A method of making a conductive textile assembly, the method comprising:

[0172] providing a textile substrate having a first surface and a second surface opposite the first surface;

[0173] positioning a backing layer on the second surface;

[0174] applying a stitching pattern, comprising a plurality of lockstitches, to the textile substrate using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread, such that the conductive thread is disposed at the first surface of the textile substrate and the thermo-fusible thread is disposed on the backing layer at the second surface;

[0175] applying an insulating layer comprising an adhesive to at least part of the conductive thread on the first surface;

[0176] heating the insulating layer and thermo-fusible thread to the activation temperature of the adhesive to cure the adhesive, thereby securing the conductive thread to the first surface;

[0177] whereby the thermo-fusible thread becomes sufficiently soft to be removed together with the backing layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0178] Embodiments of the invention will now be described, by way of non-limiting example only, with reference to the accompanying drawings in which:

[0179] FIGS. **1**(*a*) to **1**(*c*) depict steps to make an intermediate product of the current invention.

[0180] FIGS. **2**(*a*) to **2**(*c*) depict steps to make a further intermediate product according to the current invention.

[0181] FIG. **3**(*a*) is a plan view of a first side of a textile substrate with stitching applied.

[0182] FIG. **3**(*b*) is a cross-section through the line A-A of FIG. **3**(*a*) and FIG. **3**(*c*).

[0183] FIG. **3**(*c*) is a plan view of a second (opposite) side of the textile substrate and stitching of FIG. **3**(*a*).

[0184] FIGS. **4**(*a*) and **4**(*c*) are plan views of the first and second sides after an insulation adhesive has been bonded to the first surface and cured to form a conductive textile assembly.

[0185] FIG. **4**(*b*) is a cross-section through the line B-B of FIG. **4**(*a*) and FIG. **4**(*c*).

[0186] FIGS. **5**(*a*) and **5**(*c*) are plan views of the first and second sides of the assembly after a backing layer and thermo-fusible thread have been removed;

[0187] FIG. **5**(*b*) is a cross-section through the line C-C of FIG. **5**(*a*).

[0188] FIG. **6** schematically illustrates stretchability of a stitched conductive thread on a substrate.

[0189] FIG. **7** is a flow diagram of a process for making a conductive textile assembly.

[0190] FIG. **8** depicts a conductive assembly according to the invention suitable for connecting a switch to a waistband on a pair of running shorts fitted with a LED for illumination purposes.

[0191] FIG. **9** is a cross-section through the line W-W' of the conductive assembly of FIG. **8**.

[0192] FIG. **10** depicts an ECG signal monitoring device having a conductive assembly according to embodiments of the current invention.

[0193] FIGS. **11** and **12** depict alternative constructions of the conductive assembly that may be used in the device of FIG. **10**, as viewed as respective cross-sections through line X-X' of FIG. **10**.

[0194] FIG. **13** depicts a device for use in a wearable EMG signal monitoring device having a conductive pathway according to embodiments of the current invention.

[0195] FIGS. **14** and **15** depict alternative constructions of the conductive assemblies that may be used in the device of FIG. **13**, as viewed as respective cross-sections through line Y-Y' of FIG. **13**.

[0196] FIG. **16** depicts the use of the conductive assemblies of the current invention for garments illuminated by LEDs.

[0197] FIGS. **17** and **18** depict alternative constructions of the conductive assemblies that may be used in the garment of FIG. **16**, as viewed as respective cross-sections through line Z-Z' of FIG. **16**.

[0198] FIG. **19** depicts the use of continuous narrow width conductive paths for customised conductive pathways on a flexible substrate, such as a garment.

DETAILED DESCRIPTION OF EMBODIMENTS

[0199] Certain embodiments of the present invention provide means of creating conductive paths suitable for affixing to stretchable textile substrates. Further embodiments of the present invention provide means of creating conductive paths on stretchable textile substrates. These embodiments addressing one or more of the disadvantages and limitations of prior art methods discussed above.

[0200] Embodiments of the invention relate to the making of conductive paths that may be affixed to textiles or apparel. Additional embodiments of the invention relate to making a conductive path on textiles or apparel. The conductive paths described herein enable textiles or apparel to be used for smart clothing for various applications including sports, well-being, illumination, heating, communication, healthcare monitoring etc. In certain embodiments, an intermediate product may be manufactured that affixes a conductive thread, laid down using a conventional embroidery machinery or a conventional sewing machine, to an insulating adhesive that may subsequently be affixed to a textile or apparel. Additionally or alternatively, the method may use conventional embroidery machinery or a conventional sewing machine to apply a conductive thread to the textile or apparel, the thread having a sufficient level of conductivity for the desired application. Embodiments may provide for the application of a conductive path to only one side of the textile substrate, with no tangible or visible modification to the other side of the textile substrate.

[0201] In one embodiment of a method for making a conductive assembly, a conventional sewing machine or embroidery machine can be employed to apply a conductive thread on one side of a temporary substrate, and a thermo-fusible thread on the opposite side of the temporary substrate, the thermo-fusible thread being interlocked with the conductive thread at regular points along the length of the conductive thread. That is, a series of lockstitches can be applied to the temporary substrate. In additional or alternative embodiments of a method for making a conductive assembly, a conventional sewing machine or embroidery machine can be employed to apply a conductive thread on one side of a textile substrate, and a thermo-fusible thread on the opposite side of the textile substrate, the thermo-fusible thread being interlocked with the conductive thread at regular points along the length of the conductive thread. That is, a series of lockstitches can be applied to the textile substrate. For example, the thermo-fusible thread can be employed as the bobbin thread, and the conductive thread as the needle thread. As is known by persons skilled in the art, the term "needle thread" may be used interchangeably with the term "upper thread".

[0202] Some embodiments may make use of a backing layer or stabilizer layer. In such embodiments, the backing layer or stabilizer layer is disposed between the textile substrate and the thermo-fusible thread. The backing layer may be a layer of a non-stretchable material, for example a fibrous material such as paper, and serves to stabilize the textile substrate while the stitching is applied. Once the stitching work is complete the thermo-fusible thread is removed with the backing paper. This may occur during a step where the conductive thread is secured and insulated with a heat activated or heat cured adhesive. The thermo-fusible thread has a lower Vicat softening point than the activation temperature of the adhesive, such that the thermo-fusible thread softens and/or melts as the adhesive is being activated and/or cured, and can be easily removed together with the backing paper.

[0203] Some additional or alternative embodiments of the invention may make use of a temporary substrate instead of, or in addition to, a textile substrate. In these embodiments, the temporary substrate is disposed at least between the conductive and thermo-fusible threads. The temporary substrate may be a layer of a non-stretchable material, for example a fibrous material such as paper, and serves as a substrate to enable a stitched pattern to be fixed to an insulating layer whether in the presence of a textile substrate or not. Once the stitching work is complete the thermo-fusible thread is removed with the temporary substrate. This may occur during a step where the conductive thread is secured and insulated with a heat activated or heat cured adhesive. The thermo-fusible thread has a lower Vicat softening point than the activation temperature of the adhesive, such that the thermo-fusible thread softens and/or melts as the adhesive is being activated and/or cured, and can be easily removed together with the temporary substrate.

[0204] It will be appreciated that "backing paper", "backing layer" etc, when used herein, may also refer to "temporary substrate" and vice versa.

[0205] An embodiment of the invention is now described herein with reference to FIGS. **1**(*a*) to **1**(*c*).

[0206] FIG. **1**(*a*) depicts a composite **100**, that contains a temporary substrate **110** having a first surface **111** and a second surface **112** opposite the first surface and a stitching pattern **120** comprising a plurality of lockstitches **125** on the temporary substrate, such that a conductive thread **130** is disposed at the first surface of the temporary substrate and a thermo-fusible thread **140** is disposed at the second surface.

[0207] The temporary substrate may be a layer of a non-stretchable material, for example a fibrous material such as paper. When used in embodiments of the invention as depicted by FIG. **1**, the first surface **111** of the temporary substrate may not have adhesive properties.

[0208] The stitching pattern used may be as described in respect of FIG. **6** and/or in relation to the conductive textile assembly described with reference to FIGS. **3** to **5** and **7**. These patterns may apply to any of the embodiments and aspects of the invention unless explicitly stated otherwise.

