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APPAREL COMPRISING A WOUND COMPONENT AND METHODS OF MAKING THE SAME

- (57)

Articles of apparel (100) and methods of making articles of apparel that include one or more thread layers made by winding a continuous thread around anchor points. In some embodiments, the articles of apparel can include multiple pieces of material (140a, 140b), with each piece including a thread layer. In some embodiments, the article of apparel can be steamed to shape the one or more thread layers.

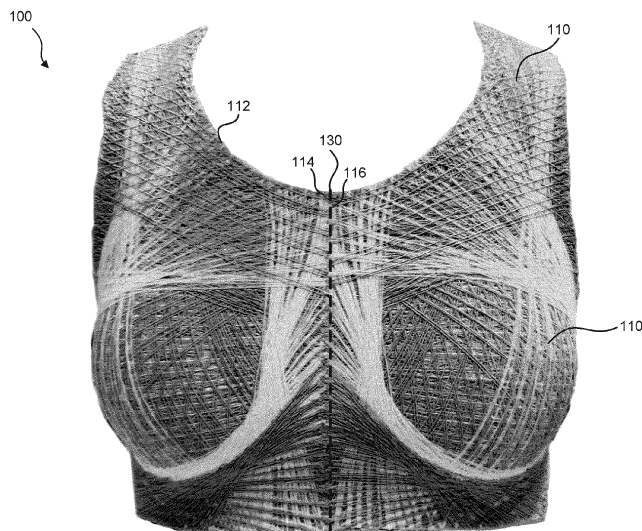


FIG. 1

Description

FIELD

[0001] The described embodiments generally relate to apparel and methods of making apparel. In particular, described embodiments relate to apparel comprising one or more pieces made by one or more winding continuous threads into a thread pattern.

BACKGROUND

[0002] Apparel can be manufactured from various materials using a wide range of techniques, including weaving and knitting. Individuals are often concerned with the durability, comfort, and/or performance characteristics for an article of apparel. This is true for apparel worn for athletic and non-athletic activities. Proper apparel should be durable, comfortable, and provide other beneficial characteristics for an individual. Therefore, a continuing need exists for innovations in apparel and methods of making apparel to suit individuals across a range of use cases.

BRIEF SUMMARY

[0003] The present application is directed to articles of apparel comprising thread patterns with one or more thread layers. The thread patterns, and the plurality of thread layers within the thread patterns, can be designed to provide desired characteristics for article of apparel.

[0004] A first embodiment (1) of the present application is directed to an article of apparel comprising a first piece of material comprising a first perimeter edge, a first thread layer comprising a first thread defining a plurality of first thread lines each extending from a first side of the perimeter edge to a second side of the first perimeter edge and crossing over each other at points of overlap between two or more of the first thread lines, and a second thread layer disposed over the first thread layer and comprising a second thread defining a plurality of second thread lines each extending from the first side of the first perimeter edge to the second side of the perimeter edge and crossing over each other at points of overlap between two or more of the second thread lines; a second piece of material comprising a second perimeter edge; and a seam along at least a portion of the first perimeter edge and the second perimeter edge that joins the first piece of material to the second piece of material.

[0005] In a second embodiment (2), the second piece of material according to the first embodiment (1) is a fabric material.

[0006] In a third embodiment (3), the fabric material according to the second embodiment (2) comprises a woven or knitted fabric.

[0007] In a fourth embodiment (4), the first thread lines according to any one of embodiments (1) - (3) are not woven or knitted together, the second thread lines ac-

cording to any one of embodiments (1) - (3) are not woven or knitted together, and the first thread lines and the second thread lines according to any one of embodiments (1) - (3) are not embroidered threads stitched to a base layer.

[0008] In a fifth embodiment (5), the second piece of material according to the first embodiment (1) or the fourth embodiment (4) comprises a third thread layer comprising a third thread defining a plurality of third thread lines each extending from a first side of the second perimeter edge to a second side of the second perimeter edge and crossing over each other at points of overlap between two or more of the third thread lines, and a fourth thread layer disposed over the third layer and comprising a fourth thread defining a plurality of fourth thread lines extending from the first side of the second perimeter edge to the second side of the second perimeter edge and crossing over each other at points of overlap between two or more of the second thread lines.

[0009] In a sixth embodiment (6), the plurality of first thread lines according to any one of embodiments (1) - (5) are directly bonded to each other at the points of overlap between two or more of the first thread lines.

[0010] In a seventh embodiment (7), the plurality of second thread lines according to any one of embodiments (1) - (6) are directly bonded to each other at the points of overlap between two or more of the second thread lines.

[0011] In an eighth embodiment (8), the first thread according to any one of embodiments (1) - (7) comprises a composite elastomeric thread comprising an elastomeric material and one or more textile materials.

[0012] In a ninth embodiment (9), the second thread according to any one of embodiments (1) - (8) comprises a polymeric thread comprising a polymeric material having melting temperature in a range of greater than or equal to 110 °C to less than or equal to 150 °C.

[0013] In a tenth embodiment (10), the first thread layer according to any one of embodiments (1) - (9) comprises a first composite elastomeric thread comprising an elastomeric material and one or more textile materials, the second thread layer according to any one of embodiments (1) - (9) comprises a second composite elastomeric thread comprising an elastomeric material and one or more textile materials, and a percentage of elastomeric material in the first composite elastomeric thread is greater than a percentage of elastomeric material in the second composite elastomeric thread.

[0014] In an eleventh embodiment (11), the article of apparel according to any one of embodiments (1) - (10) comprises a bra.

[0015] In a twelfth embodiment (12), the first piece of material according to the eleventh embodiment (11) comprises a bra strap and the second piece of material according to the eleventh embodiment (11) comprises a cup portion.

[0016] In a thirteenth embodiment (13), the first piece of material according to the eleventh embodiment (11)

comprises an underband and the second piece of material according to the eleventh embodiment (11) comprises a cup portion.

[0017] In a fourteenth embodiment (14), the article of apparel according to any one of embodiments (1) - (10) comprises a bra, the first piece of material comprises a cup portion comprising a first zone having a first stiffness and a second zone having a second stiffness, the first zone comprises a perimeter boundary, the second zone is disposed around at least a portion of the perimeter boundary of the first zone, the plurality of first thread lines extend through the first zone, and the plurality of second thread lines extend tangential to the perimeter boundary of the first zone.

[0018] In a fifteenth embodiment (15), the article of apparel according to any one of embodiments (1) - (14) further comprises a third piece of material comprising a third perimeter edge, and a second seam along at least a portion of the first perimeter edge and the third perimeter edge that joins the first piece of material to the third piece of material.

[0019] In a sixteenth embodiment (16), the article of apparel according to the fifteenth embodiment (15) comprises a pair of pants and the first piece of material is configured to wrap around a knee of a wearer.

[0020] In a seventeenth embodiment (17), the article of apparel according to the sixteenth embodiment (16) comprises a shirt and the first piece of material is configured to wrap around an elbow of a wearer.

[0021] An eighteenth embodiment (18) of the present application is directed to a method of making an article of apparel, the method comprising forming a first piece of material by a method comprising winding a continuous thread around a plurality of anchor points on a support plate to form a thread layer, the continuous thread comprising a plurality of thread lines with each thread line extending between two respective anchor points; bonding the continuous thread at points of intersection between two or more of the thread lines; and after bonding the continuous thread, cutting the thread layer to remove the first piece of material comprising a thread pattern comprising the thread layer from the support plate; and attaching the first piece of material to one or more additional pieces of material to form the article of apparel.

[0022] In a nineteenth embodiment (19), attaching the first piece of material to the one or more additional pieces of material according to the eighteenth embodiment (18) comprises seaming the first piece of material to the one or more of the additional pieces of material.

[0023] In a twentieth embodiment (20), the one or more additional pieces of material according to the eighteenth embodiment (18) or the nineteenth embodiment (19) comprises a second piece of material made by a method comprising winding a second continuous thread around a plurality of anchor points on a second support plate to form a second thread layer, the second continuous thread comprising a plurality of second thread lines with each thread line extending between two respective an-

chor points; bonding the second continuous thread at points of intersection between two or more of the thread lines; and after bonding the second continuous thread, cutting the second thread layer to remove a second piece of material comprising a second thread pattern comprising the second thread layer from the second support plate.

[0024] In a twenty-first embodiment (21), the method according to any one of embodiments (18) - (20) further comprises placing the article of apparel over a mannequin; and heating the article of apparel on the mannequin.

[0025] In a twenty-second embodiment (22), the method according to the twenty-first embodiment (21) further comprises attaching the article of apparel to the mannequin at a plurality of attachment points.

[0026] In a twenty-third embodiment (23), heating the article of apparel according to the twenty-first embodiment (21) comprises steaming the article of apparel.

[0027] In a twenty-fourth embodiment (24), the mannequin according to the twenty-third embodiment (23) comprises a plurality of steam nozzles.

[0028] In a twenty-fifth embodiment (25), steaming the article of apparel on the mannequin according to the twenty-fourth embodiment (24) comprises selectively steaming portions of the article of apparel by emitting seam from one or more of the plurality of steam nozzles.

[0029] In a twenty-sixth embodiment (26), in the method according to any one of embodiments (18) - (25), the thread layer is a first thread layer, and forming the first piece of material comprises winding a second continuous thread around the plurality of anchor points on the support plate to form a second thread layer, the second continuous thread comprising a plurality of second thread lines with each second thread line extending between two respective anchor points; and bonding the second continuous thread at points of intersection between two or more of the second thread lines.

[0030] In a twenty-seventh embodiment (27), the continuous thread of the first thread layer according to the twenty-sixth embodiment (26) is wound at a first tension and the second continuous thread according to the twenty-sixth embodiment (26) is wound at a second tension greater than the first tension.

[0031] In a twenty-eighth embodiment (28), the method according to the twenty-seventh embodiment (27) further comprises placing the article of apparel over a mannequin; and steaming the article of apparel on the mannequin, where the steaming shapes the first thread layer and the second thread layer differently to define a shaped region on the article of apparel.

[0032] In a twenty-ninth embodiment (29), the continuous thread of the first thread layer according to the twenty-sixth embodiment (26) comprises a first thread type and the second continuous thread according to the twenty-sixth embodiment (26) comprises a second thread type different from the first thread type.

[0033] In a thirtieth embodiment (30), the method according to the twenty-ninth embodiment (29) further com-

prises placing the article of apparel over a mannequin; and steaming the article of apparel on the mannequin, where the steaming shapes the first thread layer and the second thread layer differently to define a shaped region on the article of apparel.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0034]

FIG. 1 shows an article of apparel according to some embodiments.

FIG. 2 shows pieces of an article of apparel according to some embodiments.

FIGS. 3A-3C show thread layers according to some embodiments.

FIG. 4 shows an article of apparel comprising zones according to some embodiments.

FIG. 5 is an exemplary flowchart of a method of according to some embodiments.

FIG. 6 shows a machine for producing thread layers according to some embodiments.

FIG. 7 shows a heat press according to some embodiments.

FIG. 8 shows a mannequin according to some embodiments.

FIG. 9 is a graph of stiffness in a first direction at various locations on articles of apparel according to some embodiments.

FIG. 10 is a graph of stiffness in a second direction at various locations on articles of apparel according to some embodiments.

FIG. 11 is a graph of stiffness in a third direction at various locations on articles of apparel according to some embodiments.

FIG. 12 is a graph of stiffness in a fourth direction at various locations on articles of apparel according to some embodiments.

FIG. 13 is a graph of stiffness in a first direction at various locations on two articles of apparel according to some embodiments.

FIG. 14 is a graph of stiffness in a second direction at various locations on two articles of apparel according to some embodiments.

FIG. 15 illustrates an article of apparel according to some embodiments.

FIG. 16 illustrates an article of apparel according to some embodiments.

DETAILED DESCRIPTION

[0035] The present invention(s) will now be described in detail with reference to embodiments thereof as illustrated in the accompanying drawings. References to "some embodiments", "one embodiment", "an embodiment", "an exemplary embodiment", etc., indicate that the embodiment described can comprise a particular feature, structure, or characteristic, but every embodiment

may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0036] As used herein, unless specified otherwise, references to "first," "second," "third," "fourth," etc. are not intended to denote order, or that an earlier-numbered feature is required for a later-numbered feature. Also, unless specified otherwise, the use of "first," "second," "third," "fourth," etc. does not necessarily mean that the "first," "second," "third," "fourth," etc. features have different properties or values.

[0037] As used herein, "thread" means a material having a length that is substantially larger than its width. A "thread" can be a filament, a fiber, a yarn, a cable, a cord, a fiber tow, a tape, a ribbon, a monofilament, a braid, a string, a plied thread, and other forms of materials which can be spooled and laid down in a thread pattern as described herein.

[0038] An article of apparel has many purposes. Among other things, apparel can provide a unique aesthetic look, provide warming or cooling characteristics, provide support for portions of an individual's body, and provide other performance characteristics, such as air permeability, moisture wicking properties, compression properties. Each of these purposes, alone or in combination, provides for comfortable apparel suitable for use in a variety of scenarios (for example, exercise and every day activities). The features of an article of apparel (for example, the materials and components used to make apparel, and the way these materials/components are made) can be altered to produce desired characteristics, for example, durability, stiffness, weight, tackiness, texture, haptics, tackiness, and/or air permeability.

[0039] The articles of apparel described herein can be made by, or can comprise a component made by, winding one or more continuous threads around anchor points to create a desired thread layer or thread pattern. Winding the continuous thread(s) around the anchor points comprises wrapping a continuous thread around a first anchor point, extending that continuous thread to a second anchor point, wrapping that continuous thread around the second anchor point, and so on. The number and position of the anchor points can be utilized to control characteristics of the thread layer or thread pattern, and therefore characteristics of the apparel. Also, the number of times a continuous thread is wound from anchor point to anchor point can be utilized to control characteristics of the thread layer or thread pattern, and therefore characteristics of the apparel.

[0040] Continuous thread(s) of a thread layer or thread pattern can be bonded within the thread layer or thread pattern. The bonding of continuous thread(s) of a thread

layer or thread pattern can consolidate the layer or pattern and fix thread lines within the layer or pattern. In some embodiments, bonding continuous thread(s) of a thread layer or thread pattern can be utilized to control characteristics of the layer or pattern. In some embodiments, a continuous thread can be bonded to itself within a thread layer or thread pattern. In some embodiments, a continuous thread can be bonded to itself at points of overlap between different thread lines of the continuous thread (i.e., at thread line intersection points). In some embodiments, different continuous threads of a thread pattern can be bonded together. In some embodiments, different continuous threads can be bonded to each other at points of overlap between the different continuous threads (i.e., at intersection points between the different continuous threads). The bonding of continuous thread(s) can fix the continuous thread(s) in tension because the thread(s) can be wound around anchor points in tension. The bonding of thread(s) in tension can allow a thread layer or thread pattern to contract once removed from anchor points (for example using a cutting process) used to wind the layer or pattern, which can be utilized to control characteristics of the layer or pattern, and therefore characteristics of the apparel.

[0041] In some embodiments, a plurality of different continuous threads can be wound around anchor points to form a plurality of thread layers for a thread pattern. In some embodiments, different continuous threads can be wound in the same configuration (i.e., around the same anchor points and along the same paths). In some embodiments, different continuous threads can be wound in different configurations (i.e., around one or more different anchor points and/or along different paths between one or more anchor points). In some embodiments, different continuous threads can define different wound layers for an article of apparel, or portion thereof. In such embodiments, the different layers can provide different characteristics to the thread pattern, and therefore provide different characteristics on the article of apparel.

[0042] Continuous thread(s) can be wound around anchor points in various configurations to provide varying degrees of characteristics for an article of apparel. The number of anchor points, the position of the anchor points, the way continuous threads are wound around the anchor points, and/or of the material of threads wound around the anchor points can be utilized to produce apparel having desired characteristics, such as strength, stiffness, air permeability, comfort, abrasion resistance, fit, texture, haptics, tackiness, and durability. Characteristics of an article of apparel can be varied by changing the arrangement of anchor points and/or the way continuous thread(s) are wound around the anchor points. Characteristics can also be varied by altering the material of continuous thread(s).

[0043] In some embodiments, winding one or more continuous threads for an article of apparel can comprise winding one or more threads such that thread lines are

positioned tangential to area or zone on the apparel. Threading thread lines tangential to the area or zone can define a boundary demarcating the area or zone from adjacent areas or zones. By threading thread lines tangential in this manner, characteristics of an article of apparel can be tailored as described herein.

[0044] In some embodiments, the thread layer or thread patterns can be cut into desired pieces of material comprising all or a portion of the layer or pattern. In some embodiments, the multiple pieces of material can be joined at one or more seams to create an article of apparel. In some embodiments, the properties of different pieces of material can be controlled by the thread layer or thread pattern and/or by how the material comprising the thread layer or thread pattern is cut. Further, the properties for different portions of the article of apparel can be controlled by the manner in which the pieces of material are arranged and joined at the seam(s). In some embodiments, an article of apparel can comprise one or more pieces of material comprising a thread layer or thread pattern as described herein and one or more pieces of material that do not comprise a thread layer or thread pattern.