[0209] An uncured composite assembly **200** (FIG. **1**(*b*)) is then formed through use of the composite **100** by placing an insulating layer **150** comprising an adhesive on top of at least part of the conductive thread **130** on the first surface **111** of the temporary substrate **110**, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread. A cured composite assembly **200** according to the current invention is formed by subjecting the adhesive of the insulating layer **150** and thermo-fusible thread **140** to heating to the activation temperature of the adhesive and curing the adhesive in the insulating layer of the composite material, thereby securing the conductive thread **130** to the insulating layer **150**.

[0210] In certain embodiments, a composite assembly **300** (FIG. **1**(*c*)) according to the current invention may be prepared by removing the temporary substrate **110** and the thermo-fusible thread **140** before the thermo-fusible thread has time to cool to a temperature where it solidifies. In which case, the removal of the temporary substrate **110** and the thermo-fusible thread **140** may be conducted in a single processing step with the heating and curing of the adhesive that forms whole or part of the insulation layer **150**. Alternatively, the composite assembly **300** may be formed following cooling a solidification of the thermo-fusible thread **140**, in which case the composite assembly **200** is subjected to heat to a temperature that causes the thermo-fusible thread **140** to soften, thereby allowing removal of it and the temporary substrate to form composite assembly **300**.

[0211] It will be appreciated that the products prepared in the above process may be intermediate products that are suitable for affixation to a textile or apparel in a further step. In addition, further materials and layers may be included in these processes and products, as discussed in further detail herein.

[0212] As mentioned hereinbefore, an adhesive layer that forms part of the conductive assembly may be disposed between the temporary substrate and the conductive thread. An embodiment of the invention illustrating this arrangement is depicted in FIGS. **2**(*a*)-(*c*).

[0213] FIG. **2**(*a*) depicts a composite **100**, that contains a temporary substrate **110** having a first surface **111** and a second surface **112** opposite the first surface, a stitching pattern **120** comprising a plurality of lockstitches **125** on the temporary substrate, such that a conductive thread **130** is disposed at the first surface **111** of the temporary substrate and a thermo-fusible thread **140** is disposed at the second surface **112**. In addition, the embodiment of FIG. **2**(*a*) also contains an adhesive film **160** on at least part of the first surface **111** of the temporary substrate, such that it is disposed between the first surface **111** of the temporary substrate and the conductive thread **130**.

[0214] The temporary substrate may be a layer of a non-stretchable material, for example a fibrous material such as paper. When used in embodiments of the invention as depicted by FIG. **2**, the first surface **111** of the temporary substrate does not have adhesive properties.

[0215] The stitching pattern used may be as described in respect of FIG. **6** and/or in relation to the conductive textile assembly described with reference to FIGS. **3** to **5** and **7**.

[0216] An uncured composite assembly **200** (FIG. **2**(*b*)) is then formed through use of the composite **100** by placing an insulating layer **150** comprising an adhesive on top of at least part of the conductive thread **130** on the adhesive film **160**, the adhesive of the insulating layer having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread. A cured composite assembly **200** according to the current invention is formed by subjecting the adhesive of the insulating layer **150** and thermo-fusible thread **140** to heating to the activation temperature of the adhesive and curing the adhesive in the insulating layer of the composite material, thereby securing the conductive thread **130** to the insulating layer **150**, thereby essentially encapsulating the conductive thread (or part thereof) between the insulating layer **150** and the adhesive layer **160**.

[0217] When used herein, in any embodiment that calls for it, the additional adhesive layer **160** may be a material similar to (or the same as) the adhesive used as part (or whole of) the insulating layer.

[0218] In certain embodiments, a composite assembly **300** (FIG. **2**(*c*)) according to the current invention may be prepared by removing the temporary substrate **110** and the thermo-fusible thread **140** before the thermo-fusible thread has time to cool to a temperature where it solidifies. In which case, the removal of the temporary substrate **110** and the thermo-fusible thread **140** may be conducted in a single processing step with the heating and curing of the adhesive that forms whole or part of the insulation layer **150**. Alternatively, the composite assembly **300** may be formed following cooling a solidification of the thermo-fusible thread **140**, in which case the composite assembly **200** is subjected to heat to a temperature that causes the thermo-fusible thread **140** to soften, thereby allowing removal of it and the temporary substrate to form composite assembly **300**, wherein whole or part of the conductive thread may be encapsulated between the insulating layer **150** and the adhesive layer **160**.

[0219] Advantageously, as the insulating layer and additional adhesive layer(s) mentioned herein may be made of a thermoplastic material, the conductive assembly can be reshaped as desired for any particular application. In addition, and generally throughout this specification, the mentioned adhesive materials may be reactivated by heating at a later stage for lamination with other substrates, such as the addition of a fabric, to an exposed face of a layer made of such an adhesive material.

[0220] It will be appreciated that the products prepared in the above processes may be intermediate products that are suitable for affixation to a textile or apparel in a further step. As before, further materials and layers may be included in the process and products described in respect of FIG. **2**, as discussed in further detail in the embodiments below.

[0221] In one example, a textile substrate may be added to the temporary substrate (e.g. where the temporary substrate is a backing layer, such as a backing paper) to provide a conductive textile assembly. This example is discussed in more detail with reference to FIGS. **3** to **5** and **7**. For the avoidance of doubt, the mention of any materials in respect of this example may be generally applicable to any embodiment of the invention, provided said embodiment has need of similar material.

[0222] As illustrated in the flow chart of FIG. **7**, a process **500** for making a conductive textile assembly begins by setting up a conventional sewing or embroidery machine with a conductive thread as the needle thread (block **510**) and a thermo-fusible thread as the bobbin thread (block **520**).

[0223] At block **525**, the set tensions of the conductive thread and the thermo-fusible thread are adjusted in order to have a level of thread balance such that when the lockstitching is applied, the conductive thread **32** (FIG. **3**) resides entirely on the upper surface **12** of the substrate **10** while the thermo-fusible thread **34** resides mostly on the lower surface **14**. This may be achieved by setting the tension of the needle (conductive) thread **32** to be slightly higher than that of the bobbin (thermo-fusible) thread **34**. The degree to which the tension of the needle thread should be higher than that of the bobbin thread can be obtained for a given combination of threads, substrate and backing paper by routine experimentation, for example by running a small trial at a given tension setting and then running a further trial with the needle thread tension set slightly higher to check whether the needle thread is visible only on the upper surface **12**.

[0224] At block **530**, a textile substrate **10** and backing paper **20** (FIG. **3**) are positioned on the bed of the sewing machine or embroidery machine, with the backing paper **20** facing the machine bed.

[0225] Next, at block **540**, and with reference to FIG. **3**, a stitching pattern **30** is applied to the textile substrate **10**. A needle of the sewing or embroidery machine, carrying the conductive thread **32**, penetrates the upper surface **12** of the substrate **10**, traverses the lower surface **14**, and penetrates the backing paper **20**. The thermo-fusible thread **34** is looped around the conductive thread **32**, and the needle is then withdrawn back through the backing paper **20** and substrate **10**. The needle or the substrate is then repositioned according to the next desired stitch location and the process is repeated. Each such repetition results in formation of a lockstitch, such that after multiple repetitions, a stitching pattern **30** comprising a plurality of lockstitches is formed. The stitching pattern is such that the conductive thread **32** resides substantially on the upper surface **12** of the substrate **10** (with no part of it protruding from the lower surface **14**) while the thermo-fusible thread **34** resides mostly on the lower surface **14**, with parts protruding through the substrate **10** at the needle entry points **35**, those parts serving to anchor the conductive thread **32** to the substrate.

[0226] The stitching pattern **30** forms a conductive path of desired shape and dimensions. While a zig-zag stitch pattern following a substantially linear path is shown in the Figures, it will be appreciated that a wide variety of patterns are possible, depending on aesthetic and stretchability requirements. The stretchability conferred by a zig-zag or sawtooth pattern is illustrated schematically in FIG. **6**.

[0227] In general, the stretchability and stretch recovery of the assembly may depend on the type of textile substrate **10**, the type of insulation adhesive **40**, and the conductive thread pattern **30**. The stretchability of the assembly will be limited by the least stretchable component. Typically, this will be the textile substrate **10**, since most currently known textiles can only go up to around a maximum of 600% stretch within the elastic range, whereas it is known that adhesives can be engineered to have stretchability above 800%, within the elastic range. Accordingly, in order for the thread pattern **30** not to unduly limit the stretchability of the finished assembly, it is preferred that the thread pattern be applied in such a way that it is at least as stretchable as the substrate **10**, and preferably moreso. In preferred embodiments, the conductive thread pattern is applied in such a way that it can accommodate stretching of up to 750% depending on the substrate.

[0228] The stretchability of the conductive thread pattern will in general be determined by the ratio between the length of thread within the average repeat period of the thread pattern and the average repeat period (peak-to-peak distance). For example, for a zig zag pattern as shown in FIG. **6**, having within a single repeated element a first line segment **402** of length l and a second line segment **404** at an angle of a to the first line segment **402**, the stretchability S (as a percentage) can be estimated as:

$$S = 100^{*}\frac{l + \frac{l}{\cos\alpha}}{l\tan\alpha} = 100^{*}\cot\frac{\alpha}{2}.$$

[0229] It is thought that in certain cases there could be a small reduction of stretchability of the finished assembly below the stretchability of the textile substrate **10**, due to the bonding forces between the substrate **10**, conductive thread **32** and adhesive layer **40** (FIG. **4**). The present inventors have found that the reduction is typically less than about 20% of the stretchability of the textile substrate **10**.

[0230] In general, the elastic recovery of the finished assembly will depend on the type of textile substrate **10** and the type of insulation adhesive **40**. In comparative terms, most insulation adhesives provide higher elastic recovery (within the range 90-100%) than typical textile substrates (within the range 85-95%), hence considering any reduction of elastic recovery during the process **500**, the inventors believe that the finished assembly will maintain at least 90% elastic recovery.

[0231] At block **550** (FIG. **7**), the temporary assembly of substrate **10**, backing paper **20** and stitching **30** is moved to a curing station in order to apply an adhesive layer to fix the conductive thread **32** in place. The temporary assembly may be moved manually or may be automatically conveyed to the curing station, if an in-line assembly process is used.

[0232] At the curing station, with reference to FIG. **4**, a layer **40** of an insulation adhesive is applied (block **555**) onto the conductive path **30** defined by the conductive thread **32**, such that the conductive thread **32** is covered with adhesive. In some embodiments the adhesive **40** may cover only part of the thread **32**.

[0233] At block **560** (FIG. **7**), the textile assembly is heated to cure and/or activate the adhesive and melt the thermo-fusible thread **34**. A controller of a heating block at the curing station (not shown) applied to the assembly continuously monitors (block **570**) whether the temperature is at or above the activation temperature of the adhesive **40**, and loops back to block **560** to continue raising the temperature until the temperature meets the threshold. Once the threshold is reached, the adhesive is considered to be cured.

[0234] The Vicat softening point of the thermo-fusible thread **34** is lower than the activation temperature of the adhesive **40**. Accordingly, the step **560**, **570** of heating the assembly serves to simultaneously cure the adhesive **40** and soften or melt (if it is heated to above its melting temperature) the thread **34**, such that the portions **35** extending through the substrate **10** are softened sufficiently to release the conductive thread **32**. The backing paper **20** may then be removed (block **580**) with the thermo-fusible thread while the assembly is sufficiently warm, i.e., while it remains above the thread **34** softening temperature, such that only the substrate **10**, conductive path defined by thread **32**, and adhesive layer **40** remain (FIG. **5**). Advantageously, therefore, a single processing step may enable the conductive thread **32** to be secured and the backing paper **20** to be removed.

[0235] As will be appreciated by the skilled reader, the activation temperature of the adhesive **40** should be lower, and preferably substantially lower, than the melting temperatures of the substrate material **10** and the conductive thread **32**, to avoid introducing warping or other defects when the assembly is heated.

[0236] In some embodiments, the textile substrate positioned on the bed at block **530** (FIG. **7**) can be pre-laminated with a bonding film (not shown) that has a backing paper, to provide additional stability to the substrate **10**. This eliminates the need for a separate application of the backing paper at the embroidery machine, which may improve process speed, especially in an in-line process. In block **530** the laminated substrate **10** may be placed on the embroidery bed or sewing machine bed, with the non-laminated side **12** facing upwards. In these embodiments, at block **580**, instead of the backing paper **20**, the backing paper of the bonding film will be removed,

[0237] The textile substrate **10** used in the present embodiments may be made of one or a combination of methods. Non-limiting examples include knitting, weaving, non-woven manufacturing, force spinning, and electro-spinning.

[0238] Additionally, the textile substrate **10** may be manufactured using a single fibre material, filament or yarn, or a blend of fibre materials, filaments and/or yarns. The fibre material may be selected from a group consisting of: animal based fibre, plant based fibre, manmade fibre and mineral based fibre, and combinations thereof.

[0239] The conductive thread **32** useful with embodiments of the invention may be manufactured with twisted, non-twisted, air-intermingled, or core-spun conductive filament or fibre bundles. The filaments or fibres may be made at least partially out of metal such as silver, stainless steel, aluminum or copper, and may further comprise conventional manmade or natural non-conductive polymers, carbon or carbon nanotubes. Additionally the fibres, filaments, or filament bundles may be coated with an electrically insulating material comprising a non-conductive polymer such as a polyester, fluoropolymers, polyamide, PVC, or polyurethane. The conductivity of the thread **32** may vary from around a few mΩ per meter to several kΩ per meter or even up to several MΩ per meter, depending on the material combination, thickness, formation method and so on, as is well known in the art.

[0240] The thermo-fusible thread **34** may be made of mono-filament or multifilament strands of fibres having a polymer composition which has a Vicat softening point below, and preferably well below (for example, at least about 10° C. below, or at least about 30° C. below, or at least about 70° C. below, or at least about 80° C. below), the melting point of the substrate **10** and the conductive thread **32**, and the activation temperature of the insulation adhesive **40**. For example, the thermo-fusible thread may have a Vicat softening point in the range from about 50° C. to about 150° C. The polymer composition may comprise one or a combination of polyester, fluoropolymer, polyamide, polyurethane, polyolefin, and polyvinyl acetate, for example. In the presently described embodiments, the Vicat softening point is measured by test method A120 of ASTM D1525.

[0241] In some embodiments the polymer composition of the thermo-fusible thread **34** may have a melting temperature below the activation temperature of the adhesive **40** (FIGS. **4** and **5**). For example, the melting temperature may be at least about 10° C. below, or at least about 30° C. below, or at least about 70° C. below, or at least about 80° C. below, the activation temperature of the insulation adhesive **40**. For example, the thermo-fusible thread may have a melting temperature in the range from about 70° C. to about 150° C.

[0242] The insulation adhesive layer **40** may be provided in sheet form, and be directly applied with heat and pressure activation. Insulation adhesive layer **40** may comprise a polymer composition of one or a combination of polyurethane, polyester, fluoropolymer, polyacrylate, polyamide, silicone, polyolefin, polyvinyl acetate and the like. Such adhesive sheets may be provided as a single adhesive layer, a double layer fabrication with an adhesive layer adjacent a barrier film, or a three layer fabrication with having an adhesive-barrier film-adhesive structure. The barrier film may act as additional protection from electric current leakages and moisture penetration and from external electric and electromagnetic noise.

[0243] In some embodiments, the insulation adhesive **40** could be applied using a screen printing or stencil printing operation, wherein the adhesive can be cured using an external energy source such as heat, actinic radiation (such as UV or visible light), and X-rays. The adhesive **40** can comprise a polymer composition of one or a combination of polyesters, polyamides, fluoropolymers, PVC, polyurethane, polyacrylates, polyolefins, silicone and the like.

[0244] The backing paper **20** (FIG. **3**) may be provided in sheet form cut to the desired shape (e.g., the shape of a garment or part thereof, or the shape of a length of textile), and may be made of cellulose or a manmade fibre composition, preferably using a non-woven manufacturing process. The backing paper **20** is preferably non-stretchable and stiff. The backing paper **20** is preferably, but not necessarily, significantly thinner than the substrate. In some embodiments, depending on the type of substrate **10**, the backing paper **20** may be omitted altogether, but it is highly advantageous when assembling conduction paths on high stretch or lightweight substrates **10**, and in any event assists in removal of the thermo-fusible thread **34** when the thread **34** is molten.