[0045] In some embodiments, an article of apparel comprising a thread pattern or thread layer, or a piece of material comprising a thread pattern or thread layer, can be heated to shape the article or piece. In some embodiments, an article of apparel comprising a thread pattern or thread layer, or a piece of material comprising a thread pattern or thread layer, can be steamed to shape the article or piece. In some embodiments, the article of apparel or the piece of material comprising a thread pattern or thread layer can be heated or steamed on a mannequin. Steaming or heating the article or the piece can shape the article or piece. In some embodiments, heating or steaming the article or the piece can shape one or more thread layers to impart a desired shape to the article or piece. In some embodiments, heating or steaming the article or the piece can shape different thread layers differently to impart a desired shape to the article or piece.

[0046] FIG. 1 illustrates an article of apparel 100 according to some embodiments. Apparel 100 comprises a material 110 comprising a perimeter edge 112 and one or more thread patterns 120. Thread pattern(s) 120 comprise one or more thread layers (for example, thread layers 300, 320, and 340) as described herein. In some embodiments, a single thread layer can define a thread pattern 120 for article of apparel 100.

[0047] Thread layers as described herein (example, thread layers 300, 320, and 340) can each comprise a thread layer border 350 defined by the space in which thread lines of the thread layer are located. The thread layer border 350 for a thread layer is the space in which thread lines of the thread layer are located after the thread layer is removed (for example, cut) from anchor points used to wind the thread layer. A plurality of thread lines within a thread pattern can comprise a first end located at a first side of the thread layer border 350 and a second

end located at a second side of the thread layer border 350. For example, thread lines 304 of thread layer 300 can comprise a first end 310 located at a first side of thread layer border 350 and a second end 312 located at a second side of thread layer border 350.

[0048] FIGS. 3A-3C illustrate thread layer borders 350a-c for thread layers 300, 320, and 340. For a thread pattern 120 comprising a plurality of thread layers, the thread pattern 120 can comprise a thread pattern border 350 defined by the space occupied by the combination of the individual thread layers. For example, a thread pattern comprising thread layers 300, 320, and 340 comprises a thread pattern border defined by the space occupied by the combination of border 350a and border 350c. Border 350b is wholly contained within border 350a.

[0049] While articles of apparel (for example, article of apparel 100) discussed herein may be described in the context of a particular article (for example, a bra), other types of apparel may comprise features of the described embodiments. Exemplary articles of apparel comprise, but are not limited to, a sock liner, pants, shorts, leggings, a sock, a jacket, a coat, a hat, a sleeve, a shoe, a sweater, a shirt, a jersey, a bootie, a glove, a sleeve, a head band, a wrist band, or a tape.

[0050] Each thread layer of a thread pattern 120 can comprise a thread defining a plurality of thread lines each extending from a first side 114 of the perimeter edge 112 to a second side 116 of the perimeter edge 112 and crossing over each other at points of overlap between two or more of the thread lines. The thread lines extending from the first side 114 of the perimeter edge 112 to the second side 116 of the perimeter edge 112 can extend continuously from the first side 114 to the second side 116.

[0051] For example, thread pattern 120 can comprise a first thread layer comprising a first thread defining a plurality of first thread lines each extending from first side 114 of the perimeter edge 112 to second side 116 of the perimeter edge 112 and crossing over each other at points of overlap between two or more of the first thread lines. And thread pattern 120 can comprise a second thread layer disposed over the first thread layer and comprising a second thread defining a plurality of second thread lines each extending from the first side 114 of the perimeter edge 112 to the second side 116 of the perimeter edge 112 and crossing over each other at points of overlap between two or more of the second thread lines.

[0052] As used herein, sides of a perimeter edge refer to top, bottom, right, and left sides of a shape defined by the perimeter edge. The top, bottom, right, and left sides of the shape are located to the top, bottom, right, and left of a geometrical center of the shape. So, a perimeter edge will have a top side defined by the portion of the edge located above the geometrical center, a bottom side defined by the portion of the edge located below the geometrical center, a right side defined by the portion of the edge located to the right of the geometrical center, and a left side defined by the portion of the edge located to

the left of the geometrical center. The top and bottom sides does not overlap. Similarly, the left and right sides do not overlap. The top and left sides overlap at the portion of the edge located to the top-left of the geometrical center. The top and right sides overlap at the portion of the edge located to the top-right of the geometrical center. The bottom and left sides overlap at the portion of the edge located to the bottom-left of the geometrical center. The bottom and right sides overlap at the portion of the edge located to the bottom-right of the geometrical center. For purposes of determining the shape defined by the perimeter edge, the material having the perimeter edge is laid in a flat configuration with no portion of the material overlapping itself. This same construct for defining top, bottom, right, and left sides of a shape can be applied to other edges or borders described herein, for example a thread layer border 350.

[0053] As used herein, a first side of a perimeter edge (for example, first side 114) can be the top, bottom, right, or left side of the perimeter edge and a second side (for example, second side 116) of the perimeter edge can be the top, bottom, right, or left side of the perimeter edge, provided that the first and second sides are not the same side. Similarly, a third side of a perimeter edge can be the top, bottom, right, or left side of the perimeter edge and a fourth side of the perimeter edge can be the top, bottom, right, or left side of the perimeter edge, provided that the third and fourth sides are not the same, and are not the same as the first or second sides.

[0054] In some embodiments, one or more thread layers of a thread pattern 120 can comprise a thread defining (i) a plurality of thread lines each extending from a first side of a perimeter edge of a material to a second side of the perimeter edge and crossing over each other at points of overlap between two or more of the thread lines, and (ii) a plurality of thread lines each extending from a third side of the perimeter edge to a fourth side of the perimeter edge and crossing over each other at points of overlap between two or more of the thread lines. The thread lines extending from the first side to the second side can extend continuously from the first side to the second side, and the thread lines extending from the third side to the fourth side can extend continuously from the third side to the fourth side.

[0055] In some embodiments, article of apparel 100 can comprise a single piece of material 110 comprising thread pattern 120. In such embodiments, the single piece of material 110 can be joined to itself at opposing sides of perimeter edge 112 of the material 110 to create the three-dimensional shape of apparel 100. In some embodiments, the single piece of material can be joined to itself at a seam 130 joining opposing sides of perimeter edge 112 of the material 110 to create the three-dimensional shape of apparel 100.

[0056] As used herein, a "seam" is any attachment region between two portions of a single material piece or two different material pieces. Exemplary attachment regions comprise, but are not limited to, stitched attach-

ment regions, adhesive attachment regions, thermally bonded attachment regions, and interlocking attachments. Exemplary seam structures comprise, but are not limited to, a self-attaching seam, a hem, a butt stitch, a Merrow stitch (tight overlock stitch), a gathered edge, a surge stitch, an overlock stitch, and an interlocking seam construction. In some embodiments, a "seam" can comprise a region where two portions of a single material piece or two different material pieces overlap. For example, a seam can be a region where a first piece of material overlaps and is bonded to a second piece of material.

[0057] Seam(s) 130 can comprise one or more mechanical attachments, including but not limited to direct bonding attachments, adhesive attachments, interlocking mechanical attachments, and/or stitched attachments. Exemplary stitches for use in a seam construction for a seam 130 comprise, but are not limited to, a Merrow stitch (tight overlock stitch), a gathered edge, a surge stitch, or an overlock stitch.

[0058] In some embodiments, article of apparel 100 can comprise a plurality of pieces of material 140, where at least one of the pieces comprises a thread layer or thread pattern as described herein. For example, as shown in FIG. 2, apparel 100 can comprise a first piece of material 140a and a second piece of material 140b. In such embodiments, a first piece of material 140a comprises a first perimeter edge 142a and second piece of material 140b comprises a second perimeter edge 142b. Apparel 100 comprising first piece of material 140a and a second piece of material 140b can comprise a seam 130 along at least a portion of the first perimeter edge 142a and the second perimeter edge 142b that joins the first piece of material 140a to the second piece of material 140b.

[0059] In some embodiments, first piece of material 140a can comprise a thread pattern 150a. In some embodiments, second piece of material 140b can comprise a thread pattern 150b. In some embodiments, first piece of material 140a can comprise a thread pattern 150a and second piece of material 140b can comprise a thread pattern 150b. In some embodiments, first piece of material 140a can be a fabric material without a thread layer or thread pattern as described herein. In some embodiments, second piece of material 140b can be a fabric material without a thread layer or thread pattern as described herein.

[0060] Thread pattern(s) 150 can comprise one or more thread layers (for example, thread layers 300, 320, and 340) as described herein. In some embodiments, a single thread layer can define a thread pattern 150 for a piece of material.

[0061] Each thread layer of a thread pattern 150 comprises a thread defining a plurality of thread lines each extending from a first side 144 of the perimeter edge 142 to a second side 146 of the perimeter edge 142 and crossing over each other at points of overlap between two or more of the thread lines. The thread lines extending from the first side 144 of the perimeter edge 142 to the second

side 146 of the perimeter edge 142 can extend continuously from the first side 144 to the second side 146.

[0062] For example, thread pattern 150a can comprise a first thread layer comprising a first thread defining a plurality of first thread lines each extending from a first side 144a of the perimeter edge 142a to a second side 146a of the perimeter edge 142a and crossing over each other at points of overlap between two or more of the first thread lines. And thread pattern 150a can comprise a second thread layer disposed over the first thread layer and comprising a second thread defining a plurality of second thread lines each extending from the first side 144a of the perimeter edge 142a to the second side 146a of the perimeter edge 142a and crossing over each other at points of overlap between two or more of the second thread lines.

[0063] As another example, thread pattern 150b can comprise a third thread layer comprising a third thread defining a plurality of third thread lines each extending from a first side 144b of the perimeter edge 142b to a second side 146b of the perimeter edge 142b and crossing over each other at points of overlap between two or more of the third thread lines. And thread pattern 150b can comprise a fourth thread layer disposed over the third thread layer and comprising a fourth thread defining a plurality of fourth thread lines each extending from the first side 144b of the first perimeter edge 142b to the second side 146b of the perimeter edge 142b and crossing over each other at points of overlap between two or more of the second thread lines.

[0064] In some embodiments, one or more thread layers of a thread pattern 150 can comprise a thread defining (i) a plurality of thread lines each extending from a first side 144 of a perimeter edge 142 to a second side 146 of the perimeter edge 142 and crossing over each other at points of overlap between two or more of the thread lines, and (ii) a plurality of thread lines each extending from a third side 148 of the perimeter edge 142 to a fourth side 149 of the perimeter edge 142 and crossing over each other at points of overlap between two or more of the thread lines. The thread lines extending from the first side 144 to the second side 146 can extend continuously from the first side 144 to the second side 146, and the thread lines extending from the third side 148 to the fourth side 149 can extend continuously from the third side 148 to the fourth side 149.

[0065] In embodiments comprising a plurality of pieces of material 140, each piece of material can either be a piece of material comprising a thread layer or thread pattern as described herein or a piece of fabric material without a thread layer or thread pattern as described herein. Article of apparel can comprise any number of pieces of material 140 joined at seams 130 along at least a portion of their perimeter edges 142. For example, article of apparel 100 can comprise a third piece of material 140c comprising a perimeter edge 142c, a fourth piece of material 140d comprising a perimeter edge 142d, and fifth piece of material 140e comprising a perimeter edge

142e, and/or a sixth piece of material 140f comprising a perimeter edge 142f.

[0066] In some embodiments, a piece of fabric material without a thread layer or thread pattern can be a non-woven, woven, or knitted fabric material. Exemplary materials for fabric materials comprise, but are not limited to, thermoplastic polyurethane (TPU), polyester, polyamide, polyethylene (PE), PE foam, polyurethane (PU) foam, nylon, ultra-high molecular weight polyethylene (for example, DYNEEMA® (a type of ultra-high molecular weight polyethylene)), carbon fiber, KEVLAR® (a type of para-aramid), synthetic spider silk, cotton, wool, natural or artificial silk, polyethersulfone (PES), ELASTAN® (a polyether-polyurea copolymer), or a blend of two or more of these materials.

[0067] Any number of pieces of material 140 can be joined at one or more seams 130 to form an article of apparel.

[0068] As non-limiting example, article of apparel 100 can comprise a bra comprising multiple pieces of material 140 joined at one or more seams 130 to form the bra. In such embodiments, as shown for example in FIG. 2, a piece of material 140b can comprise a bra strap 160 and another piece of material 140a can comprise a cup portion 162. As another example, a piece of material 140c can comprise an underband 164 and another piece of material 140a can comprise a cup portion 162.

[0069] In some embodiments, article of apparel 100 can comprise at least two pieces of material 140a, 140b, with at least one of the pieces comprising a thread pattern 150 and configured to wrap around a portion of a wearer's body. For example, piece 140a can comprise a thread pattern 150 and be configured to wrap around a portion of a wearer's body. In such embodiments, piece 140a can comprise a perimeter edge 142a joined to itself at a seam 130. For example, all or a portion of a first side 144a of perimeter edge 142a can be joined to all or a portion of a second side 146a of perimeter edge 142a. Also in such embodiments, at least a portion of perimeter edge 142a can be joined to at least a portion of perimeter edge 142b of second piece 140b at a seam 130. For example, a portion of third side 148a of perimeter edge 142a can be joined to at least a portion of a perimeter edge 142b of second piece 140b at a seam 130.

[0070] Pieces of material 140 configured to wrap around a portion of a wearer's body comprise, but are not limited to, underbands, waistbands, knee wraps, elbow wraps, ankle wraps, sleeves, leggings, and collars.

[0071] In some embodiments, article of apparel 100 can comprise at least three pieces of material 140a, 140b, 140c with at least one of the pieces comprising a thread pattern 150 and configured to wrap around a portion of a wearer's body. For example, piece 140a can comprise a thread pattern 150 and be configured to wrap around a portion of a wearer's body. In such embodiments, piece 140a can comprise a perimeter edge 142a joined to itself at a seam 130. For example, all or a portion of a first side 144a of perimeter edge 142a can be joined to all or a

portion of a second side 146a of perimeter edge 142a. Also in such embodiments, at least a portion of perimeter edge 142a can be joined to at least a portion of perimeter edge 142b of second piece 140b at a seam 130. For example, a portion of third side 148a of perimeter edge 142a can be joined to at least a portion of a perimeter edge 142b of second piece 140b at a seam 130. Further in such embodiments, at least a portion of perimeter edge 142a can be joined to at least a portion of perimeter edge 142c of third piece 140c at a seam 130. For example, a portion of fourth side 149a of perimeter edge 142a can be joined to at least a portion of a perimeter edge 142c of second piece 140c at a seam 130.

[0072] As a non-limiting example, an article of apparel can comprise a pair of pants comprising the first piece of material 140a configured to wrap around a knee of a wearer, the second piece of material 140b located above the first piece 140a, and the third piece of material 140c located below the first piece 140a. FIG. 15 shows an article of apparel comprising a piece 140a comprising a thread pattern 150 and configured to wrap around the elbow of a wearer's body according to some embodiments. As another non-limiting example, an article of apparel can comprise a shirt comprising the first piece of material 140a configured to wrap around an elbow of a wearer, the second piece of material 140b located above the first piece 140a, and the third piece of material 140c located below the first piece 140a. FIG. 16 shows an article of apparel comprising a piece 140a comprising a thread pattern 150 and configured to wrap around the knee of a wearer's body according to some embodiments.

[0073] FIGS. 3A-3C illustrate exemplary thread layers 300, 320, and 340 according to some embodiments. Thread layer 300 comprises a continuous thread 302 wound around anchor points 390. Thread layer 320 comprises a continuous thread 322 wound around anchor points 390. Thread layer 340 comprises a continuous thread 342 wound around anchor points 390. In some embodiments, anchor points 390 can be different sets of anchor points around which different thread layers are wound. In some embodiments, a plurality of thread layers can wound around the same set of anchor points 390. In such embodiments, separate thread layers can be wound over each other, with one thread layer disposed over one or more other thread layers.

[0074] As used herein, "anchor point" means a location to which a thread or group of thread lines is fixedly attached. A thread or thread line can be wrapped, wound, bonded, or otherwise attached at an anchor point. An anchor point can be a location on an article of apparel. For example, an anchor point can be a hole or opening left behind by a structure (for example, pin, projection, or nub) used to wind continuous thread(s) of a thread layer and/or thread pattern. In some embodiments, a thread layer or thread pattern for an article of apparel may not comprise any anchor point locations because all the anchor point locations present during winding of the thread

layer or thread pattern have been removed (for example, cut off). An anchor point can be a structure (for example, pin, projection, or nub) used to wind continuous thread(s) of a thread layer and/or thread pattern. And the anchor point structure may or may not form a portion of a thread layer or thread pattern for an article of apparel.