[0245] In addition, the backing paper **20** may be a material (or a treated material) that does not stick to the adhesive materials.

[0246] FIG. **8** depicts a conductive assembly for the connection of a switch to a waistband of a pair of running shorts that may be illuminated by LEDs therein. The conductive assembly **600** is disposed within an inner and outer fabric (not shown for clarity), where the conductive wires **620** (arranged in a pattern that may match any of those disclosed hereinbefore) are fixed to an insulating substrate **610**. The conductive wires **620** and substrate **610** extend through the garment and enable the connection of a power module **630** (not shown) to a switch **640** (not shown). The LEDs may be affixed to the depicted conductive pathways directly, or may be connected by way of a separate conductive pathway affixed to the switch **640** (not shown).

[0247] The conductive wires **620** for this application require high conductivity levels and may be made from a stainless steel conductive thread, insulated by the insulating layer. Additionally, the conductive wires may be further insulated by an insulation coating. For example, the stainless steel conductive thread may be polyester-coated stainless steel threads, which have a linear density of 0.15 g/m (1500 dtex), along with a resistance of 0.6 Ohms/cm.

[0248] As depicted the switch may be connected to the power module by three conductive wires **620**, and the maximum length from the switch to the power module may be 30 cm. The width and repeat length of the serpent wave pattern may be around 2 cm and 1.5 cm respectively.

[0249] FIG. **9** depicts the conductive assembly **600** (FIG. **8**) in cross-section through lines W-W'. As depicted, the conductive wires **620** are affixed to the insulation layer **610**, which is in turn bonded to a fabric **650**, in this case a narrow-width elastic, on one side and to an inner fabric **660** on the other side.

[0250] Construction of the garment of FIG. **9** will now be described by reference to the process depicted in FIG. **1** (by analogy) and the final product of FIG. **9**.

[0251] 1. The narrow width elastic **650** is laid onto the first face **111** of a temporary substrate **110**.

[0252] 2. A stitching pattern using a conductive thread **620** (**130** in FIG. **1**) and a thermo-fusible thread **140** comprising a plurality of lockstitches is embroidered onto the intermediate composite, such that the conductive thread **620** is disposed on the surface of the narrow width elastic **650**, the narrow width elastic being between the conductive thread and the first face **111** of the temporary substrate **110**, and the thermo-fusible thread **140** is located on the second surface **112** of the temporary substrate.

[0253] 3. The insulation layer **610** (**110** in FIG. **1**), which is pre-laminated with the inner fabric **660** is placed onto the conductive thread **620** and the narrow width elastic **650** and the composite material is subjected to the heating/curing step described with reference to FIG. **1** to bond the adhesive of the insulation layer **610** to the conductive thread and narrow width elastic **650**.

[0254] 4. The temporary substrate **110** is then removed, along with the thermo-fusible thread **140**. This removal may be conducted immediately following the heating/curing step before the thermo-fusible thread has time to reach a temperature where it can solidify. Alternatively, this removal may be conducted in a separate step, where heat is applied to soften the thermo-fusible thread in order to remove it at the same time as the backing paper.

[0255] It will be appreciated that the outer **650** and/or inner **660** fabrics used in this embodiment may not be present. In this case, the removal step may be followed by subsequent lamination of the outer and/or inner fabrics to the adhesive in the insulation layer.

[0256] The narrow-width elastic fabric of FIG. **9** may be a blend of polyester/rubber and elastane, which has a width of 60 mm and a linear density of 50 g/m. The narrow-width elastic fabric **650**, which acts as a fibrous layer in this embodiment, may be pre-laminated to the insulation layer. The inner fabric may be a cotton/elastane 85/15 blend, warp knitted with a GSM of 150, where the inner fabric may be provided with a backing paper bound thereto, which acts as the temporary substrate (**110**).

[0257] It will be appreciated that the inclusion of the inner fabric may improve the feel of the conductive assembly to a user.

[0258] FIG. **10** depicts a conductive assembly **700** for use in an ECG signal monitoring medical device. The conductive assembly comprises an insulation adhesive layer **710**, along with additional layers relating to an outer and inner fabric, an additional adhesive layer and a thin sandwiched fabric layer (as shown in FIG. **11** and/or FIG. **12**). The conductive assembly also comprises conductive wires **720** and, as suitable for the desired use, conductive connection nodes **730** for connection to a communication module and ECG sensors **740**, both attached to the conductive wires **720**.

[0259] The device uses small number of peripheral ECG sensors **740** that are connected to a central communication module (not shown), where the maximum length from the central communication module to the peripheral ECG sensors **740** is less than 20 cm. The width and repeat length of the serpent wave pattern of the conductive wires **720** is around 1 cm and 1.5 cm respectively

[0260] FIG. **11** provides a cross-section of the layers used in one potential conductive assembly used in the device depicted in FIG. **10**, as viewed through the line X-X'. As shown in FIG. **11**, the conductive assembly may contain conductive wires (e.g. stainless steel conductive thread) sandwiched between an insulation layer **710** (comprising an adhesive) and a further adhesive layer **750**. The insulation layer **710** is bonded to an inner fabric **770**, while the additional adhesive layer is bonded to an outer fabric **760**. It will be appreciated that typical methods of connecting the conductive threads to the conductive nodes **730** and ECG sensors **740** may be used, or the nodes can be stitched/embroidered continuously with conductive thread.

[0261] Stainless steel threads are used as the conductive wire **720**, which threads have a linear density of 0.11 g/m (1100 dtex). The resistivity of the threads is around 0.6 Ohms/cm, which provides high conductivity and very low susceptibility to noise, suitable for use in a medical device.

[0262] Both the insulation layer adhesive **710** and the additional adhesive layer **750** each may comprise a polyurethane thermal bonding material as the adhesive and a barrier layer (i.e. a thermoplastic material). This means that the additional adhesive layer may also act as an additional insulation layer. The total thickness of the insulation adhesive and barrier layers may be 150 μm, where the barrier layers contribute 100 μm thickness to this total, while the two polyurethane glue layers each contribute 25 μm. It will be appreciated that the use of thermoplastic materials provide the ability to re-shape the conductive assemblies for custom uses.

[0263] The outer fabric used may be a polyester/elastane 90/10 blend, warp knitted fabric with a GSM of 200, and the inner fabric may be a cotton/elastane 85/15 blend, warp knitted with a GSM of 150.

[0264] A first process to make the device depicted in FIG. **11** is described below, with reference to the process depicted in FIG. **1** (by analogy) and the final product of FIG. **11**.

[0265] 1. A stitching pattern using a conductive thread **720** and thermo-fusible thread **140** comprising a plurality of lockstitches is embroidered onto the temporary substrate, such that the conductive thread **720** is disposed onto the first surface **111** of a temporary substrate

110, and the thermo-fusible thread **140** is disposed on the second surface **112** of the temporary substrate.

[0266] 2. The insulation layer **710** (which may be wholly or partly an adhesive; **110** in FIG. **1**), which is pre-laminated to the inner fabric **770**, is placed onto the conductive thread **720** and the temporary substrate **110**. The insulation layer **710** is then subjected to the heating/curing step described in the process of FIG. **1**.

[0267] 3. The temporary substrate **110** is then removed, along with the thermo-fusible thread **140** to expose the conductive thread **720** and a face of the insulation adhesive layer **710**. This removal may be conducted immediately following the heating/curing step before the thermo-fusible thread has time to reach a temperature where it can solidify. Alternatively, this removal may be conducted in a separate step, where heat is applied to soften the thermo-fusible thread in order to remove it at the same time as the backing paper.

[0268] 4. The additional adhesive layer **750**, pre-laminated with the outer fabric **760** is placed onto the conductive thread **720** and the insulation adhesive layer **710** and subjected to bonding (e.g. in a process similar to the heating/curing step described with reference to FIG. **1**).

[0269] A second process to make the device depicted in FIG. **11** is described below, with reference to the process depicted in FIG. **1** (by analogy) and the final product of FIG. **11**.

[0270] 1. A stitching pattern using a conductive thread **720** and thermo-fusible thread **140** comprising a plurality of lockstitches is embroidered onto a an additional adhesive layer **750** on top of a first surface **111** of a backing paper **110**, such that the conductive thread **720** is disposed onto the additional adhesive layer **750** and the thermo-fusible thread **140** is disposed on a second surface **112** of the temporary substrate. As noted hereinbefore, the backing paper **110** may not adhere to the adhesive, thereby allowing ease of removal.

[0271] 2. An insulation adhesive **710** (**110** in FIG. **1**), which is pre-laminated with the inner fabric **770**, is placed onto the conductive thread **720** and at least the insulation layer **710** is subjected to the heating/curing step described in the process depicted in FIG. **1**. It will be appreciated that the additional adhesive layer may also be subjected to curing in the same heating/curing step.

[0272] 3. The temporary substrate **110** is then removed, along with the thermo-fusible thread **140** to expose a face of the additional adhesive layer **750**. This removal may be conducted immediately following the heating/curing step before the thermo-fusible thread has time to reach a temperature where it can solidify. Alternatively, this removal may be conducted in a separate step, where heat is applied to soften the thermo-fusible thread in order to remove it at the same time as the backing paper.

[0273] 4. An outer fabric **760** is placed onto the exposed face of the additional adhesive layer **750** and laminated onto said face (e.g. in a process similar to the heating/curing step described with reference to FIG. **1**).

[0274] Alternatively the outer fabric **760** and/or inner fabric **770** can be laminated in a subsequent step without pre-lamination onto the adhesive materials **710** and/or **750**.

[0275] It will be appreciated that in both processes described above, the inner **770** fabric used in this embodiment may not be present. In this case, the process may further involve subsequent lamination of the inner fabric to the insulation layer **710**.

[0276] FIG. **12** provides a cross-section of the layers used in one potential construction of the device depicted in FIG. **10**, as viewed through line X-X'. The device of FIG. **12** is essentially identical to that of FIG. **11**, except that it further contains a thin layer of fabric **780** sandwiched between the insulation layer **710** and the further adhesive layer **750**. The materials used in the device of FIG. **12** are identical to those of FIG. **11**, with the addition of a thin fabric layer, which may be of any suitable material, for example the thin fabric layer may be a 80/20 polyester/elastane blend with a GSM of 100.

[0277] This thin layer of fabric may provide increased durability to the conductive assembly, either during manufacture, or at any stage in the resulting lifecycle of the product that it becomes attached to.

[0278] A first process to make the composite assembly depicted in FIG. **12** may be described with reference to the process described in FIG. **1** (reference may be made to the reference numerals of FIG. **1** and the attendant description to aid understanding).

[0279] 1. A thin fabric layer **780** is laid onto the first face **111** of the temporary substrate **110**.

[0280] 2. A stitching pattern using a conductive thread **720** and thermo-fusible thread **140** comprising a plurality of lockstitches is embroidered onto the composite material of step (1), such that the conductive thread **720** is disposed on the surface of the thin fabric layer **780**, the thin fabric layer being between the conductive thread and the first face **111** of the temporary substrate **110**, and the thermo-fusible thread **140** is located on the second surface **112** of the temporary substrate.

[0281] 3. The insulation adhesive **710** (**110** in FIG. **1**), pre-laminated with the inner fabric **770** is placed onto the conductive thread **720** and the thin fabric layer **780** and subjected to the heating/curing step previously described with reference to FIG. **1**.

[0282] 4. The temporary substrate **110** is then removed, along with the thermo-fusible thread **140**, to expose a face of the thin fabric layer **780**. This removal may be conducted immediately following the heating/curing step before the thermo-fusible thread has time to reach a temperature where it can solidify. Alternatively, this removal may be conducted in a separate step, where heat is applied to soften the thermo-fusible thread in order to remove it at the same time as the backing paper.

[0283] 5. The additional adhesive layer **750**, pre-laminated with the outer fabric **760** is placed onto the exposed face of the thin fabric layer **780** and subjected to bonding (e.g. in a process similar to the heating/curing step described with reference to FIG. **1**).

[0284] Alternatively the outer fabric **760** and/or inner fabric **770** can be laminated at a subsequent step without pre-lamination onto the adhesive materials **710** and/or **750**.

[0285] A second process to manufacture the conductive assembly depicted in FIG. **12** involves providing a temporary substrate having the additional adhesive layer **750** disposed directly thereupon, with the thin fabric layer **780** disposed on the additional adhesive layer. A stitching pattern using a conductive thread and thermo-fusible thread comprising a plurality of lockstitches is applied to the intermediate composite, such that the conductive thread **720** is applied onto the thin fabric layer and the thermo-fusible thread is disposed on the temporary substrate (e.g. a backing paper that is non-sticky). Following this, the insulation layer **710**, which is laminated/bonded to the inner fabric **770**, is applied, heated and cured. As discussed hereinbefore the backing paper, along with the thermo-fusible thread may be removed immediately after the heating/curing step (or at some stage before the thermo-fusible thread has had a chance to re-solidify), or in a subsequent step requiring heating of the backing paper and thermo-fusible thread to a temperature sufficient to soften said thermo-fusible thread to facilitate its removal along with the backing paper. Following said removal, an outer fabric **760** is applied and bonded to the additional adhesive layer **750** of the intermediate product produced by said removal.

[0286] FIG. **13** depicts a conductive assembly **800** for use in a device for monitoring muscle activity (EMG signal monitoring) in a non-medical device. The conductive assembly comprises an insulation adhesive layer **810**, along with additional layers relating to an outer and inner fabric, an additional adhesive layer and a thin sandwiched fabric layer (as shown in FIG. **14** and/or FIG. **15**). The conductive assembly also comprises conductive wires **820** connected to a central module **830** (not shown) and a plurality of sensors **840** as shown in FIG. **13**.

[0287] This application requires moderate conductivity levels and good insulation/shielding. In addition, the system uses a plurality of sensors **840** distributed far apart from each other which are connected to a central communication module **830**. Given this, the maximum length separating the central module from each peripheral sensor is less than 150 cm. As can be seen in FIG. **13**, when the conductive wires are close to the central module, the wires **820** are arranged close together and then separate as needed to connect to a respective sensor. The width and the repeat length of the zig zag pattern is around 3 mm and 4 mm respectively.

[0288] FIG. **14** provides a cross-section of the layers used in one potential construction of the device depicted in FIG. **13**, as viewed through line Z-Z'. As shown in FIG. **14**, the device may contain conductive wires (e.g. silver/nylon conductive threads) sandwiched between an insulation layer **810** (comprising an adhesive) and a further adhesive layer **870**. The insulation layer **810** is bonded to an inner fabric **850**, while the additional adhesive layer is bonded to an outer fabric **840**. It will be appreciated that typical methods of connection for the central module **830** and the plurality of sensors **840** may be used.

[0289] The processes to make the conductive assembly depicted in FIG. **14** are essentially identical to the processes described in respect of manufacturing the conductive assembly of FIG. **11**, except for the noted differences in the materials used.

[0290] In the above device silver coated nylon threads which have a linear density of 270 dtex, and a resistance of 2 Ohms/cm were used to maintain moderate conductivity, with good softness and high flexibility. These materials also provide good signal quality and reasonable precision. This is because high precision wiring is not necessary in a consumer product and would also increase the cost of the product.

[0291] Both the insulation layer adhesive **810** and the additional adhesive layer **870** may each comprise polyurethane thermal bonding materials as the adhesive, along with a barrier layer. The total thickness of the insulation adhesive and barrier layers may be 150 μm, where the barrier layers contribute 100 μm thickness to this total, while the two polyurethane glue layers **810**, **870** are each 25 μm thick.

[0292] The outer fabric **840** may be a nylon/elastane 85/15 blend, warp knitted fabric with a GSM of 250, and the inner fabric may be a nylon/elastane 90/10 blend, weft knitted with a GSM of 120.