[0075] A continuous thread wrapped or wound around an anchor point need not be wrapped or wound completely (i.e., 360 degrees) around the anchor point. A continuous thread wrapped or wound around an anchor point can be wrapped or wound around only a portion of the anchor point. For example, a continuous thread wrapped or wound around an anchor point can be wrapped or wound around 25% (90 degrees) of an anchor point's perimeter, 50% (180 degrees) of an anchor point's perimeter, 75% (270 degrees) of a pin's perimeter, or 100% (360 degrees) of an anchor point's perimeter. In some embodiments, a continuous thread can be wrapped or wound around an anchor point's perimeter more than once before being threaded to the next anchor point. For example, a continuous thread can be wrapped or wound around an anchor point's perimeter one and a half times (540 degrees) or twice (720 degrees) before being threaded to the next anchor point.

[0076] Continuous thread 302 can be wrapped around a plurality of anchor points 390 and comprises a plurality of thread lines 304. Each thread line 304 extends between two respective anchor points 390. Continuous thread 302 can be wrapped around a plurality of anchor points 390 in tension such that individual thread lines 304 are in tension when wrapped around anchor points 390. In some embodiments, the tension at which thread lines 304 are wound can range from 2 centinewtons (cN) to 10 centinewtons (cN). In some embodiments, the tension at which thread lines 304 are wound can range from 2 centinewtons (cN) to 6 centinewtons (cN).

[0077] In some embodiments, different thread lines 304 can be wrapped around anchor points 390 at different tensions to impart desired characteristics to thread layer 300. In some embodiments, a first set of thread lines 304 can be wound at a first tension in a range from 2 centinewtons (cN) to 10 centinewtons (cN) and a second set of thread lines 304 can be wound at a second tension in a range from 2 centinewtons (cN) to 10 centinewtons (cN), where the first tension is greater than or less than the second tension. In some embodiments, the first tension can be at least 0.5 cN greater than or less than the second tension. In some embodiments, the first tension can be at least 1 cN greater than or less than the second tension.

[0078] By winding continuous thread 302 in tension, thread layer 300 can be bonded while thread lines 304 are under tension such that thread lines 304 are in tension in a bonded thread layer or thread pattern. Bonding thread lines 304 while thread lines 304 are under tension fixes the thread lines 304 in tension within a layer or pattern. Fixing thread lines 304 in tension will result in thread lines 304 wanting to contract when thread layer 300 is

removed (for example, cut) from anchor points 390 used to wind thread layer 300. In cases where a portion of a thread line 304 is not bonded in a fully fixed position, the thread line 304 can contract when removed from anchor points. In such embodiments, the portion(s) of the thread line 304 that is/are fixed during a bonding process will be under tension while the other portion(s) will be free to contract. In such embodiments, the portion(s) of the thread line 304 that is/are fixed during a bonding process can be under tension within a thread layer or thread pattern on an article of apparel while the other portion(s) will not be under tension within the layer or pattern.

[0079] In embodiments where different thread lines 304 are wound at different tensions, different thread lines 304 of thread layer 300 will be under different values of tension in thread layer 300. The tension of thread lines 304 can be utilized to control characteristics of thread layer 300, and therefore an article of apparel comprising thread layer 300.

[0080] In some embodiments, these techniques of winding and bonding thread lines 304 under tension can be used to impart a desired shape to an article of apparel. For example, in some embodiments, areas of a thread pattern comprising thread lines 304 wound at high tension can define a concave or convex shape on an article of apparel. As another example, areas of a thread pattern comprising thread lines 304 wound at low tension may not impart a concave or convex shape on an article of apparel. In some embodiments, winding different thread lines 304 at different tensions can create localized, shaped regions (for example, a concave or convex area) on an article of apparel. Further, the density of thread lines 304 wound under tension can influence the shape of an article of apparel. For example, in some embodiments, areas of a thread layer or thread pattern comprising a high density of thread lines 304 wound under high tension can define a concave or convex shape on an article of apparel.

[0081] In some embodiments, areas of a thread pattern comprising a high density of low melting temperature polymeric material can define the perimeter of a concave or convex shape on an article of apparel. In some embodiments, one or more thread layers comprising a continuous thread comprising a low melting temperature polymeric material can be wound tangential to an edge (for example edge 360) of the thread layer(s) to define the perimeter of a concave or convex shape on an article of apparel. In such embodiments, the edge of the thread layer(s) can comprise a first density of low melting temperature polymeric material measured in g / m^2 (grams per meter squared) and the area adjacent to or within the edge the thread layer(s) can comprise a second density of low melting temperature polymeric material measured in g / m^2 that is less than the first density. In some embodiments, the second density can be at least 10% less than the first density. In some embodiments, the second density can be at least 20% less than the first density.

[0082] In some embodiments, areas of a thread pattern

comprising a high density of low melting temperature polymeric material can define area having a concave or convex shape on an article of apparel. In some embodiments, one or more thread layers comprising a continuous thread comprising a low melting temperature polymeric material can be wound such that the area having a concave or convex shape comprises a first density of low melting temperature polymeric material measured in g / m² and the area surrounding the concave or convex shape comprises a second density of low melting temperature polymeric material measured in g / m² that is less than the first density. As a non-limiting example, one or more thread layers comprising a continuous thread comprising a low melting temperature polymeric material can be wound such that the area corresponding to a cup portion on a bra has a first density of low melting temperature polymeric material measured in g / m² and the area surrounding the cup portion comprises a second density of low melting temperature polymeric material measured in g / m² that is less than the first density. In some embodiments, the second density can be at least 10% less than the first density. In some embodiments, the second density can be at least 20% less than the first density.

[0083] The number of thread lines 304 for thread layer 300 fixed at an anchor point 390 is defined by the "thread line communication number" of an anchor point 390. As used herein, "thread line communication number" means the number of thread lines extending from an anchor point to different anchor points. Two thread lines extending between the same two anchor points (i.e., overlaying thread lines) only counts as "1" for purposes of calculating a thread line communication number for the anchor points. For example, a thread line communication number of five means that an anchor point has five thread lines extending from it with each of the five thread lines leading to another, different anchor point. As another example, a thread line communication number of six means that an anchor point has six thread lines extending from it with each of the six thread lines leading to another, different anchor point.

[0084] Similarly, the number of thread lines fixed at an anchor point 390 for a thread pattern comprising a plurality of thread layers is defined by the "thread line communication number" of an anchor point 390 for the thread pattern. For a thread pattern, the "thread line communication number" of an anchor point 390 is the total number of thread lines, for the plurality of layers, extending from an anchor point to different anchor points.

[0085] Anchor points 390 can have a thread line communication number of "X" or more for a thread layer or a thread pattern. In some embodiments, two or more respective anchor points 390 can have a thread line communication number of "X" or more. In some embodiments, all the anchor points 390 for a thread layer or a thread pattern can have a thread line communication number of "X" or more. "X" can be, for example, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 45, or 50, within

a range having any two of these values as end points. For example, in some embodiments "X" can be in a range of 2 to 50, 3 to 50, 4 to 50, 5 to 50, 6 to 50, 7 to 50, 8 to 50, 9 to 50, 10 to 50, 15 to 50, 20 to 50, 25 to 50, 30 to 50, 35 to 50, 40 to 50, or 45 to 50. In some embodiments, "X" can be greater than 50. In some embodiments, "X" can range from 2 to 100, 10 to 100, or 20 to 100.

[0086] A thread layer, for example thread layer 300, can comprise any suitable number of thread lines. In some embodiments, a thread layer can comprise 10 or more thread lines. In some embodiments, a thread layer can comprise 20 or more thread lines. In some embodiments, a thread layer can comprise 50 or more thread lines. In some embodiments, a thread layer can comprise 100 or more thread lines. In some embodiments, a thread layer can comprise 200 or more thread lines. In some embodiments, a thread layer can comprise 300 or more thread lines. In some embodiments, a thread layer can comprise 500 or more thread lines. In some embodiments, a thread layer can comprise a number of thread lines in a range of 10 to 300. For example, a thread layer can comprise 10 to 300, 50 to 300, 100 to 300, or 150 to 300 thread lines. In some embodiments, a thread layer can comprise 10 to 500 thread lines. In some embodiments, a thread layer can comprise 100 to 500 thread lines. In some embodiments, a thread layer can comprise 100 to 1000 thread lines.

[0087] In some embodiments, thread lines 304 can be bonded at anchor points 390. In such embodiments, thread lines 304 can be bonded at anchor points 390 via an adhesive, a bonding layer, thermal (conductive or convective) heat (for example, in a heat press or oven), IR (infrared) heating, laser heating, microwave heating, steam, a mechanical fastener (for example, a clip), hook and loop fasteners, needle-punching, hydro-entanglement, ultrasonic/vibratory entanglement, felting, knotting, chemical bonding with a catalyst of biomaterial, adhesive spraying (for example, CNC adhesive spray deposition), or by pushing one thread line through the other thread line(s).

[0088] In some embodiments, thread lines 304 can be directly bonded together at anchor points 390. In some embodiments, thread lines 304 can be directly bonded together at anchor points 390 via a polymeric material of continuous thread 302. For example, heat and/or pressure can be applied to directly bond thread lines 304 at anchor points 390. In embodiments where heat and/or pressure is utilized to directly bond the polymeric material of thread lines 304, the thread lines 304 can be thermally fused together at one or more anchor points 390. In embodiments comprising direct bonding of thread lines 304 at anchor points 390, thread lines 304 can be directly bonded at anchor points 390 without the use of an adhesive or bonding layer.

[0089] In some embodiments, thread lines 304 can be bonded together via a bonding layer. In some embodiments, thread lines 304 can be bonded together at anchor points 390 via a bonding layer. In such embodiments,

the bonding layer can be, for example, a laminated layer, an adhesive layer, a stitched layer, a cured layer, or a screen-printed layer.

[0090] In some embodiments, thread lines 304 can be bonded together without the use of a bonding layer. For example, in some embodiments, thread lines 304 can be directly bonded together via, for example, but not limited to, local bonding via an adhesive, direct local bonding via material(s) of thread lines 304, needle punching, hydro-entanglement, and ultrasonic/vibratory entanglement.

[0091] In some embodiments, thread lines 304 can be bonded at points where two or more thread lines 304 overlap in thread layer 300 (i.e., intersection points 306). Thread lines 304 can be bonded at intersection points 306 via an adhesive, a bonding layer, thermal (conductive or convective) heat (for example, in a heat press or oven), IR (infrared) heating, laser heating, microwave heating, steam, a mechanical fastener (for example, a clip), hook and loop fasteners, needle-punching, hydro-entanglement, ultrasonic/vibratory entanglement, felting, knotting, chemical bonding with a catalyst of biomaterial, adhesive spraying (for example, CNC adhesive spray deposition), or by pushing one thread line through the other thread line(s). Intersection points for thread lines can be referred to as "overlap points" or "points of overlap."

[0092] In some embodiments, thread lines 304 can be directly bonded together at intersection points 306. In some embodiments, thread lines 304 can be directly bonded together at intersection points 306 via the polymeric material of continuous thread 302. In embodiments comprising direct bonding of thread lines 304 at intersection points 306, thread lines 304 can be bonded at intersection points 306 without the use of an adhesive or bonding layer. For example, heat and/or pressure can be applied to thread layer 300 to directly bond thread lines 304 at intersection points 306. In embodiments where heat and/or pressure is utilized to directly bond the polymeric material of thread lines 304, the thread lines 304 can be thermally fused together at one or more intersection points 306.

[0093] In some embodiments, a bonding layer can bond thread lines 304 together at a plurality of intersection points 306 within thread layer 300. In such embodiments, the bonding layer can be, for example, a laminated layer, an adhesive layer, a stitched layer, a cured layer, a screen-printed layer, or a chopped fiber layer comprising polymeric fibers that can bond thread lines 304.

[0094] In some embodiments, continuous thread 302 can comprise overlaying thread lines 304. As used herein, "overlaying thread lines" means two or more thread lines that follow the same path between two respective anchor points. Overlaying thread lines need not be overlaid directly over each other. Two or more thread lines are considered overlaying as long as they extend between the same two anchor points.

[0095] The thread lines 304 of thread layer 300 may

not be woven or knitted together. In such embodiments, thread lines 304 can be referred to as "non-woven" and "non-knitted" thread lines. The thread lines 304 of thread layer 300 may not be embroidered threads stitched to a base layer. In such embodiments, thread lines 304 may be referred to as "non-embroidered" thread lines.

[0096] In some embodiments, continuous thread 302 can be a polymer thread. As used herein "polymer thread" means a thread composed at least in part of a polymeric material. In some embodiments, a polymer thread can be composed entirely of one or more polymeric materials. In some embodiments, a polymer thread can comprise a polymeric material coated around a core (which may or may not be composed of a polymeric material). In such embodiments, the core can be encapsulated by the coating material. In some embodiments, a polymer thread can comprise a non-polymer core coated, covered, or encapsulated with a polymeric material. In some embodiments, a polymer thread can comprise a polymer core coated, covered, or encapsulated with a non-polymeric material. In some embodiments, a polymer thread can be a braided thread with one or more braids composed of a polymeric material. In some embodiments, the polymeric material(s) of a polymer thread can be thermoplastic material(s). In some embodiments, continuous thread 302 can be a thread coated with an activatable agent, for example a heat activated adhesive or a UV-activated adhesive. In some embodiments, a CNC machine for winding a continuous thread 302 with an activatable agent coating can comprise a robotic arm for activating the coating as continuous thread 302 is being wound around anchor points 390.

[0097] Suitable polymeric materials for polymer threads discussed herein comprise, but are not limited to, thermoplastic polyurethane (TPU), a rubber, and silicone. In some embodiments, the TPU can be recycled TPU. In some embodiments, the polymeric material can be a photo-reactive (infrared or ultraviolet light reactive) polymeric material, such as a photo-reactive TPU. In some embodiments, the polymeric material can be soluble (for example, water-soluble). In embodiments comprising polymer threads with a coated core, suitable materials for the core comprise, but are not limited to, polyester, nylon, ultra-high molecular weight polyethylene (for example, DYNEEMA® (a type of ultra-high molecular weight polyethylene)), carbon fiber, KEVLAR® (a type of para-aramid), bioengineered woven, knit or layered materials (for example, synthetic spider silk), woven, knit or layered plant based materials, cotton, wool, and natural or artificial silk. In some embodiments, polymer threads can be thermoplastic polyurethane coated polyester threads. In some embodiments, continuous thread 302 can be a non-polymer thread composed of non-polymer materials, such as carbon fiber, cotton, wool, or silk. In some embodiments, continuous thread 302 can be a thread composed of a biomaterial, such as mango yarn or bio-silk. In some embodiments, polymer threads can be a thermoplastic melt yarn, polymer yarn with non-melt

core, and other similar types of yarn.

[0098] In some embodiments, the polymeric material for polymer threads can comprise a melting temperature in a range of greater than or equal to 110 °C to less than or equal to 150 °C. In such embodiments, the polymeric material can be referred to as a "low melting temperature polymeric material."

[0099] In some embodiments, continuous thread 302 can comprise an elastomeric thread. A suitable elastomeric material for an elastomeric continuous thread 302 comprises, but is not limited to, ELASTAN® (a polyether-polyurea copolymer). In some embodiments, the elastomeric thread can comprise a percent elongation in a range of 100% to 300%, including subranges. For example, in some embodiments, the elastomeric thread can comprise a percent elongation in a range of 100% to 300%, 150% to 300%, 200% to 300%, 100% to 250%, or 100% to 200%. Unless specified otherwise, percent elongation of an elastomeric thread is measured according to ISO 2062 (Textiles - Yarns from packages - Determination of single-end breaking force and elongation at break).

[0100] In some embodiments, continuous thread 302 can comprise a composite elastomeric thread comprising an elastomeric material and one or more textile materials. Suitable textile materials for composite elastomeric threads comprise, but are not limited to, polyethersulfone (PES), rayon (for example, TENCEL™), cotton, polyester, and nylon. In some embodiments, the percent of elastomeric material in a composite elastomeric thread can be in a range of 10% to 80%, including subranges. For example, a composite elastomeric thread can comprise 10% to 80% elastomeric material, 15% to 80% elastomeric material, 20% to 80% elastomeric material, 25% to 80% elastomeric material, 30% to 80% elastomeric material, 40% to 80% elastomeric material, 50% to 80% elastomeric material, 10% to 70% elastomeric material, 10% to 60% elastomeric material, 10% to 50% elastomeric material, 10% to 40% elastomeric material, 10% to 35% elastomeric material, 10% to 25% elastomeric material, or 10% to 20% elastomeric material.

[0101] In some embodiments, a composite elastomeric thread comprise an elastomeric material core with one or more textile materials covering the core. As a non-limiting example, a composite elastomeric thread can comprise a polyester covered ELASTAN® core.

[0102] In some embodiments, an elastomeric thread can comprise a melting temperature greater than 150 °C. In some embodiments, both the elastomeric material and the or more textile materials of a composite elastomeric thread can comprise a melting temperature greater than 150 °C.

[0103] In some embodiments, continuous thread 302 can be a plied thread. In some embodiments, the plied thread can be plied while winding thread 302. For example, a winding assembly used to wind thread 302 can ply the thread using thread from a plurality of thread spools (see for example, winding assembly 640). In some em-

bodiments, the plied thread can be a pre-plied thread spooled around a thread spool.

[0104] In some embodiments, a plied thread can comprise one or more elastomeric threads and one or more polymeric threads. In such embodiments, a plied thread can comprise one or more elastomeric threads and one or more polymeric threads comprising a low melting temperature polymeric material.