[0293] FIG. **15** provides a cross-section of the layers used in one potential construction of the conductive assembly part of the device depicted in FIG. **13**. The conductive assembly of FIG. **15** is essentially identical to that of FIG. **14**, except that it further contains a stabilisation adhesive layer **860** sandwiched between the insulation layer **810** and the further adhesive layer **870**. Thus materials used in the device of FIG. **15** are identical to those of FIG. **14**, with the addition of the stabilisation adhesive layer **860**, which may be of any suitable material.

[0294] The stabilisation adhesive layer **860** may be 25 μm thick. For example, the stabilisation adhesive layer **860** may be a polyurethane based adhesive with enhanced dimensional and structural reinforcement, said reinforcement being present mainly to retain the original dimensions of the composite structure without shrinkage and non-recoverable deformations such as skewing, during prolonged straining and exposure to excessive heat. The dimensional and structural stability may be achieved by a composite construction with a fibrous reinforcement such as thermoset elastic nonwoven, embedded in polyurethane adhesive. The function of the additional stabilization adhesive layer is to provide improved dimensional stability and durability to the composite structure after washing and to give additional protection to the conductive thread.

[0295] A first process to make the conductive assembly depicted in FIG. **15** is essentially identical to the first process described to make the conductive assembly of FIG. **12**, except for the materials used. It will be apparent that the application of a stabilisation adhesive may differ from that of a layer of fabric. For example, in certain embodiments having the stabilisation adhesive, only the insulation layer comprising an adhesive is required, whereas the additional layer of adhesive is required when the thin layer of fabric is used.

[0296] A second process to manufacture the conductive assembly depicted in FIG. **15** involves providing a temporary substrate having the additional adhesive layer **870** disposed directly thereupon, with the stabilisation adhesive layer **860** disposed on the additional adhesive layer **870**. A stitching pattern using a conductive thread and thermo-fusible thread comprising a plurality of lockstitches is applied to the intermediate composite, such that the conductive thread **820** is applied onto the stabilisation adhesive layer **870** and the thermo-fusible thread **140** is disposed on the temporary substrate (e.g. a backing paper that is non-sticky). Following this, the insulation layer **810**, which is laminated/bonded to the inner fabric **850**, is applied, heated and cured. As discussed hereinbefore the backing paper, along with the thermo-fusible thread may be removed immediately after the heating/curing step (or at some stage before the thermo-fusible thread has had a chance to re-solidify), or in a subsequent step requiring heating of the backing paper and thermo-fusible thread to a temperature sufficient to soften said thermo-fusible thread to facilitate its removal along with the backing paper. Following said removal, an outer fabric **840** is applied and bonded to the additional adhesive layer **870** of the intermediate product produced by said removal to provide the desired conductive assembly.

[0297] FIG. **16** depicts the use of the conductive pathways of the current invention for garments illuminated by LEDs. As depicted, part of a garment **900** contains conductive pathways **920** connected to conductive connection modes **930** at one end (and thereby to a power module; not shown) and to an LED Array **940** at the other end.

[0298] Conductive wiring **920** for this application requires high conductivity levels. The system contains a number of LED arrays **940** that are spaced apart from each other and which are connected to a central power module by the conductive wires **920** by way of conductive nodes **930**, where the maximum distance from the central module to the LED arrays is less or equal to about 200 cm. The width and the repeat length of the zig zag pattern of the conductive wires **920** is around 0.8 cm and 1 cm, respectively.

[0299] FIG. **17** provides a cross-section of the layers used in one potential construction of the device depicted in FIG. **16**. As shown in FIG. **17**, the device may contain conductive wires (e.g. stainless steel conductive threads) sandwiched between an insulation layer **955** (comprising an adhesive) and a further adhesive layer **910**. The insulation layer **955** is bonded to an outer fabric **960**, while the additional adhesive layer is bonded to an inner fabric **970**. It will be appreciated that typical methods of connection for the conductive nodes **930** and the plurality of LED arrays **940** may be used, or the nodes can be stitched/embroidered continuously with the conductive thread.

[0300] The processes to make the device depicted in FIG. **17** are essentially identical to the processes described in respect of manufacturing the conductive assembly of FIG. **11**, except for the noted differences in the materials used.

[0301] In the above application stainless steel threads which have a linear density of 0.23 g/m (2200 dtex), and a resistance of 0.3 Ohms/cm were used to maintain high conductivity, for powering the LED arrays without significant loss of energy (thereby maximising battery capacity).

[0302] Both the insulation layer adhesive **955** and the additional adhesive layer **910** may each comprise polyurethane thermal bonding materials as the adhesive, along with a barrier layer. The total thickness of the insulation adhesive and barrier layers may be 150 μm, where the barrier layers contribute 100 μm thickness to this total, while the two polyurethane glue layers **910**, **955** are each 25 μm thick.

[0303] The outer fabric **960** may be a nylon/elastane 85/15 blend, weft knitted fabric with a GSM of 200, and the inner fabric may be a polyester/elastane 90/10 blend, weft knitted with a GSM of 150.

[0304] FIG. **18** provides a cross-section of the layers used in one potential construction of the conductive assembly part of the device depicted in FIG. **16**. The conductive assembly of FIG. **18** is essentially identical to that of FIG. **17**, except that it further contains a mesh fabric **980** and stabilisation adhesive layer **990** sandwiched between the insulation layer **955** and the further adhesive layer **910**. Thus, the materials used in the device of FIG. **18** are identical to those of FIG. **17**, with the addition of the mesh fabric layer **980** and stabilisation adhesive layer **990**.

[0305] The stabilisation adhesive layer **990** may be 25 μm thick. The function of the additional stabilisation adhesive layer is to provide improved dimensional stability and durability to the composite structure after washing and to give additional protection to the conductive thread. The stabilisation adhesive may be of any suitable material that is capable of providing this function, such as a polyurethane-based adhesive with enhanced dimensional and structural reinforcement, said reinforcement being present mainly to retain the original dimensions of the composite structure without shrinkage and non-recoverable deformations such as skewing, during prolonged straining and exposure to excessive heat. The dimensional and structural stability may be achieved by a composite construction with a fibrous reinforcement such as thermoset elastic nonwoven, embedded in polyurethane adhesive.

[0306] The mesh fabric layer may be of any suitable material, such as a polyester/elastane based warp knit mesh, and is also intended to provide improved dimensional stability and durability to the composite structure after washing and to give additional protection to the conductive thread.

[0307] A first process to make the conductive assembly depicted in FIG. **18** is essentially identical to the first process described to make the conductive assembly of FIG. **15**, except for the presence of both a stabilisation adhesive and a layer of mesh fabric.

[0308] A second process to manufacture the conductive assembly depicted in FIG. **18** involves providing a temporary substrate having the stabilisation adhesive layer **990** directly thereupon, with the mesh fabric **980** on top of said stablisation adhesive layer **990**. A stitching pattern using a conductive thread and thermo-fusible stitched comprising a plurality of lockstitches is applied to the intermediate composite, such that the conductive thread **920** is applied onto the mesh fabric layer **980** and the thermo-fusible thread is disposed on the temporary substrate (e.g. a backing paper). Following this, the insulation layer **955**, which is laminated/bonded to the outer fabric **960**, is applied, heated and cured. As discussed hereinbefore the backing paper, along with the thermo-fusible thread may be removed immediately after the heating/curing step (or at some stage before the thermo-fusible thread has had a chance to re-solidify), or in a subsequent step requiring heating of the backing paper and thermo-fusible thread to a temperature sufficient to soften said thermo-fusible thread to facilitate its removal along with the backing paper. Following said removal, the stabilisation adhesive layer **990** is exposed and a further adhesive layer, bonded to an inner fabric **970**, may be applied and bonded to the stabilisation adhesive layer **990** to provide the desired product.

[0309] FIG. **19** is identical to FIG. **16**, except that the conductive wires are provided as part of a tape **995** that may be cut to and reshaped to the desired size and shape. In other words, the techniques described herein of using a temporary holding mechanism with thermo-fusible thread and backing paper can be employed to make continuous narrow width conductive pathways that can be laid down on a textile substrate of a finished or semi-finished garment to a required shape or a pattern using a continuous thermal bonding machine.

[0310] Such a continuous tape can be made using a standard zig-zag sewing machine and a continuous tape-bonding machine.