[0105] In some embodiments, a plied thread can comprise a plurality of different types of threads. For example, a plied thread can comprise one or more polymer threads and one or more non-polymer threads. As another example, a plied thread can comprise one or more polymer threads comprising a first polymer material and one or more threads comprising a second, different, polymer material.

[0106] In some embodiments, continuous thread 302 can be a composite co-extruded thread. In such embodiments, different portions of the composite co-extruded thread are formed of different materials. In such embodiments, the different materials of the composite co-extruded thread can provide varying mechanical characteristics to a thread layer or thread pattern.

[0107] In some embodiments, continuous thread 302 can be a foamable thread. In such embodiments, a foaming agent in the foamable thread can be activated to expand the thread after the thread is wound in a thread layer. The foaming agent in a foamable thread can be activated by, for example, heat. In such embodiments, continuous thread 302 can be wound in a thread layer to provide areas of increased padding on an article of apparel.

[0108] In some embodiments, continuous thread 302 can be a dissolvable thread. Dissolvable threads can be dissolved after being wound in a thread layer by a solvent. In such embodiments, a portion of a thread layer can be removed by dissolving the dissolvable thread.

[0109] In some embodiments, continuous thread 302 can be an "active thread." As used herein, an "active thread" is a thread that changes in length when activated by an activating agent. An active thread can expand or contract in length when activated by an activating agent. Exemplary activating agents comprise, but are not limited to, heat, water, and electrical current. In embodiments comprising an active thread, dimensional characteristics of a thread layer, and therefore a thread pattern, can be altered after winding the thread layer. For example, in some embodiments, the dimensional characteristics of a thread layer can be altered while heating a thread pattern within a heat press or on a mannequin as described herein. In such embodiments, the altering the dimension characteristics can impart a desired shape to an article of apparel.

[0110] In some embodiments, continuous thread 302 can be a composed of a viscoelastic shear thickening (dilatant) material. The elastic modulus of a dilatant material is dependent on the rate of strain applied to the material. By incorporating a thread composed of a dila-

tant material in a thread layer, the stiffness of the thread layer can change depending on the degree of stain applied to the thread layer during use. For example, a thread layer can remain relatively compliant during a low stress activity, for example walking, but increase in stiffness when high stress levels are applied during a high stress activity, such as running.

[0111] In some embodiments, continuous thread 302 of thread layer 300 can have a denier in the range of 1 denier to 3000 denier, including subranges. For example, continuous thread 302 can have a denier of 1, 10, 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2500, or 3000 denier, or within any range having any two of these values as endpoints. For example, in some embodiments, continuous thread 302 can have a denier in the range of 10 denier to 2500 denier, 50 denier to 2000 denier, 100 denier to 1900 denier, 200 denier to 1800 denier, 300 denier to 1700 denier, 400 denier to 1600 denier, 500 denier to 1500 denier, 600 denier to 1400 denier, 700 denier to 1300 denier, 800 denier to 1200 denier, 900 denier to 1100 denier, or 900 denier to 1000 denier.

[0112] Thread patterns as described herein can comprise any number of thread layers. For example, a thread pattern can comprise two or more, three or more, four or more, five or more, six or more, seven or more, eight or more, nine or more, ten or more, fifteen or more, or twenty or more thread layers. For example, a thread pattern can comprise thread layer 300, thread layer 320, and thread layer 340.

[0113] Continuous threads of any thread layer (for example, thread layers 320 and 340) can be wound around and extended between anchor points 390 in the same fashion as described above for continuous thread 302. Further, thread lines of the continuous threads of any thread layer (for example, thread layers 320 and 340) can be bonded in the same manner as described above for thread layer 300.

[0114] Like continuous thread 302, continuous thread for other thread layers (for example, threads 322 and 342) can comprise a plurality of thread lines (for example, thread lines 324 and 344) wound around and extending between two respective anchor points. In some embodiments, continuous threads of different thread layers can be the same thread material. In some embodiments, continuous threads of different thread layers can be composed of different thread materials. In such embodiments, the materials for different continuous threads in a thread pattern can be selected to provide targeted characteristics to areas of a thread pattern, and therefore an article of apparel. In some embodiments, the denier of continuous threads in different thread layers within a thread pattern can be selected to provide varying degrees of a characteristic (for example, strength or stretchability) to different areas of the thread pattern.

[0115] In embodiments comprising a thread pattern with a plurality of thread layers, the plurality of thread

layers can be layered over each other. For example, thread layer 300 can define a first layer of a thread pattern and second thread layer 320 can define a second layer of the thread pattern. Different thread layers of a thread pattern can be disposed over each other in areas of overlap between the two thread layers. For example, a first thread layer 300 can be disposed over second thread layer 320, or vice versa, in areas of overlap between the two thread layers. Different layers defined by different continuous wound threads can provide different characteristics to different areas of a thread pattern, and therefore can provide different characteristics to different areas of an article of apparel.

[0116] In embodiments comprising a thread pattern with a plurality of thread layers, the plurality of thread layers can be bonded to each other in the thread pattern. In some embodiments, one or more of the layers can be directly bonded to each other via the polymeric material of a continuous thread defining thread lines for at least one of the layers. In some embodiments, one or more of the layers can be bonded via a bonding layer. In such embodiments, the bonding layer can be, for example, a laminated layer, an adhesive layer, a stitched layer, a cured layer, or a screen-printed layer.

[0117] In some embodiments, one or more thread layers of a thread pattern can serve to bond other thread layers of the thread pattern together. In such embodiments, these one or more thread layers can be wound using a polymeric thread, which when heated, bonds other layers of the thread pattern together at anchor points and/or intersection points between continuous threads. For example, in a thread pattern comprising three thread layers, one of the three thread layers (for example, the middle thread layer) can be a wound using a polymeric thread that serves to bond all three thread layers together. In some embodiments, one or more thread layers of a thread pattern can be defined by a wound continuous thread coated or impregnated with an adhesive. In some embodiments, the adhesive can be activated with the application of heat. In some embodiments, the adhesive can be a dissolvable adhesive that, when contacted with a solvent, such as water, fully or partially dissolves to bond thread layers together.

[0118] In some embodiments, a thread pattern can be visibly exposed on the outer surface of an article of apparel. In some embodiments, no lamination layer or supporting textile layer is disposed over a thread pattern on the outer surface of an article of apparel. In some embodiments, a thread pattern can be devoid of a lamination layer.

[0119] In some embodiments, the elastomeric content of different thread layers can be varied to provide varying degrees of a characteristic (for example, strength or stretchability) through a thickness of an article of apparel. In some embodiments, the elastomeric content of thread layers disposed closer to a wearer's body in use can be higher than the elastomeric content of thread layers disposed further away from a wearer's body in use.

[0120] In some embodiments, a first thread layer (for example, thread layer 300) can comprise an elastomeric thread comprising a first percentage of elastomeric material and a second thread layer disposed over the first thread layer (for example, thread layer 320) can comprise elastomeric thread comprising a second percentage of elastomeric material, and the first percentage can be greater than the second percentage. In some embodiments, the first percentage can be at least 2% greater than the second percentage. In some embodiments, the first percentage can be at least 5% greater than the second percentage. In such embodiments, the first thread layer can provide a higher degree of stretchability and/or softer hand feel.

[0121] In some embodiments, a first thread layer (for example, thread layer 300) can comprise a first composite elastomeric thread comprising an elastomeric material and one or more textile materials, and a second thread layer disposed over the first thread layer (for example, thread layer 320) can comprise a second composite elastomeric thread comprising an elastomeric material and one or more textile materials. In such embodiments, a percentage of elastomeric material in the first composite elastomeric thread can be greater than a percentage of elastomeric material in the second composite elastomeric thread. In some embodiments, the first percentage can be at least 2% greater than the second percentage. In some embodiments, the first percentage can be at least 5% greater than the second percentage. In such embodiments, the first thread layer can provide a high degree of stretchability and/or softer hand feel.

[0122] In some embodiments, a thread pattern can comprise a plurality of thread layers with an elastomeric content gradient. In some embodiments, a thread pattern can comprise a plurality of thread layers with a decreasing elastomeric content gradient. In some embodiments, the gradient can be at least 2% for a plurality of consecutive thread layers in a thread pattern. In some embodiments, the gradient can be at least 5% for a plurality of consecutive thread layers in a thread pattern. In some embodiments, the gradient can be at least 10% for a plurality of consecutive thread layers in a thread pattern.

[0123] As a non-limiting example, a thread pattern comprising a decreasing elastomeric content gradient of 2% for three consecutive thread layers can comprise a first thread layer with a 10% elastomeric content, a second thread layer with an 8% elastomeric content, and a third layer with a 6% elastomeric content. In some embodiments, the elastomeric content gradient can extend across three or more thread layers. In some embodiments, the elastomeric content gradient can extend across four or more thread layers. In some embodiments, the elastomeric content gradient can extend across five or more thread layers.

[0124] In some embodiments, the low melting temperature polymeric material content of different thread layers can be varied to provide varying degrees of a characteristic (for example, strength or stretchability) through a

thickness of an article of apparel. In some embodiments, the low melting temperature polymeric material content of thread layers disposed further away from a wearer's body in use can be higher than the low melting temperature polymeric material content of thread layers disposed closer to a wearer's body in use.

[0125] In some embodiments, a first thread layer (for example, thread layer 300) can comprise a plied thread comprising a first percentage of low melting temperature polymeric material and a second thread layer disposed over the first thread layer (for example, thread layer 320) can comprise a plied thread comprising a second percentage of low melting temperature polymeric material, and the first percentage can be less than the second percentage. In some embodiments, the first percentage can be at least 2% less than the second percentage. In some embodiments, the first percentage can be at least 5% less than the second percentage. In such embodiments, the second thread layer can provide a higher degree of stiffness and/or support.

[0126] In some embodiments, a thread pattern can comprise a plurality of thread layers with a low melting temperature polymeric material content gradient. In some embodiments, a thread pattern can comprise a plurality of thread layers with an increasing low melting temperature polymeric material gradient. In some embodiments, the gradient can be at least 2% for a plurality of consecutive thread layers in a thread pattern. In some embodiments, the gradient can be at least 5% for a plurality of consecutive thread layers in a thread pattern. In some embodiments, the gradient can be at least 10% for a plurality of consecutive thread layers in a thread pattern.

[0127] As a non-limiting example, a thread pattern comprising an increasing low melting temperature polymeric material content gradient of 5% for three consecutive thread layers can comprise a first thread layer with 0% low melting temperature polymeric material content, a second thread layer with a 5% low melting temperature polymeric material content, and a third layer with a 10% low melting temperature polymeric material content. In some embodiments, the low melting temperature polymeric material content gradient can extend across three or more thread layers. In some embodiments, the low melting temperature polymeric material content gradient can extend across four or more thread layers. In some embodiments, the low melting temperature polymeric material content gradient can extend across five or more thread layers.

[0128] In some embodiments, a thread pattern can comprise a plurality of thread layers with an elastomeric content gradient and a low melting temperature polymeric material content gradient. In some embodiments, a thread pattern can comprise a plurality of thread layers with a decreasing elastomeric content gradient and an increasing low melting temperature polymeric material content gradient. In some embodiments, a thread pattern can comprise a plurality of thread layers with an increasing elastomeric content gradient and a decreasing low

melting temperature polymeric material content gradient.

[0129] Varying the elastomeric content and/or low melting temperature polymeric material content across layers as described herein can create a material property blend across the layers. For example, decreasing elastomeric content while increasing low melting temperature polymeric material content can create a thread pattern with relatively high stretchability for thread layers disposed closer to a wearer's body in use and relatively high stiffness for thread layers disposed further away from a wearer's body in use.

[0130] In some embodiments, the density of low melting temperature polymeric material measured in g/m^2 can be varied within a thread layer to provide varying degrees of a characteristic (for example, strength or stretchability) in different zones of a thread pattern. In some embodiments, one or more thread layers comprising a continuous thread comprising a low melting temperature polymeric material can be wound such that the a first zone (for example, zone 410) comprises a first density of low melting temperature polymeric material measured in g / m^2 and a second zone (for example, zone 400) comprises a second density of low melting temperature polymeric material measured in g / m^2 that is less than the first density.

[0131] In some embodiments, the density of elastomeric material measured in g/m^2 can be varied within a thread layer to provide varying degrees of a characteristic (for example, strength or stretchability) in different zones of a thread pattern. In some embodiments, one or more thread layers comprising a continuous thread comprising an elastomeric thread can comprise a first zone (for example, zone 400) comprising a first elastomeric material density measured in g / m^2 and a second zone (for example, zone 410) comprising a second elastomeric material density measured in g / m^2 that is less than the first density.

[0132] Thread patterns, and thread layers within the thread patterns, as described herein can provide targeted characteristics (for example, strength, stiffness, air permeability, comfort (stretchability), tackiness, abrasion resistance, water resistance texture, tackiness and haptics) to certain zones of an article of apparel. For example, in some embodiments, a thread pattern, or a portion thereof, can provide a first degree of a characteristic in one zone of an article of apparel and a second degree of that characteristic in a second zone of the article of apparel.

[0133] In some embodiments, different thread layers of a thread pattern can provide a first degree of a characteristic in one zone of an article of apparel and a second degree of that characteristic in a second zone of the article of apparel. In some embodiments, different thread layers of a thread pattern can comprise different thread patterns to provide targeted characteristics to different zones of an article of apparel. In some embodiments, different thread layers of a thread pattern can comprise thread lines oriented in different directions to provide tar-

geted characteristics to different zones of an article of apparel.

[0134] FIG. 4 illustrates zones on article of apparel 100 according to some embodiments. As illustrated in FIG. 4, apparel 100 comprises a first piece of material 140a and a second piece of material 140b. First piece of material 140a comprises a first zone 400, a second zone 410, and a third zone 420. Second piece of material 140b comprises the first zone 400 and the third zone 420. That said, article of apparel can comprise any number of pieces of material 140 with any number of zones. In some embodiments, as shown for example, in FIG. 4, a zone can extend from one piece of material to a second piece of material.

[0135] First zone 400 represents a zone on article of apparel 100 comprising a first degree of one or more characteristics (for example, strength, stiffness, air permeability, comfort (stretchability), tackiness, abrasion resistance, texture, tackiness, or haptics). Second zone 410 represents a zone on article of apparel 100 comprising a second degree of the same one or more characteristics (for example, strength, stiffness, air permeability, comfort (stretchability), tackiness, abrasion resistance, texture, tackiness, or haptics). Third zone 420 represents a zone on article of apparel 100 comprising a third degree of the same one or more characteristics (for example, strength, stiffness, air permeability, comfort (stretchability), tackiness, abrasion resistance, texture, tackiness, or haptics). For example, first zone 400 can comprise a first stiffness, second zone 410 can comprise a second stiffness greater than or less than the first stiffness, and the third zone 420 can comprise a third stiffness greater than or less than the first stiffness and greater than or less than second stiffness.

[0136] In some embodiments, zones on an article of apparel, for example, all or a portion of first zone 400, second zone 410, or a third zone 420, can be shaped regions on an article of apparel as described herein.

[0137] Each zone on an article of apparel can comprise one or more perimeter boundaries defining the bounds of each zone. For example, as shown in FIG. 4, zone 400 comprises perimeter boundaries 402 and 404, zone 410 comprises perimeter boundary 412, and zone 420 comprises perimeter boundaries 422 and 424.

[0138] In some embodiments, the perimeter boundary of each zone on an article of apparel can be defined by one or more thread layers of a thread pattern. In some embodiments, the perimeter boundary of each zone on an article of apparel can be defined thread lines of a thread layer within a thread pattern.

[0139] In some embodiments, the perimeter boundary of one or more zones on an article of apparel can be defined thread lines extending tangential to the perimeter boundary of the zone. In such embodiments, winding a continuous thread for one or more thread layers can comprise winding the continuous thread(s) such that thread lines are positioned tangential to the perimeter boundary of a zone. In other words, by threading thread lines tan-

gential to the zone, the thread lines can define a perimeter boundary of the zone.

[0140] Threading thread lines tangential to a zone can result in a relatively high density of thread lines around the zone. A high density of thread lines can serve to demarcate the zone from adjacent or surrounding zones.

[0141] In some embodiments, threading thread lines tangential to a zone can also comprise threading thread lines such that a relatively high density of thread lines are located near a perimeter boundary of the zone. By threading a high density of thread lines nearly tangential to a zone, characteristics of a thread pattern or thread layer near the zone can be controlled.

[0142] In some embodiments, a thread layer can comprise a continuous thread with a plurality of thread lines extending tangential to an edge 360 of the thread layer. The edge 360 can be, for example, a portion of a thread layer or thread pattern border 350 or a perimeter edge of an opening in a thread layer or thread pattern.

[0143] In some embodiments, winding thread lines tangential to a perimeter boundary of a zone (for example, zone 400, 410, or 420) can create an increased thickness at the perimeter boundary. In some embodiments, the increased thickness can create a bump or similar feature at the perimeter boundary. In some embodiments, the increased thickness can create a bump or similar feature designed to provide desired aesthetics and/or texture. In some embodiments, the increased thickness can create a bump or similar feature designed to provide increased strength or stiffness at the perimeter boundary. In some

embodiments, the increased thickness can create a bump or similar feature designed to provide increased cushioning at the perimeter boundary.

[0144] In some embodiments, a thread layer can comprise a continuous threads with a plurality of thread lines extending tangential to an opening located in the thread layer. By threading thread lines tangential to an opening, the thread layer can define an opening that defines the perimeter boundary of a zone. In some embodiments, threading thread lines tangential to an opening can provide strength at a perimeter of the opening. In some embodiments, threading thread lines tangential to an opening can provide stretchability at a perimeter of the opening. In some embodiments, threading thread lines tangential to an opening can provide stiffness at a perimeter of the opening.

[0145] In some embodiments, methods of making an article of apparel can comprise defining a perimeter boundary for a zone, and winding a continuous thread around anchor points such that the continuous thread comprises a set of thread lines, with each thread line in the set extending between two respective anchor points and tangential to the perimeter boundary. In the examples described below, thread lines extending tangential to the perimeter boundary are described as "boundary-tangential thread lines."

[0146] FIG. 3C illustrates a thread layer 340 comprising a continuous thread 342 with thread lines 344 extend-

ing tangential to a perimeter boundary according to some embodiments. Thread layer 340 comprises an edge 360. Edge 360 can define all or a portion of a perimeter boundary for a zone on an article of apparel. For example, edge 360 can define a portion of perimeter boundary 402 of first zone 400 on article of apparel 100.

[0147] Thread lines 344 of continuous thread 342 can comprise a plurality of thread lines 344 extending between two respective anchor points 390 and extending tangential to edge 360. Thread lines 344 extending tangential to edge 360 can be referred to as "boundary-tangential thread lines." FIG. 3C shows a plurality of boundary-tangential thread lines 346.

[0148] Thread lines 344 of continuous thread 342 can also comprise a plurality of thread lines 344 extending between two respective anchor points 390 and not tangential to edge 360. Thread lines 344 not extending tangential to edge 360 can be referred to as "non-boundary-tangential thread lines." FIG. 3C shows a plurality of non-boundary-tangential thread lines 348.

[0149] In some embodiments, thread lines 346 extending tangential to edge 360 are not wound around an anchor point located at edge 360. In some embodiments, thread layer 340 can be devoid of anchor points located at edge 360.

[0150] Boundary-tangential thread lines 346 can comprise thread lines 346 that overlap each other at an overlap point 347 in thread layer 340. Any two boundary-tangential thread lines 346 of thread layer 340 can overlap each other at an overlap point 347.

[0151] Boundary-tangential thread lines 346 that overlap each other at an overlap point 347 can be disposed at an angle relative to each other. The relative angle of the two thread lines 346 can be defined by the angle of intersection (θ) at an overlap point 347. Unless specified otherwise, the angle of intersection (θ) is the angle formed by the intersection of two thread lines 346 and is measured on the side of the thread lines 346 facing edge 360 (as shown in FIG. 3C).

[0152] In some embodiments, the angle of intersection (θ) at an overlap point 347 can be in the range of 90° to 179°, including subranges. For example, θ can be 90°, 100°, 110°, 120°, 130°, 140°, 150°, 160°, 170°, or 179°, or within a range having any two of these values as endpoints, inclusive of the endpoints. In some embodiments, θ can be in a range of 90° to 179°, 100° to 179°, 110° to 179°, 120° to 179°, 130° to 179°, 140° to 179°, 150° to 179°, 160° to 179°, or 170° to 179°. In some embodiments, θ can be greater than 90°, greater than 120°, or greater than 150°.

[0153] Thread layer 340 can comprise any suitable number of boundary-tangential thread lines 346. In some embodiments, thread layer 340 can comprise four or more boundary-tangential thread lines 346. In some embodiments, thread layer 340 can comprise 10 or more boundary-tangential thread lines 346. In some embodiments, thread layer 340 can comprise 20 or more boundary-tangential thread lines 346. In some embodiments,

thread layer 340 can comprise 30 or more boundary-tangential thread lines 346. In some embodiments, thread layer 340 can comprise 50 or more boundary-tangential thread lines 346. In some embodiments, thread layer 340 can comprise a number of boundary-tangential thread lines 346 in a range of 2 to 50. For example, thread layer 340 can comprise 2 to 50, 4 to 50, 10 to 50, 20 to 50, or 30 to 50 boundary-tangential thread lines 346.

[0154] In some embodiments, a plurality of adjacent anchor points 390 used to form thread layer 340 can each comprise a boundary-tangential thread line 346 extending therefrom. As used herein, a first anchor point described as "adjacent" to second anchor point means that the second anchor point is the first anchor point's first or second closest anchor point neighbor. An anchor point will typically include two "adjacent" anchor point neighbors, typically located on opposing sides of the anchor point. In embodiments including equally spaced anchor points, an anchor point's first and second closest anchor point neighbors can be located at the same distance from the anchor point. As an example, anchor points 390a and 390c are adjacent to anchor point 390b in FIG. 3C.

[0155] In some embodiments, boundary-tangential thread lines 346 overlapping at an overlap point 347 can be directly bonded to each other at the overlap point 347. In some embodiments, boundary-tangential thread lines 346 overlapping at an overlap point 347 can be directly bonded to each other via a polymeric material of the boundary-tangential thread lines 346.

[0156] In some embodiments, an anchor point 390 can comprise a boundary-tangential thread line 346 extending therefrom and a plurality of non-boundary-tangential thread lines 348 extending therefrom. In some embodiments, an anchor point 390 can have a thread line communication number and at least one of the threads counted in the thread line communication number can be a boundary-tangential thread line 346 and the remainder of the thread lines can be non-boundary-tangential thread lines 348.

[0157] By threading thread lines in this fashion, thread layer 340 can comprise a high density of thread lines near edge 360 and extending nearly tangential to edge 360. By threading a high density of thread lines in this fashion, characteristics of thread layer 340 at edge 360 can be controlled. For example, the softness, stretchability, stiffness, and/or strength of thread layer 340 at edge 360 can be controlled by threading thread lines as described above.

[0158] By controlling the characteristics of thread layer 340 at edge 360, edge 360 can be utilized to define all or a portion of a perimeter boundary of a zone (e.g., zone 400, 410, or 420). In some embodiments, an article of apparel 100 can comprise a first zone (for example, zone 400) comprising a perimeter boundary (for example, perimeter boundary 402) and a second zone (for example, zone 410) disposed around at least a portion of the perimeter boundary of the first zone. Thread lines of a thread

layer extending tangential to the perimeter boundary 402 of the first zone 400 can demarcate the first zone 400 from the second zone 410. In addition, the thread lines extending tangential to the perimeter boundary 402 of the first zone 400 can provide a targeted characteristic to the second zone 410.

[0159] In some embodiments, the first zone 400 can comprise thread lines extending through the first zone 400 in various directions to impart a first degree of one or more characteristics (for example, a relatively high degree of stretchability) and second zone 410 can comprise thread lines extending tangential to perimeter boundary 402 of the first zone 400 to impart a second degree of the one or more characteristics (for example, a relatively low degree of stretchability).

[0160] For example, article of apparel 100 can comprise a bra comprising a piece of material 140a comprising a thread pattern and comprising a cup portion 162 comprising first zone 400 having a first stretchability and second zone 410 having a second stretchability. A plurality of thread lines (for example, thread lines of thread layers 300 and 320) can extend through the first zone 400 to impart the first stretchability to zone 400 and a plurality of thread lines (for example thread lines of thread layer 340) can extend tangential to the perimeter boundary 402 of the first zone 400 to impart the second stretchability to second zone 410.

[0161] Any article of apparel, for example, a shirt, leggings, or a sleeve, can comprise one or more pieces of material 140 comprising a thread pattern comprising a first zone 400 having a first degree of one or more characteristics and second zone 410 having a second degree of the degree of one or more characteristics. A plurality of thread lines (for example, thread lines of thread layers 300 or 320) can extend through the first zone 400 to impart the first characteristic to the first zone 400 and a plurality of thread lines (for example thread lines of thread layer 340) can extend tangential to the perimeter boundary 402 of the first zone 400 to impart the second characteristic to second zone 410. Similarly, any number of zones can be created by winding thread lines tangential to a perimeter boundary of the zone.

[0162] In some embodiments, a perimeter boundary for a zone can be defined by two different thread layers. In such embodiments, an edge 360a of a first thread layer can define a first portion the perimeter boundary of the zone and an edge 360b of a second thread layer define a second portion the perimeter boundary of the zone. For example, piece of material 140f in FIG. 2 can comprise a zone 400 comprising a perimeter boundary 402 defined by edge 360a of a first thread layer and edge 360b of a second thread layer.

[0163] In some embodiments, one or more characteristics (for example, strength, stiffness, air permeability, comfort (stretchability), tackiness, abrasion resistance, texture, tackiness, or haptics) can gradually transition from a first degree of the characteristic in a first zone to a second degree of the characteristic in a second zone.

In some embodiments, a thread layer within a thread pattern can serve to gradually transition from a first degree of the characteristic in a first zone to a second degree of the characteristic in a second zone. In some embodiments, a thread layer within a thread pattern can comprise a thread line group extending from an anchor point that overlaps all or a portion of a perimeter boundary of a zone and is configured to gradually transition from the first degree of the characteristic in a first zone to the second degree of the characteristic in a second zone.

[0164] For example, thread layer 320 can comprise a thread line group 330 with thread lines extending from a single anchor point 390 and oriented in a particular direction within thread layer 320. By arranging the thread line group 330 such that the group overlaps all or a portion of a perimeter boundary for a zone (for example, perimeter boundary 402 of zone 400 in FIG. 4), the thread line group 330 can gradually transition from the first degree of the characteristic in a first zone to the second degree of the characteristic in a second zone due to the variable spacing of the thread lines as they extend from the single anchor point 390 to other anchor points on an opposing side of the thread layer 320. In such embodiments, the thread line group 330 can comprise a plurality of thread lines extending from a first anchor point 390 at a first side of the thread layer 320 to a plurality of anchor points 390 at a second side of the thread layer 320. Also in such embodiments, after thread layer 320 is removed (for example, cut) from the anchor points 390, the thread lines within the thread line group 330 can have a first spacing at a first side of the thread layer 320 and a second spacing greater than the first spacing at a second side of the thread layer 320. In such embodiments, the thread lines within the thread line group 330 can fan out as the thread lines extend from the first side of the thread layer 320 to the second side of the thread layer 320.

[0165] Any suitable number of thread line groups 330 can be utilized to gradually transition from a first degree of a characteristic in a first zone to a second degree of the characteristic in a second zone. The ability to control the number of thread lines within a thread line group 330 and the spacing of thread lines within the group 330 can provide a high degree of control in how quickly or slowly a first characteristic transitions to a second characteristic.

[0166] Thread patterns, and thread layers within the thread patterns, as described herein can provide targeted characteristics (for example, strength, stiffness, air permeability, comfort (stretchability), tackiness, abrasion resistance, water resistance texture, tackiness and haptics) to particular locations on an article of apparel. For example, in some embodiments, a thread pattern, or a portion thereof, can provide a first degree of a characteristic at one or more first locations on an article of apparel and a second degree of that characteristic at one or more second locations on the article of apparel.

[0167] In some embodiments, different thread layers of a thread pattern can provide a first degree of a characteristic at one or more first locations on an article of

apparel and a second degree of that characteristic at one or more second locations on the article of apparel. In some embodiments, different thread layers of a thread pattern can comprise different thread patterns to provide targeted characteristics at different locations on an article of apparel. In some embodiments, different thread layers of a thread pattern can comprise thread lines oriented in different directions to provide targeted characteristics to different locations on an article of apparel.

[0168] In some embodiments, thread patterns, and thread layers within the thread patterns, as described herein can provide targeted stiffness to different locations on an article. In some embodiments, a thread pattern, or a portion thereof, can comprise a first stiffness measured in particular direction at one or more first locations on an article of apparel and a second stiffness measured in the particular direction at one or more second locations on the article of apparel. In some embodiments, a thread pattern, or a portion thereof, can comprise a first stiffness measured in a first direction at one or more first locations on an article of apparel and a second stiffness measured in a second direction at the one or more first locations.

[0169] Unless specified otherwise, stiffness values described herein are measured by clamping a 3-millimeter (mm) section of the article of apparel between clamps of an INSTRON® machine, pre-cycling the machine at 4 cycles set to a 3-mm extension, and measuring the force (in Newtons) at a 5 mm extension in a 5th cycle. Stiffness value measurements are repeated three times and the average is reported as the stiffness.

[0170] FIG. 9 shows a graph of stiffness measured in a first direction (the superior-inferior direction "SI" shown in FIG. 4) at various locations (labeled 1-16 in FIG. 4) for four sample bras comprising multiple thread patterns 150 according to some embodiments. The stiffness of a control sample at the various locations was also measured. A 500 N load cell was used to measure the stiffness values shown in FIG. 9.

[0171] FIG. 10 shows a graph of stiffness measured in a second direction (the lateral-medial direction "LM" shown in FIG. 4) at various locations (labeled 1-16 in FIG. 4) for the four sample bras. The stiffness of the control sample at the various locations was also measured. A 500 N load cell was used to measure the stiffness values shown in FIG. 10. The second direction is perpendicular to the first direction.

[0172] FIG. 11 shows a graph of stiffness measured in a third direction (right-diagonal direction "D_R" shown in FIG. 4) at various locations (labeled 1-16 in FIG. 4) for the four sample bras. The stiffness of the control sample at various locations was also measured. A 500 N load cell was used to measure the stiffness values shown in FIG. 11. The third direction is a diagonal direction oriented at a 45 degree angle relative to the first direction and the second direction.

[0173] FIG. 12 shows a graph of stiffness measured in a forth direction (left-diagonal direction "D_L" shown in FIG. 4) at some locations (labeled 1-16 in FIG. 4) for two

of the four sample bras. A 500 N load cell was used to measure the stiffness values shown in FIG. 12. The fourth direction is a diagonal direction perpendicular to the third direction.

[0174] FIG. 13 shows a graph of stiffness measured in the first direction (direction "SI" at various locations (labeled 1-12 in FIG. 4) for two sample bras (Samples 5 and 6) comprising multiple thread patterns 150 according to some embodiments. A 10 kilonewton (kN) load cell was used to measure the stiffness values for Sample 5. A 500 newton (N) load cell was used to measure the stiffness values for Sample 6.

[0175] FIG. 14 shows a graph of stiffness measured in the second direction (direction "LM") at various locations (labeled 1-12 in FIG. 4) for Samples 5 and 6. A 10 kilonewton (kN) load cell was used to measure the stiffness values for Sample 5. A 500 newton (N) load cell was used to measure the stiffness values for Sample 6.

[0176] As shown in the graphs of FIGS. 9-13, thread patterns described herein can provide different degrees of stiffness at different locations on an article of apparel. In some embodiments, the different degrees of stiffness can be different degrees of stiffness measured in the same direction at different locations. In some embodiments, the different degrees of stiffness can be different degrees of stiffness measured in different directions at the same location.

[0177] In some embodiments, an article of apparel can comprise a first stiffness measured in a first direction, for example direction "SI," at a first location and a second stiffness measured in the first direction at a second location. In some embodiments, the first stiffness in the first direction can range from 3 N / 5 mm to 22 N / 5 mm, including subranges. For example, in some embodiments, the first stiffness can range from 3 N / 5 mm to 22 N / 5 mm, from 3 N / 5 mm to 20 N / 5 mm, from 3 N / 5 mm to 15 N / 5 mm, from 5 N / 5 mm to 22 N / 5 mm, or from 10 N / 5 mm to 22 N / 5 mm. In some embodiments, the second stiffness in the first direction can range from 3 N / 5 mm to 22 N / 5 mm, including subranges. For example, in some embodiments, the second stiffness can range from 3 N / 5 mm to 22 N / 5 mm, from 3 N / 5 mm to 20 N / 5 mm, from 3 N / 5 mm to 15 N / 5 mm, from 5 N / 5 mm to 22 N / 5 mm, or from 10 N / 5 mm to 22 N / 5 mm.

[0178] In some embodiments, the first stiffness in the first direction can be greater than the second stiffness in the first direction. In some embodiments, the first stiffness in the first direction can be at least 5% greater than the second stiffness in the first direction. In some embodiments, the first stiffness in the first direction can be at least 10% greater than the second stiffness in the first direction. In some embodiments, the first stiffness in the first direction can be at least 30% greater than the second stiffness in the first direction. In some embodiments, the first stiffness in the first direction can be at least 100% greater than the second stiffness in the first direction. In some embodiments, the first stiffness in the first direction can be at least 150% greater than the second stiffness

in the first direction.

[0179] In some embodiments, an article of apparel can comprise three or more locations with different stiffness values measured in the first direction. In such embodiments, each of the three locations can have stiffness values that are each at least 5% 10%, or 30% different from each other. In some embodiments, an article of apparel can comprise four or more locations with different stiffness values measured in the first direction. In such embodiments, each of the four locations can have stiffness values that are each at least 5% 10%, or 30% different from each other. In some embodiments, an article of apparel can comprise five or more locations with different stiffness values measured in the first direction. In such embodiments, each of the five locations can have stiffness values that are each at least 5% 10%, or 30% different from each other.