1. Providing a narrow-width continuous paper tape and stitching a zig-zag thread pattern with a conductive thread as either the needle or the bobbin thread and a thermo-fusible thread as the other thread onto the paper tape. The paper tape should not form a permanent bond to the adhesive of the insulation barrier tape used in step 2.

2. A thermally bondable narrow-width insulation barrier tape is applied onto the conductive thread side using a continuous thermal bonding machine, followed by removal of the continuous paper tape, along with the thermo-fusible thread. This exposes the conductive thread on the side that has not been covered.

3. A second layer of thermally bondable narrow-width insulation barrier tape is then applied on the exposed side of the conductive thread to encapsulate it (wholly or in part).

[0311] The resulting tape may then be bonded to a substrate such as a garment directly or at a later date. As discussed hereinbefore, the insulation barrier tapes (and adhesives therein) may be thermoplastic materials, thereby allowing for the tapes to be reshaped during application to a garment. This reshaping ability enables the tapes discussed herein to provide custom sizes and shapes to fit the needs of a particular garment, which would be difficult to achieve otherwise. While FIG. **19** shows the conductive pathways as being straight lines, the ability to reshape the conductive assembly tapes enables other shapes to be made too, such as curves and combinations thereof. This increases the design freedom of the conductive pathways that may be laid on a garment and makes it easy to customise the conductive pathway layout to suit a particular application.

[0312] As will be appreciated, the insulation barrier in step 2 and/or 3 can be pre-laminated with to include a fabric substrate (e.g. a knitted fabric) on one side to give additional aesthetic or functional properties, which is forms part of the continuous conductive pathway tape. In addition, it should be noted that the conductive assemblies mentioned in FIGS. **9**, **11**, **12**, **14**, **15**, **17** and **18** can be adapted as necessary to provide pre-made conductive tapes. For example, this may involve not attaching an outer and/or inner fabric.

[0313] Embodiments of the invention may also relate to the following:

A. A textile assembly or a garment assembly comprising:

- **[0314]** a. at least one piece of textile substrate where, at least one electrically conductive thread is layered on the base textile substrate's surface to form a conductive path and;
- **[0315]** b. at least one insulation adhesive layer fully or partially covering the surface of at least one conductive thread and the base textile substrate, where one surface of the assembly has the base textile substrate's visual and haptic properties unaltered.

B. A textile assembly or a garment assembly as in paragraph B where, the base substrate

- **[0316]** a. is pretreated or pre coated with at least one or a combination of
  - **[0317]** i. an insulation adhesive
  - **[0318]** ii. a functional chemical composition
  - **[0319]** iii. a composition providing electromagnetic shielding on at least one side of the base substrate
- **[0320]** b. is without any pretreatment or a coating

C. A textile assembly or a garment assembly as in paragraph A where, a secondary textile substrate fully or partially covers the insulation adhesive layer.

D. A textile assembly or a garment assembly as in paragraphs A, B or C where, the assembly has at least 80% stretchability and at least 90% of stretch recovery of the said textile substrate in any direction of elongation.

E. A textile assembly or a garment assembly as in paragraphs A, B or C where, the electrical conductivity of any conductive path is not altered at any level and direction of stretch.

F. A textile assembly or a garment assembly as in paragraphs A, B or C where,

- **[0321]** a. the assembly retains the integrity of all conductive paths and all insulation adhesive layers, and without imparting any visual defects
- **[0322]** b. all the conductive paths retain their conductivity levels
- **[0323]** c. all the insulation adhesive layers retain their initial levels of insulation after at least 50 wash and tumble dry cycles, using the process outlined in the test method AATCC 124.

G. A textile assembly or a garment assembly as in paragraphs A, B or C, wherein the textile substrates are produced by method selected from a group comprising knitting, weaving, non-woven, electro-spinning or blow-spinning.

H. A textile assembly or a garment assembly as in paragraphs A, B or C, wherein textile substrates are manufactured with one or a blend of fibre material, filament or yarn selected from a group comprising animal based fibre, plant based fibre, manmade fibre and mineral based fibre or any combination thereof.

I. A textile assembly or a garment assembly as in paragraphs A, B or C, where the said electrically conductive thread, consists of one or more continuous filament bundles made of metal coated polymer composition with a thread count ranging from 25 dtex to 2500 dtex and electrical resistivity ranging from a few mΩ per meter to several MΩ per meter. The conductive thread described herein may have

- **[0324]** a. A protective insulation polymer coating
- **[0325]** b. No coating

J. A textile assembly or a garment assembly as in paragraphs A, B or C, where the said conductive thread is layered in one or a combination of

- **[0326]** a. Any regular wave pattern including but not limited to
  - **[0327]** i. a zig zag wave pattern
  - **[0328]** ii. A sinusoidal wave pattern
  - **[0329]** iii. A square wave pattern
  - **[0330]** iv. An omega shape wave patterns
- **[0331]** b. Any irregular wave pattern with one or a combination of uniform and variable width sections.

K. A textile assembly or a garment assembly as in paragraph A, where the said conductive pathway is in the shape of one or a combination of

- **[0332]** a. Any regular geometric shape including but not limited to
  - **[0333]** i. A straight line
  - **[0334]** ii. section of a circle
  - **[0335]** iii. section of an ellipse
  - **[0336]** iv. section of a parabola
  - **[0337]** v. section of a hyperbola
- **[0338]** b. any irregular geometric shape

L. A textile assembly or a garment assembly as in paragraph A or paragraph B where the said insulation adhesive

- **[0339]** a. is in sheet form
  - **[0340]** i. made of a polymer composition of one or a combination of polyurethane, polyester, fluoropolymer, polyacrylate, polyamide or silicone.
  - **[0341]** ii. with a single adhesive layer fabrication, double layer fabrication with adhesive-barrier film or 3 layer fabrication with adhesive-barrier film-adhesive fabrication.
  - **[0342]** iii. Where the adhesive sheet is bonded using heat and pressure.
- **[0343]** b. is in paste form
  - **[0344]** i. made of a polymer composition of one or a combination of Polyesters, fluoropolymer, polyacrylate, Polyurethane, Polyolefin, silicone.

[0345] ii. applied using a screen printing or stencil printing method

[0346] iii. where the adhesive is be cured with external energy source such as heat, UV, IR etc. This adhesive can be made of a polymer composition of one or a combination of Polyesters, fluoropolymers, polyacrylates, Polyamides, PVC, Polyurethane, Polyolefin, silicone etc.

[0347] c. retains at least 90% of stretch & Recovery properties of the textile substrate after application.

M. A process of making a textile assembly or an apparel assembly, wherein a conventional stitching process is employed for layering the electrically conductive thread on the surface of the textile substrate. The said process comprises the following steps

[0348] The stitching machine is set up with the conductive thread as the needle thread and the thermo-fusible thread as the bobbin thread.

[0349] A backing paper is placed beneath the textile substrate and the required conductive path is stitched according to the desired pattern onto the textile substrate with the non-woven backing paper.

[0350] The insulation adhesive is applied onto the conductive path fully or partially covering the conductive thread.

[0351] The composite textile is heated to cure/activate the adhesive and melt the thermo-fusible thread.

[0352] The backing paper is removed with the thermo-fusible thread while the composite is sufficiently warm.

N. A process of making a textile or apparel assembly as in paragraph M, wherein the stitching machine is a conventional patterning (eg: zig zag) sewing machine with the substrate guided manually.

O. A process of making a textile or apparel assembly as in paragraph M, wherein the stitching machine is a conventional embroidery machine, with the substrate guided by a preprogrammed electronic pattern.

P. A process of making a textile or apparel assembly as in paragraph M, wherein the textile substrate is produced by a method selected from the group consisting of: knitting, weaving, non-woven, electro-spinning, blow-spinning, and combinations thereof.

Q. A process of making a textile or apparel assembly as in paragraph M, wherein the textile substrate is manufactured with one or a blend of fibre material, filament or yarn selected from a group comprising animal based fibre, plant based fibre, manmade fibre and mineral based fibre or any combination thereof.

R. A process of making a textile or apparel assembly as in paragraph M, where the said electrically conductive thread, is made of one or more silver coated polyamide continuous filament bundles with a thread count ranging from 25 dtex to 2500 dtex and electrical resistivity ranging from a few mΩ per meter to several MΩ per meter.