[0180] In some embodiments, an article of apparel can comprise a first stiffness measured in a second direction, for example direction "LM," at a first location and a second stiffness measured in the second direction at a second location. In some embodiments, the first stiffness in the second direction can range from 3 N / 5 mm to 22 N / 5 mm, including subranges. For example, in some embodiments, the first stiffness can range from 3 N / 5 mm to 22 N / 5 mm, from 3 N / 5 mm to 20 N / 5 mm, from 3 N / 5 mm to 15 N / 5 mm, from 5 N / 5 mm to 22 N / 5 mm, or from 10 N / 5 mm to 22 N / 5 mm. In some embodiments, the second stiffness in the second direction can range from 3 N / 5 mm to 22 N / 5 mm, including subranges. For example, in some embodiments, the second stiffness can range from 3 N / 5 mm to 22 N / 5 mm, from 3 N / 5 mm to 20 N / 5 mm, from 3 N / 5 mm to 15 N / 5 mm, from 5 N / 5 mm to 22 N / 5 mm, or from 10 N / 5 mm to 22 N / 5 mm.

[0181] In some embodiments, the first stiffness in a second direction can be greater than the second stiffness in a second direction. In some embodiments, the first stiffness in a second direction can be at least 5% greater than the second stiffness in a second direction. In some embodiments, the first stiffness in a second direction can be at least 10% greater than the second stiffness in a second direction. In some embodiments, the first stiffness in a second direction can be at least 30% greater than the second stiffness in a second direction. In some embodiments, the first stiffness in the second direction can be at least 100% greater than the second stiffness in a second direction. In some embodiments, the first stiffness in the second direction can be at least 150% greater than the second stiffness in the second direction.

[0182] In some embodiments, an article of apparel can comprise three or more locations with different stiffness values measured in the second direction. In such embodiments, each of the three locations can have stiffness values that are each at least 5% 10%, or 30% different from each other. In some embodiments, an article of apparel can comprise four or more locations with different stiffness values measured in the second direction. In

direction can range from 3 N / 5 mm to 22 N / 5 mm, including subranges. For example, in some embodiments, the second stiffness can range from 3 N / 5 mm to 22 N / 5 mm, from 3 N / 5 mm to 20 N / 5 mm, from 3 N / 5 mm to 15 N / 5 mm, from 5 N / 5 mm to 22 N / 5 mm, or from 10 N / 5 mm to 22 N / 5 mm.

[0190] In some embodiments, the first stiffness in the first direction can be greater than the second stiffness in the second direction. In some embodiments, the first stiffness in the first direction can be at least 5% greater than the second stiffness in the second direction. In some embodiments, the first stiffness in the first direction can be at least 10% greater than the second stiffness in the second direction. In some embodiments, the first stiffness in the first direction can be at least 30% greater than the second stiffness in the second direction. In some embodiments, the first stiffness in the first direction can be at least 100% greater than the second stiffness in the second direction. In some embodiments, the first stiffness in the first direction can be at least 150% greater than the second stiffness in the second direction.

[0191] FIG. 5 shows a method 500 of making an article of apparel (for example, apparel 100) according to some embodiments. In step 510, a plurality of anchor points (for example, anchor points 390) on a support structure can be defined. In some embodiments, the support structure can be a support plate (for example, support plate 630). In some embodiments, the support structure can be a mannequin (for example, mannequin 800). In some embodiments, the anchor points can comprise projections on a support plate. In some embodiments, the anchor points can comprise projections extending laterally from a perimeter edge of a support plate. In some embodiments, the anchor points can comprise pins on a support plate.

[0192] In step 520, one or more continuous threads (for example, continuous thread 302) can be wound (wrapped) around the anchor points 390 such that individual thread lines (for example, thread lines 304) of the continuous thread(s) extend between two respective anchor points. Winding continuous thread(s) in step 520 forms one or more desired thread layers (for example, thread layer 300) and/or a thread pattern comprising a plurality of thread layers (for example, a thread pattern 150 comprising thread layers 300, 320, and 340). During winding step 520, anchor points can be defined by fixed or moveable members, such as pins, projections, nubs, or shafts coupled to a support structure, or any other similar fixed anchor point discussed herein. These fixed members serve to support continuous thread(s) during winding step 520. For example, thread(s) can be wound around anchor points on a plate, a three-dimensional object (for example, a mannequin), or a frame. For example, the anchor points can be pins coupled to a mannequin (e.g., mannequin 800). As another example, the anchor points can be projections extending from support plate (for example support plate 630).

[0193] In some embodiments, the plate, object, or

frame can be held stationary and a winding device can wind thread(s) around stationary anchor points. In some embodiments, the plate, object, or frame can move relative to a stationary thread source during winding. In some embodiments, the plate, object, or frame can move relative to a winding device that wind thread(s) around the moving anchor points.

[0194] In step 530, the continuous thread(s) can be bonded within the thread layer or thread pattern. In some embodiments, continuous thread(s) can be bonded at points of intersection between thread lines via, for example, an adhesive, a bonding layer, thermal (conductive or convective) heat (for example, in a heat press or oven), IR (infrared) heating, laser heating, microwave heating, steam, a mechanical fastener (for example, a clip), hook and loop fasteners, needle-punching, hydro-entanglement, ultrasonic/vibratory entanglement, felting, knotting, chemical bonding with a catalyst of biomaterial, adhesive spraying (for example, CNC adhesive spray deposition), or by pushing one thread line through the other thread line(s). In some embodiments, continuous thread(s) can be directly bonded at points of intersection between thread lines.

[0195] In some embodiments, continuous thread(s) can be bonded at the anchor points via, for example, an adhesive, a bonding layer, thermal (conductive or convective) heat (for example, in a heat press or oven), IR (infrared) heating, laser heating, microwave heating, steam, a mechanical fastener (for example, a clip), hook and loop fasteners, needle-punching, hydro-entanglement, ultrasonic/vibratory entanglement, felting, knotting, chemical bonding with a catalyst of biomaterial, adhesive spraying (for example, CNC adhesive spray deposition), or by pushing one thread line through the other thread line(s). In some embodiments, continuous thread(s) can be directly bonded at the anchor points.

[0196] In some embodiments, step 530 can comprise the formation of a bonding layer for bonding thread lines together.

[0197] In some embodiments, method 500 can comprise multiple winding steps 520 and multiple bonding steps 530. For example, a portion of a thread pattern can be wound in a first winding step 520 and then that portion can be bonded in a first bonding step 530. Then a second portion of a thread pattern can be wound in a second winding step 520 and that portion can be bonded in a second bonding step 530. In some embodiments, bonding step 530 can comprise a preliminary bonding step to hold the pattern of a thread layer or thread pattern until a final bonding step is performed. For example, a preliminary bonding step can allow a thread layer or thread pattern to be removed from anchor points and be finally bonded after removal.

[0198] In some embodiments, steps 220 and 230 can be performed in the absence of a base layer disposed between the thread layer or thread pattern and a support structure comprising the anchor points. As used herein "base layer" means a layer of material employed to fa-

cilitate the placement or arrangement of threads when winding and/or bonding a thread layer or thread pattern. A base layer can be a layer to which threads are bonded, stitched, woven into, printed on, deposited on, or otherwise in contact with on an article of apparel. A layer attached to a thread pattern after formation of the thread pattern is complete is not considered a base layer.

[0199] In some embodiments, a base layer can define a layer of material for an article of apparel. For example, base layer can be base fabric layer over which a thread layer or thread pattern is wound. In such embodiments, a thread layer or thread pattern can be bonded to the base fabric layer in step 530. In such embodiments, the base fabric layer can define a layer for a piece of material comprising the thread layer or thread pattern.

[0200] In step 540, a piece of material comprising the wound and bonded thread layer or thread pattern can be removed from the support structure. In some embodiments, removing the piece of material from the support structure can comprise cutting the material comprising

from the support structure. In some embodiments, the cutting process can comprise a laser cutting process.

[0201] In step 540, the piece of material can be cut to define a shape utilized to form all or a portion of an article of apparel. For example, the piece of material can be cut to define a perimeter shape for a bra strap. As another example, in some embodiments, the piece of material can be cut to define a shape for a sleeve. FIGS. 2 and 4 illustrate various pieces of material 140 cut to define a shape for forming a portion of an article of apparel according to some embodiments.

[0202] In some embodiments, cutting in step 540 can define all or a portion of a thread layer border 350 for thread layers of thread pattern and all or a portion of a thread pattern border 350.

[0203] In step 550, the piece of material 140 can be shaped into an article of apparel. In some embodiments, shaping the piece of material 140 can comprise joining the piece of material to itself at a seam 130.

[0204] In some embodiments, shaping the piece of material in step 550 can comprise attaching the piece of material 140 to one or more additional pieces of material 140 to form an article of apparel. For example two pieces of material 140a and 140b can be attached to form an article of apparel. In some embodiments, attaching the piece of material 140 to the one or more additional pieces of material 140 can comprise seaming the piece of material 140 to one or more of the additional pieces of material 140 at one or more seams 130 as described herein.

[0205] In some embodiments, attaching the piece of material 140 to the one or more additional pieces of material 140 can comprise attaching the piece of material 140 to another piece of material comprising a thread layer or thread pattern as described herein. In such embodiments, the other piece of material can be made using steps 510-540. In some embodiments, attaching the piece of material 140 to one or more additional pieces of material 140 can comprise attaching the piece of material

140 to another piece of material 140 without a thread layer or thread pattern as described herein.

[0206] In some embodiments, method 500 can comprise step 560. In step 560, the article of apparel formed in step 550 can be heated. In some embodiments, step 560 can comprise placing the article of apparel over a mannequin, for example mannequin 800 illustrated in FIG. 8, and heating the article of apparel on the mannequin 800. In some embodiments, the article can be heated to a temperature in a range of 80 °C to 120 °C or in a range of 90 °C to 110 °C.

[0207] In some embodiments, step 560 can comprise attaching the article of apparel to the mannequin 800 at a plurality of attachment points 810. In some embodiments, mannequin 800 can be an adjustable mannequin configured to be adjusted to an individual's body type. For example, one or more of the cup size, underbust, torso length, shoulder width, or chest width of mannequin 800 can be adjusted.

[0208] In some embodiments, step 560 can comprise steaming the article of apparel. In some embodiments, step 560 can comprise placing the article of apparel over a mannequin, for example mannequin 800 illustrated in FIG. 8, and steaming the article of apparel on the mannequin 800. In some embodiments, an external steam source (for example, a steamer) can be used steam the article of apparel in step 560. In some embodiments, mannequin 800 can comprise a plurality of steam nozzles 820 configured to eject steam to steam the article of apparel in step 560.

[0209] In some embodiments, heating the article of apparel in step 560 can comprise selectively heating portions of the article of apparel. In some embodiments, steaming the article of apparel in step 560 can comprise selectively steaming portions of the article of apparel. In some embodiments, steaming the article of apparel in step 560 can comprise selectively seaming portions of the article of apparel by emitting seam from one or more of the plurality of steam nozzles 820 on mannequin 800.

[0210] In some embodiments, heating or steaming article of apparel in step 560 can shape the article of apparel into a desired shape. In such embodiments, heating or steaming article of apparel in step 560 can define one or more shaped regions on the article of apparel. In some embodiments, the heat or steam can interact with the thread lines of different thread layers (e.g., thread layer 300 and thread layer 320) differently due to the different composition and/or tension of the thread lines within the thread layers. This difference in interaction can cause the thread lines of the different thread layers to behave differently when steam is applied. For example, the thread lines of one thread layer can contract or expand to a different degree in the presence of heat or steam compared to the thread lines of another thread layer. This different in contraction or expansion can impart desired shape characteristics (for example, a convex shape, a constricted shaped, or a flat shape) on different regions of the article of apparel.

[0211] For example, a continuous thread of a first thread layer (for example, layer 300) wound at a first tension and a second continuous thread of a second thread layer (for example, layer 320) wound at a second tension greater than the first tension can contract or expand differently in the presence of heat or steam. In such an embodiment, heating or steaming the article of apparel can shape the first thread layer and the second thread layer differently to define a shaped region on the article of apparel.

[0212] As another example, a continuous thread of a first thread layer (for example, layer 300) comprising a first thread type and a second continuous thread of a second thread layer (for example, layer 320) comprising a second thread type different from the first type can contract or expand differently in the presence of heat or steam. In such an embodiment, heating or steaming the article of apparel can shape the first thread layer and the second thread layer differently to define a shaped region on the article of apparel.

[0213] FIG. 6 illustrates a computer numerical control (CNC) machine 600 for winding thread(s) in step 520 according to some embodiments. Machine 600 comprises a robot 605 for winding a thread layer (for example, thread layer 300) and/or a plurality of thread layers for a thread pattern (for example, thread pattern 120) comprising thread lines (for example, thread lines 304) around anchor points 390 on a support plate 630.

[0214] Robot 605 can comprise one or more thread spools 610 for threading and winding thread lines of one or more thread layers around anchor points 390. In some embodiments, CNC machine 600 can comprise a winding assembly 640 comprising a plurality of thread spools 610 for threading and winding a plurality of different threads.

[0215] In some embodiments, CNC machine 600 can comprise one or more thread tensioners 612 configured to apply a desired tension to thread(s) that are wound around anchor points 390. CNC machine 600 can comprise a controller 615 configured to wind one or more thread layers around anchor points 390 using a thread model and input data. In some embodiments, controller 615 can control tensioners 612 to wind thread(s) at desired tensions.

[0216] In some embodiments, CNC machine 600 can wind a plurality of threads from a plurality of thread spools 610 simultaneously when winding a thread layer. In some embodiments, machine 600 can be used to simultaneously wind "overlying thread lines" from a plurality of thread spools 610.

[0217] In some embodiments, CNC machine 600 can comprise two or more robots 605 for winding a plurality of threads simultaneously. In such embodiments, the two or more robots 605 can wind different threads in different regions of a thread pattern simultaneously.

[0218] In some embodiments, robot 605 can ply two or more threads from different thread spools 610. In such embodiments, a thread layer or thread pattern can com-

prise one or more plied threads. As used herein, "plying" two or more threads means coupling the two or more threads together by twisting at least one of the two or more threads. In some embodiments, plying can comprise twisting one or more threads around one or more non-twisted threads. In some embodiments, plying can comprise twisting two or more threads together.

[0219] In some embodiments, a tensioner 612 can be a mechanical tensioning device with digitally controlled impedance that is used to dynamically control how tight a thread is fed through machine 600. In some embodiments, the tension value for thread can be changed dynamically by adjusting the voltage in tensioner 612. In some embodiments, tensioner 612, can be a manually adjustable tensioner. In some embodiments, tensioner 612 can comprise a spring configured to adjust the amount of tension applied to thread(s). The spring can be manually controlled or digitally controlled.

[0220] As discussed herein, adjusting the tension as the thread is wound can provide a number of benefits. With elastic threads, tensioning the threads places a preload on them, allowing them to act as if they have a different stiffness in a thread pattern. By dynamically adjusting the tension, one thread can behave with a range of stiffness, which allows for customized zones of stiffness and compliance without the need for changing thread material. This change in stiffness between different zones can be large or small. For example, high stiffness can be provided in areas where high tensioned threads are bonded together and low stiffness can be provided in areas where stretch is preferred.

[0221] In some embodiments, the tension at which a continuous thread for a thread layer is wound can range from 2 centinewtons (cN) to 10 centinewtons (cN). In some embodiments, the tension at which a continuous thread for a thread layer is wound can range from 2 centinewtons (cN) to 6 centinewtons (cN).

[0222] In some embodiments, the tension at which continuous threads of different thread layers are wound can provide varying degrees of a characteristic (for example, strength or stretchability) through a thickness of an article of apparel. In some embodiments, the tension at which continuous threads are wound for thread layers disposed closer to a wearer's body in use can be lower than the tension at which continuous threads are wound for thread layers disposed further away from a wearer's body in use.

[0223] In some embodiments, a first thread layer (for example, thread layer 300) can comprise a continuous thread 302 wound at a first tension and a second thread layer disposed over the first thread layer (for example, thread layer 320) can comprise a continuous thread 322 wound at a second tension greater than the first tension. In some embodiments, the second tension can be at least 0.5 cN greater than the first tension. In some embodiments, the second tension can be at least 1 cN greater than the first tension. In such embodiments, the first thread layer can provide a higher degree of softness

and/or hand feel for wearer.

[0224] FIG. 7 shows a heat press 700 for bonding thread in step 530 according to some embodiments. Heat press 700 can apply pressure and heat to a thread layer or thread pattern to bond continuous thread(s) at locations of anchor points and/or intersection points between thread lines. In some embodiments, heat press 700 can provide heat at a predetermined temperature equal to or above the melting point of polymeric material(s) of polymer thread(s) of a thread layer or thread pattern. In some embodiments, heat press 700 can provide heat at a predetermined temperature below the melting point of polymeric material(s) of polymer thread(s) of a thread layer or thread pattern, but high enough to cause the polymeric material(s) to bond (fuse) together, or to other materials of the thread layer or thread pattern.

[0225] Heat can be applied to a thread layer or thread pattern in heat press 700 in one or more ways, such as but not limited to, radio frequency heat sealing (welding), high frequency heat sealing (welding), infra-red welding, and steaming. Heat transfer between a thread layer or thread pattern and a heat press 700 can be via conduction and/or convection. In some embodiments, heat can be applied to a single outer surface of a thread layer or thread pattern in heat press 700. In some embodiments, heat can be applied to both outer surfaces of a thread layer or thread pattern in heat press 700.

[0226] In some embodiments, heat can be uniformly applied to a thread layer or thread pattern within heat press 700. In such embodiments, the temperature at which a thread layer or thread pattern is bonded within heat press 700 can be substantially the same across all portions of the layer or pattern. In some embodiments, heat can be non-uniformly applied to a thread layer or thread pattern within heat press 700. In such embodiments, the temperature at which a thread layer or thread pattern is bonded within heat press 700 is different for different portions and/or regions of the layer or pattern. By varying the bonding temperature of different portions and/or regions of a thread layer or pattern in heat press 700, characteristics of the thread layer or thread pattern in different portions and/or regions of an article of apparel can be varied.

[0227] In some embodiments, the heat applied to a thread layer or thread pattern can be controlled by controlling heat applied to heat press 700. In some embodiments, the heat applied to a thread pattern or thread layer can be additionally or alternatively controlled by one or more inserts 740 disposed between an interior surface of heat press 700 and the thread layer or thread pattern. In such embodiments, insert(s) 740 can control the heat applied to by controlling the heat transfer between heat press 700 and the thread layer or thread pattern. In some embodiments, insert(s) 740 can serve to uniformly distribute heat across all or a portion of a thread layer or thread pattern within heat press 700. In some embodiments, insert(s) 740 can serve to vary the bonding temperature of different portions and/or regions of a thread

layer or thread pattern in heat press 700.

[0228] In some embodiments, different amounts of heat can be uniformly or non-uniformly applied to a thread layer or thread pattern within heat press 700 in separate steps. In such embodiments, the separate steps can serve to selectively soften, melt, and/or activate particular threads of a thread layer or thread pattern within heat press 700. For example, a first step can soften or melt the polymeric material of a first thread and a second heating step can soften or melt the polymeric material of a second thread. As another example, a first heating step can soften or melt the polymeric material of a first thread and a second heating step can activate an activatable agent of a second thread.

[0229] In some embodiments, after applying heat and pressure to the thread pattern in heat press 700, the thread layer or thread pattern can be removed from heat press 700 to cool. In some embodiments, after applying heat and pressure to the thread layer or thread pattern in heat press 700, the thread layer or thread pattern can be removed from heat press 700 and placed in a cold press.

[0230] It is to be appreciated that the Detailed Description section, and not the Summary and Abstract sections, is intended to be used to interpret the claims. The Summary and Abstract sections may set forth one or more but not all exemplary embodiments of the present invention(s) as contemplated by the inventor(s), and thus, are not intended to limit the present invention(s) and the appended claims in any way.

[0231] The present invention(s) have been described above with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries can be defined so long as the specified functions and relationships thereof are appropriately performed.

[0232] The foregoing description of the specific embodiments will so fully reveal the general nature of the invention(s) that others can, by applying knowledge within the skill of the art, readily modify and/or adapt for various applications such specific embodiments, without undue experimentation, without departing from the general concept of the present invention(s). Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed embodiments, based on the teaching and guidance presented herein. It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by the skilled artisan in light of the teachings and guidance.

[0233] The breadth and scope of the present invention(s) should not be limited by any of the above-described exemplary embodiments but should be defined only in accordance with the following claims and their equivalents.

[0234] In the following, further preferred embodiments are described to facilitate understanding:

Embodiment 1. An article of apparel, comprising:

a first piece of material comprising:

a first perimeter edge,

a first thread layer comprising a first thread defining a plurality of first thread lines each extending from a first side of the perimeter edge to a second side of the first perimeter edge and crossing over each other at points of overlap between two or more of the first thread lines, and

a second thread layer disposed over the first thread layer and comprising a second thread defining a plurality of second thread lines each extending from the first side of the first perimeter edge to the second side of the perimeter edge and crossing over each other at points of overlap between two or more of the second thread lines;

a second piece of material comprising a second perimeter edge; and

a seam along at least a portion of the first perimeter edge and the second perimeter edge that joins the first piece of material to the second piece of material.

Embodiment 2. The article of apparel of embodiment 1, wherein the second piece of material is a fabric material.

Embodiment 3. The article of apparel of embodiment 2, wherein the fabric material comprises a woven or knitted fabric.

Embodiment 4. The article of apparel of any one of the preceding embodiments, wherein the first thread lines are not woven or knitted together, and the second thread lines are not woven or knitted together; and

wherein the first thread lines and the second thread lines are not embroidered threads stitched to a base layer.

Embodiment 5. The article of apparel of any one of the preceding embodiments, wherein the second piece of material comprises:

a third thread layer comprising a third thread defining a plurality of third thread lines each extending from a first side of the second perimeter edge to a second side of the second perimeter edge and crossing over each other at points of overlap between two or more of the third thread

lines, and

a fourth thread layer disposed over the third layer and comprising a fourth thread defining a plurality of fourth thread lines extending from the first side of the second perimeter edge to the second side of the second perimeter edge and crossing over each other at points of overlap between two or more of the second thread lines.

Embodiment 6. The article of apparel of any one of the preceding embodiments, wherein the plurality of first thread lines are directly bonded to each other at the points of overlap between two or more of the first thread lines.

Embodiment 7. The article of apparel of any one of the preceding embodiments, wherein the plurality of second thread lines are directly bonded to each other at the points of overlap between two or more of the second thread lines.

Embodiment 8. The article of apparel of any one of the preceding embodiments, wherein the first thread comprises a composite elastomeric thread comprising an elastomeric material and one or more textile materials.

Embodiment 9. The article of apparel of any one of the preceding embodiments, wherein the second thread comprises a polymeric thread comprising a polymeric material having melting temperature in a range of greater than or equal to 110 °C to less than or equal to 150 °C.

Embodiment 10. The article of apparel of any one of the preceding embodiments, wherein the first thread layer comprises a first composite elastomeric thread comprising an elastomeric material and one or more textile materials,

wherein the second thread layer comprises a second composite elastomeric thread comprising an elastomeric material and one or more textile materials, and

wherein a percentage of elastomeric material in the first composite elastomeric thread is greater than a percentage of elastomeric material in the second composite elastomeric thread.

Embodiment 11. The article of apparel of any one of the preceding embodiments, wherein the article of apparel comprises a bra.

Embodiment 12. The article of apparel of embodiment 11, wherein the first piece of material comprises a bra strap and the second piece of material comprises a cup portion.

Embodiment 13. The article of apparel of embodiment 11, wherein the first piece of material comprises an underband and the second piece of material comprises a cup portion.

Embodiment 14. The article of apparel of any one of the preceding embodiments, wherein:

the article of apparel comprises a bra,
the first piece of material comprises a cup portion comprising a first zone having a first stiffness and a second zone having a second stiffness,
the first zone comprises a perimeter boundary,
the second zone is disposed around at least a portion of the perimeter boundary of the first zone,
the plurality of first thread lines extend through the first zone, and
the plurality of second thread lines extend tangential to the perimeter boundary of the first zone.

Embodiment 15. The article of apparel of any one of the preceding embodiments, further comprising a third piece of material comprising a third perimeter edge, and a second seam along at least a portion of the first perimeter edge and the third perimeter edge that joins the first piece of material to the third piece of material.

Embodiment 16. The article of apparel of embodiment 15, wherein the article of apparel comprises a pair of pants, and wherein the first piece of material is configured to wrap around a knee of a wearer.

Embodiment 17. The article of apparel of embodiment 15 or 16, wherein the article of apparel comprises a shirt, and wherein the first piece of material is configured to wrap around an elbow of a wearer.

Embodiment 18. A method of making an article of apparel, the method comprising:

forming a first piece of material by a method comprising:

winding a continuous thread around a plurality of anchor points on a support plate to form a thread layer, the continuous thread comprising a plurality of thread lines with each thread line extending between two respective anchor points;
bonding the continuous thread at points of intersection between two or more of the thread lines; and
after bonding the continuous thread, cutting the thread layer to remove the first piece of

material comprising a thread pattern comprising the thread layer from the support plate; and

attaching the first piece of material to one or more additional pieces of material to form the article of apparel.

Embodiment 19. The method of embodiment 18, wherein attaching the first piece of material to the one or more additional pieces of material comprises seaming the first piece of material to the one or more of the additional pieces of material.

Embodiment 20. The method of embodiment 18 or 19, wherein the one or more additional pieces of material comprises a second piece of material made by a method comprising:

winding a second continuous thread around a plurality of anchor points on a second support plate to form a second thread layer, the second continuous thread comprising a plurality of second thread lines with each thread line extending between two respective anchor points;
bonding the second continuous thread at points of intersection between two or more of the thread lines; and
after bonding the second continuous thread, cutting the second thread layer to remove a second piece of material comprising a second thread pattern comprising the second thread layer from the second support plate.

Embodiment 21. The method of embodiment 18, 19 or 20, further comprising:
placing the article of apparel over a mannequin; and
heating the article of apparel on the mannequin.

Claims

1. An article of apparel (100), comprising:

a first piece of material (140a) comprising:

a first perimeter edge (142a),
a first thread layer comprising a first thread defining a plurality of first thread lines each extending from a first side (144a) of the perimeter edge (142a) to a second side (146a) of the first perimeter edge (142a) and crossing over each other at points of overlap between two or more of the first thread lines, and
a second thread layer disposed over the first thread layer and comprising a second thread defining a plurality of second thread

lines each extending from the first side (144a) of the first perimeter edge (142a) to the second side (146a) of the perimeter edge (142a) and crossing over each other at points of overlap between two or more of the second thread lines;

a second piece of material (140b) comprising a second perimeter edge (142b); and
a seam (130) along at least a portion of the first perimeter edge (142a) and the second perimeter edge (142b) that joins the first piece of material (140a) to the second piece of material (140b).

2. The article of apparel (100) of claim 1, wherein the second piece of material (140b) is a fabric material, and wherein preferably the fabric material comprises a woven or knitted fabric.

3. The article of apparel (100) of claim 1 or 2, wherein the first thread lines are not woven or knitted together, and the second thread lines are not woven or knitted together; and
wherein the first thread lines and the second thread lines are not embroidered threads stitched to a base layer.

4. The article of apparel (100) of any one of the preceding claims, wherein the second piece of material (140b) comprises:

a third thread layer comprising a third thread defining a plurality of third thread lines each extending from a first side (144b) of the second perimeter edge (142b) to a second side (146b) of the second perimeter edge (142b) and crossing over each other at points of overlap between two or more of the third thread lines, and
a fourth thread layer disposed over the third layer and comprising a fourth thread defining a plurality of fourth thread lines extending from the first side (144b) of the second perimeter edge (142b) to the second side (146b) of the second perimeter edge (142b) and crossing over each other at points of overlap between two or more of the second thread lines.

5. The article of apparel (100) of any one of the preceding claims, wherein the plurality of first thread lines are directly bonded to each other at the points of overlap between two or more of the first thread lines, and/or wherein preferably the plurality of second thread lines are directly bonded to each other at the points of overlap between two or more of the second thread lines.

6. The article of apparel (100) of any one of the pre-

ceding claims, wherein the first thread comprises a composite elastomeric thread comprising an elastomeric material and one or more textile materials.

7. The article of apparel (100) of any one of the preceding claims, wherein the second thread comprises a polymeric thread comprising a polymeric material having melting temperature in a range of greater than or equal to 110 °C to less than or equal to 150 °C.

8. The article of apparel (100) of any one of the preceding claims, wherein the first thread layer comprises a first composite elastomeric thread comprising an elastomeric material and one or more textile materials,

wherein the second thread layer comprises a second composite elastomeric thread comprising an elastomeric material and one or more textile materials, and

wherein a percentage of elastomeric material in the first composite elastomeric thread is greater than a percentage of elastomeric material in the second composite elastomeric thread.

9. The article of apparel of any one of the preceding claims, wherein the article of apparel comprises a bra, and wherein preferably the first piece of material (140a) comprises a bra strap (160) and the second piece of material (140b) comprises a cup portion (162), and/or wherein preferably the first piece of material (140a) comprises an underband (164) and the second piece of material (140b) comprises a cup portion (162).

10. The article of apparel (100) of any one of the preceding claims, wherein:

the article of apparel (100) comprises a bra,
the first piece of material (140a) comprises a cup portion (162) comprising a first zone (400) having a first stiffness and a second zone (410) having a second stiffness,
the first zone (400) comprises a perimeter boundary,
the second zone is disposed around at least a portion of the perimeter boundary (412) of the first zone (400),
the plurality of first thread lines extend through the first zone (400), and
the plurality of second thread lines extend tangential to the perimeter boundary of the first zone (400).

11. The article of apparel (100) of any one of the preceding claims, further comprising a third piece of material (140c) comprising a third perimeter edge (142c), and a second seam along at least a portion

of the first perimeter edge (142a) and the third perimeter edge (142c) that joins the first piece of material (140a) to the third piece of material (140c) and wherein preferably the article of apparel comprises a pair of pants, and wherein the first piece of material (140a) is configured to wrap around a knee of a wearer and/or wherein preferably the article of apparel comprises a shirt, and wherein the first piece of material (140a) is configured to wrap around an elbow of a wearer.

12. A method of making an article of apparel, the method comprising:

forming a first piece of material (140a) by a method comprising:

winding a continuous thread (302) around a plurality of anchor points (390) on a support plate (630) to form a thread layer (300), the continuous thread comprising a plurality of thread lines (304) with each thread line extending between two respective anchor points (390);
bonding the continuous thread (302) at points of intersection between two or more of the thread lines (304); and
after bonding the continuous thread (302), cutting the thread layer to remove the first piece of material (140a) comprising a thread pattern (120) comprising the thread layer (300) from the support plate (630); and

attaching the first piece of material (140a) to one or more additional pieces of material (140) to form the article of apparel (100).

13. The method of claim 12, wherein attaching the first piece of material (140a) to the one or more additional pieces of material (140) comprises seaming the first piece of material (140a) to the one or more of the additional pieces of material (140).

14. The method of claim 12 or 13, wherein the one or more additional pieces of material (140) comprises a second piece of material (140b) made by a method comprising:

winding a second continuous thread around a plurality of anchor points (390) on a second support plate to form a second thread layer (320), the second continuous thread comprising a plurality of second thread lines with each thread line extending between two respective anchor points (390);
bonding the second continuous thread at points of intersection between two or more of the thread lines; and

after bonding the second continuous thread, cutting the second thread layer to remove a second piece of material comprising a second thread pattern comprising the second thread layer from the second support plate.

15. The method of claim 12, 13 or 14, further comprising:

placing the article of apparel (100) over a mannequin; and
heating the article of apparel on the mannequin.