S. A process of making a textile or apparel assembly as in paragraph M, where the backing paper is in sheet form cut to the desired shape, made of cellulose or manmade fibre composition predominantly using a non-woven or paper manufacturing process, which is non stretchable and stiff.

T. A process of making a textile or apparel assembly as in paragraph M, where the said non-conductive thread

[0353] a. Is made of mono-filament or multifilament strand of fibres made of polymer composition comprising one or a combination of Polyester, fluoropolymer, polyacrylate, Polyamide, Polyurethane, Polyolefin, and Polyvinyl Acetate.

[0354] b. Which melts at temperatures around 70° C.-150° C.

[0355] While preferred embodiments of the invention have been shown and described, modifications and variations may be made thereto by those of ordinary skill in the art without departing from the spirit and scope of the present invention. In addition, it should be understood that aspects of the various embodiments may be interchanged both in whole or in part. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only, and is not intended to be limitative of the invention as further described in the appended claims.

[0356] For example, the zig zag stitching/embroidery pattern **30** can be changed to a different stitching pattern depending on aesthetic and stretchability requirements. In some embodiments, one or more heat pressing steps may be introduced to the process in order to improve flatness of the stitched/embroidered piece after the stitching pattern **30** is applied but before application of adhesive. In other embodiments, additional heat curing steps can be introduced in order to facilitate the removal of the backing paper **20**. In further embodiments, electro flocking of short staple fibres can be performed on the adhesive prior to it being cured, to provide extra comfort to the wearer as well as providing electrostatic/electromagnetic shielding.

1. A method of making a conductive assembly for use in textiles, the method comprising:

(a) providing a composite material comprising:

a temporary substrate having a first surface and a second surface opposite the first surface;

a stitching pattern comprising a plurality of lockstitches on the temporary substrate, such that a conductive thread is disposed at the first surface of the temporary substrate and a thermo-fusible thread is disposed at the second surface; and

an insulating layer comprising an adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread; and

(b) heating the insulating layer and thermo-fusible thread to the activation temperature and curing the adhesive in the insulating layer of the composite material, thereby securing the conductive thread to the insulating layer.

2. A method according to claim **1**, further comprising removing the temporary substrate from the insulating layer to remove the thermo-fusible thread.

3. A method of making a conductive assembly for use in textiles, the method comprising:

(a) providing a composite material comprising:

a temporary substrate having a first surface and a second surface opposite the first surface,

a stitching pattern comprising a plurality of lockstitches on the temporary substrate, such that a conductive thread is disposed at the first surface of the temporary substrate and a thermo-fusible thread is disposed at the second surface; and

an insulating layer comprising a cured adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread, where the cured adhesive secures the conductive thread to the insulating layer; and

(b) heating the insulating layer and thermo-fusible thread to a temperature at or below the activation temperature and removing the temporary substrate from the insulating layer to remove the thermo-fusible thread.

4. A method according to claim **1**, wherein the heating and curing steps are carried out substantially simultaneously.

5-6. (canceled)

7. A method according to claim **1**, wherein the composite material further comprises a textile substrate having a first face and a second face opposite the first face, where the second face of the textile substrate is disposed towards the first surface of the temporary substrate and the first face is disposed towards the conductive thread, optionally wherein:

(a) the first surface of the temporary substrate is temporarily laminated to the second face of the textile substrate with a bonding film; and/or

(b) the composite material further comprises one or more of the following on the first face and/or the second face of the textile substrate: a support adhesive; a mesh fabric; an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

8. A method according to claim **1**, wherein the stitching pattern comprising a plurality of lockstitches, is applied to the temporary substrate using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread.

9-12. (canceled)

13. A method of making a conductive assembly for use in textiles, the method comprising:

(a) providing a composite material comprising:

a stabilisation substrate having a first surface and a second surface opposite the first surface,

a patterned conductive thread is disposed at the first surface of the stabilisation substrate; and

an insulating layer comprising a cured adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread, where the cured adhesive secures the conductive thread to the insulating layer;

(b) providing a textile fabric; and

(c) bonding the textile fabric to the stabilisation substrate.

14. A method according to claim **13**, wherein the textile fabric further comprises an insulating adhesive layer and the insulating adhesive layer is bonded to the stabilisation substrate, optionally wherein the stabilisation substrate is a mesh fabric or a stabilisation adhesive.

15. (canceled)

16. A method according to claim **1**, wherein the activation temperature of the adhesive of the insulating layer is at least 10° C. higher than the Vicat softening point of the thermo-fusible thread, preferably at least 30° C. higher, more preferably at least 70° C. higher, and even more preferably at least 80° C. higher.

17-21. (canceled)

22. A conductive assembly for use in textiles comprising:

a temporary substrate having a first surface and a second surface opposite the first surface;

a stitching pattern, comprising a plurality of lockstitches, the lockstitches being formed using a needle thread and a bobbin thread, one of the needle thread and the bobbin thread being a conductive thread and the other being a thermo-fusible thread, such that the conductive thread is disposed at the first surface of the temporary substrate and the thermo-fusible thread is disposed on the second surface; and

an insulating layer comprising an adhesive applied to at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread.

23. A conductive assembly according to claim **22**, wherein the adhesive of the insulating layer is a cured thermoplastic insulation adhesive.

24-25. (canceled)

26. A conductive assembly according to claim **22**, further comprising a textile substrate having a first face and a second face opposite the first face, where the second face of the textile substrate is disposed towards the first surface of the temporary substrate and the first face is disposed towards the conductive thread, optionally wherein the first surface of the temporary substrate is laminated to the second face of the textile substrate with a bonding film.

27-31. (canceled)

32. A conductive assembly for use in textiles, comprising:

a stabilisation substrate having a first surface and a second surface opposite the first surface,

a patterned conductive thread is disposed at the first surface of the stabilisation substrate; and

an insulating layer comprising a cured adhesive on top of at least part of the conductive thread on the first surface, the adhesive having an activation temperature which is higher than the Vicat softening point, as measured by method A120 of ASTM D1525, of the thermo-fusible thread, where the cured adhesive secures the conductive thread to the insulating layer; and

a textile fabric bonded to the stabilisation substrate.

33. A conductive assembly according to claim **32**, wherein the textile fabric further comprises an insulating adhesive layer and the insulating adhesive layer is bonded to the stabilisation substrate, optionally wherein the stabilisation substrate is a mesh fabric or a stabilisation adhesive.

34. A conductive assembly for use in textiles, comprising:

an insulating layer having a first surface and a second surface opposite the first surface;

a conductive thread disposed at the first surface of the insulating layer and having a pattern, wherein

wherein the insulating layer comprises a cured thermoplastic insulation adhesive in contact with the conductive thread, which is held by the cured adhesive.

35-36. (canceled)

37. A method according to claim **34**, further comprising one or more of the following on the first face and/or the second face of the textile substrate: a support adhesive; a mesh fabric; an insulation adhesive; a functional chemical composition; or a composition providing electromagnetic shielding.

38-41. (canceled)

42. A conductive assembly according to claim **22**, wherein the pattern has a geometry configured to accommodate stretching of a textile substrate, optionally wherein:

(a) the pattern comprises one or more of: a triangle wave pattern; a sawtooth pattern; a sinusoidal pattern; an omega-shaped pattern; a square wave pattern, and an irregular wave pattern; and/or

(b) the pattern comprises at least some irregularly spaced portions.

43-46. (canceled)

47. A conductive assembly according to claim **22**, wherein the composite material further comprises short staple fibres flocked on the adhesive of the insulation layer.

48-49. (canceled)

50. A conductive assembly according to claim **34**, wherein the pattern has a geometry configured to accommodate stretching of a textile substrate, optionally wherein:

(a) the pattern comprises one or more of: a triangle wave pattern; a sawtooth pattern; a sinusoidal pattern; an omega-shaped pattern; a square wave pattern, and an irregular wave pattern; and/or

(b) the pattern comprises at least some irregularly spaced portions.

51. A conductive assembly according to claim **34**, wherein the composite material further comprises short staple fibres flocked on the adhesive of the insulation layer.

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