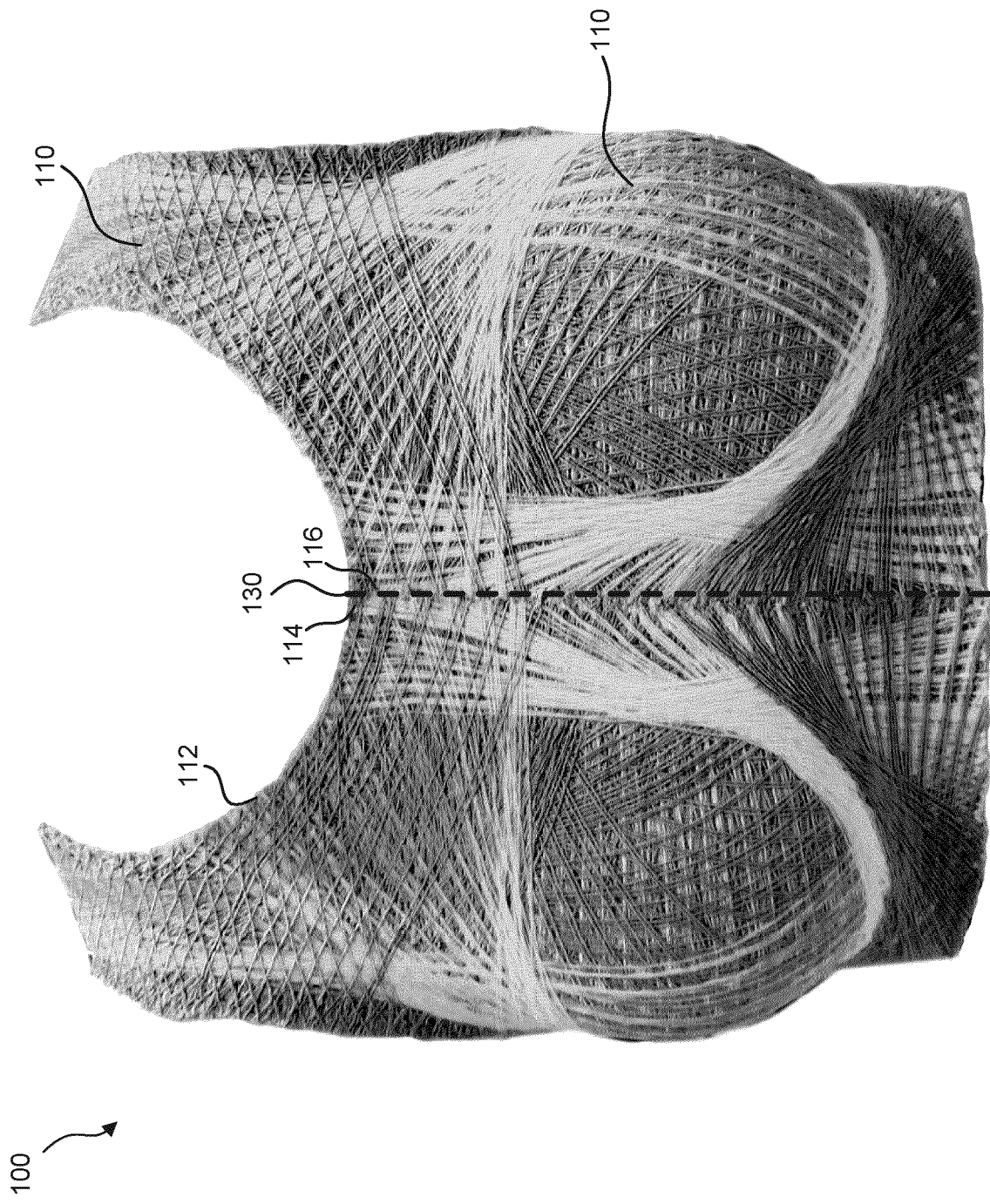


FIG. 1

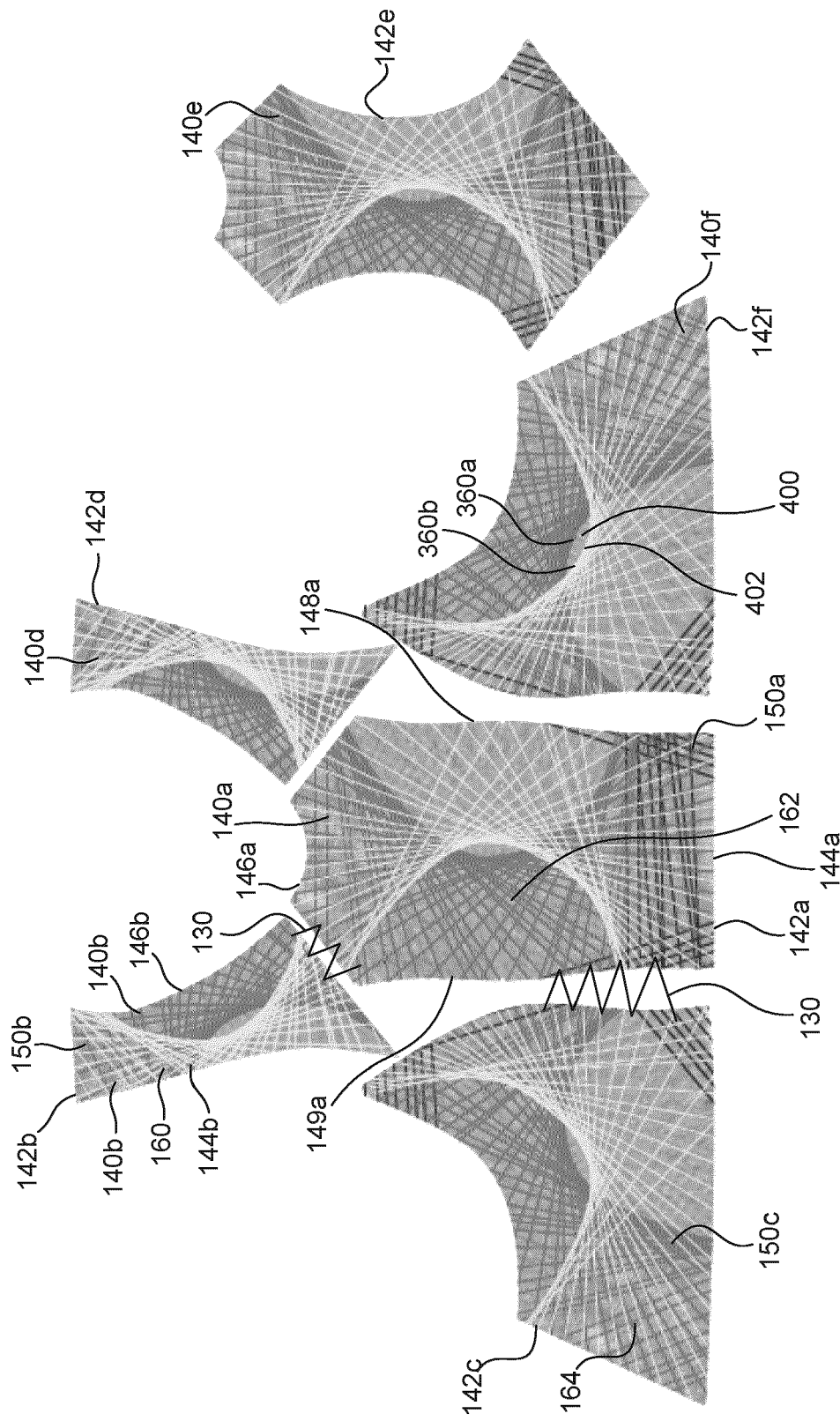


FIG. 2

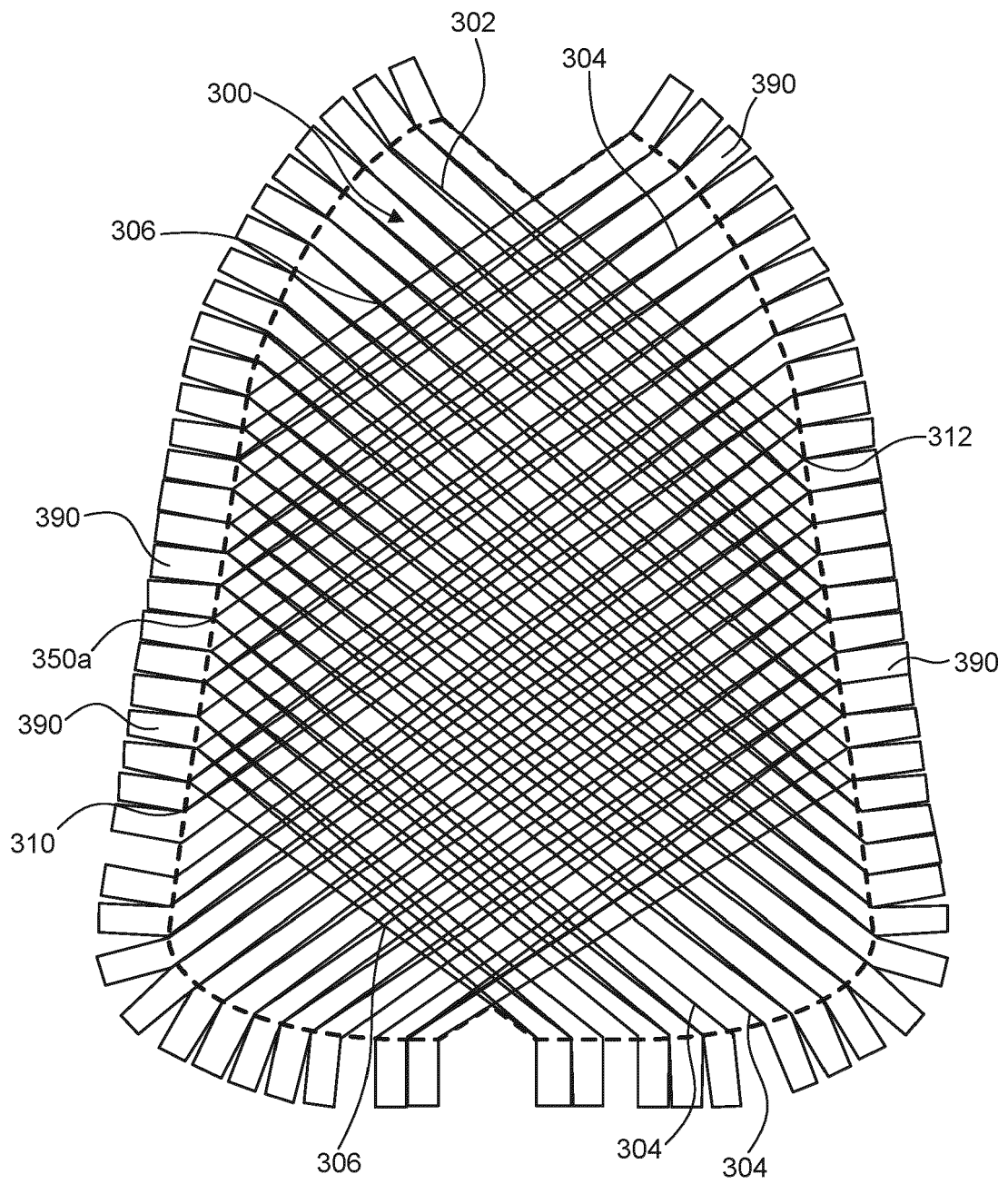


FIG. 3A

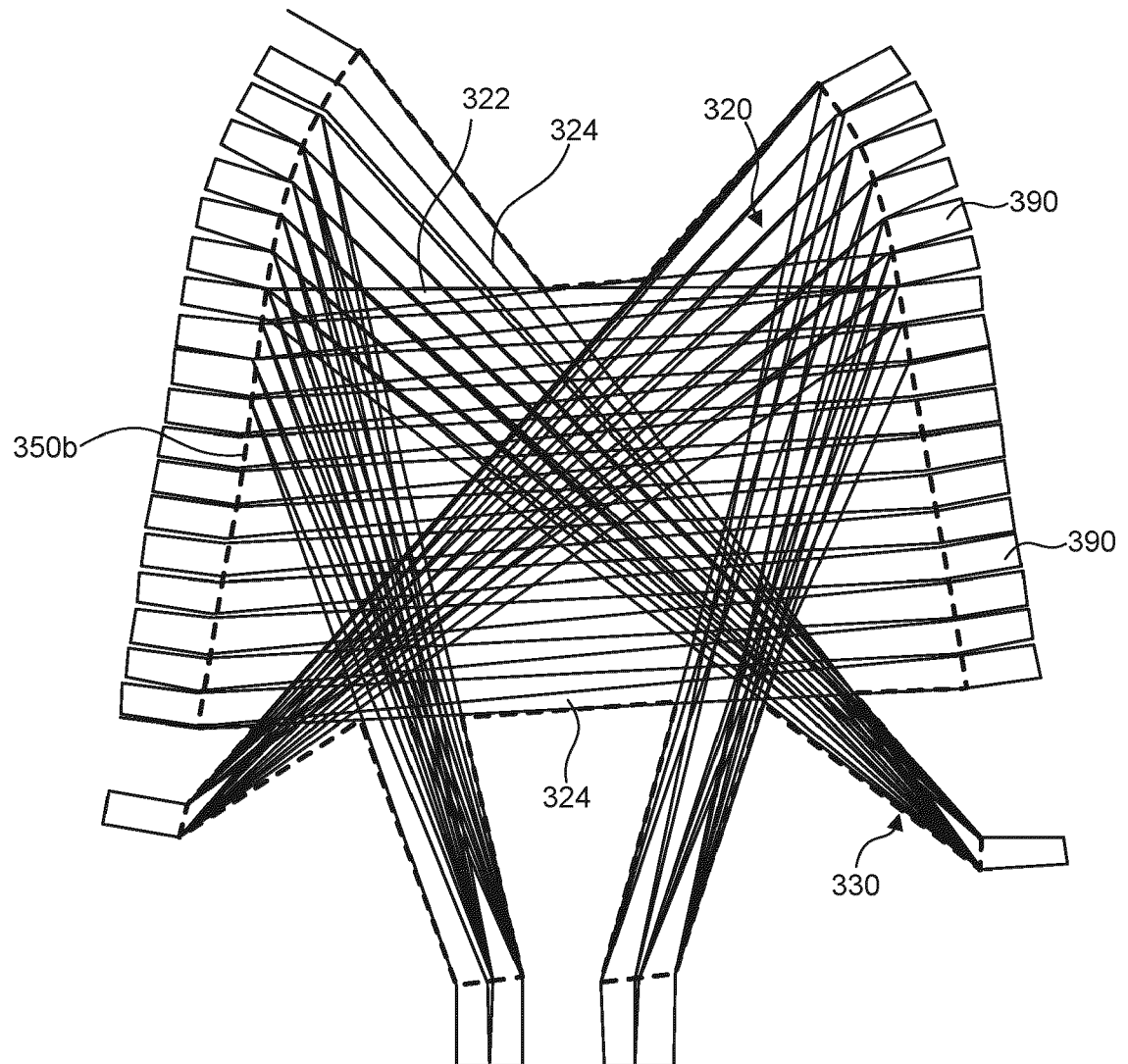


FIG. 3B

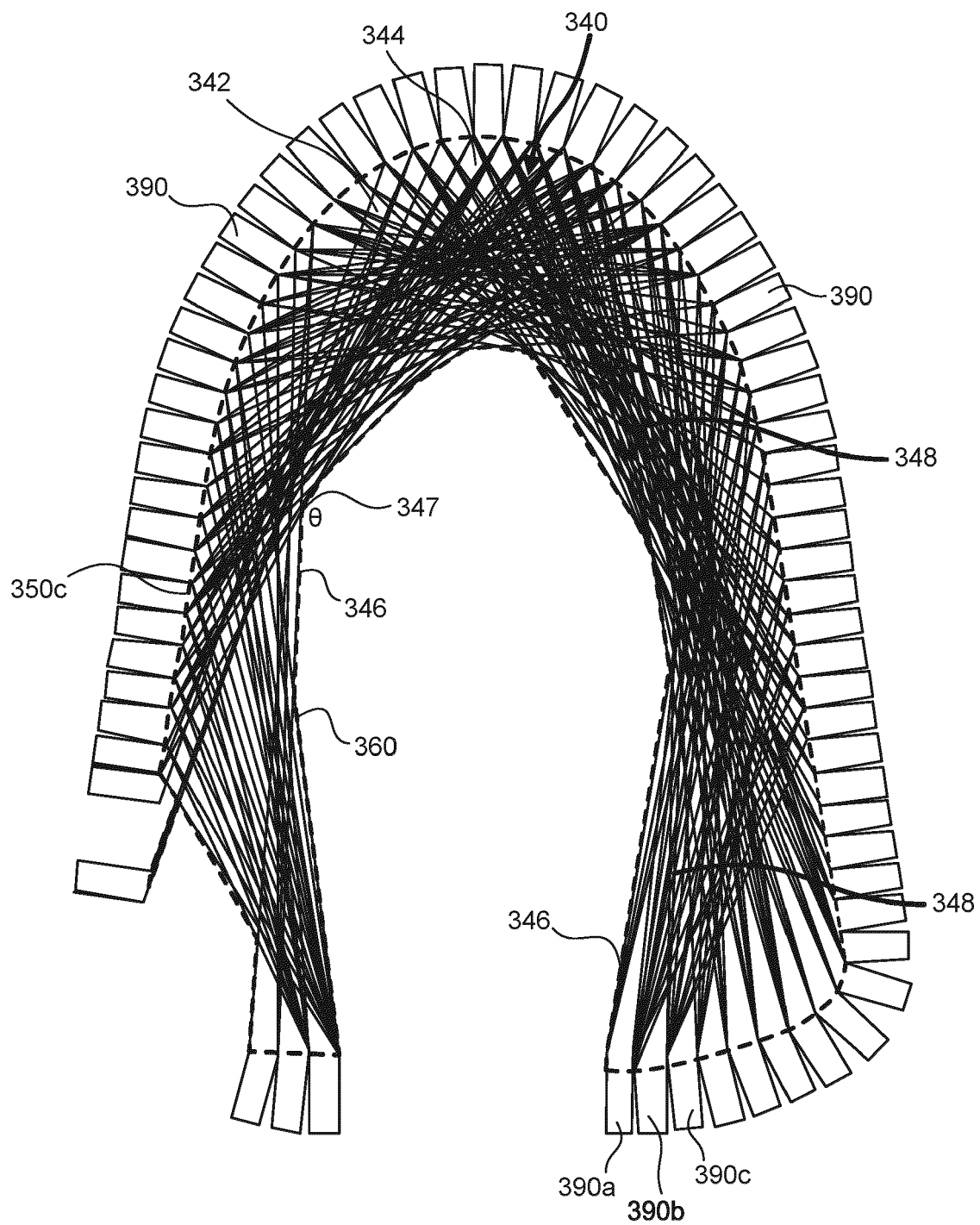


FIG. 3C

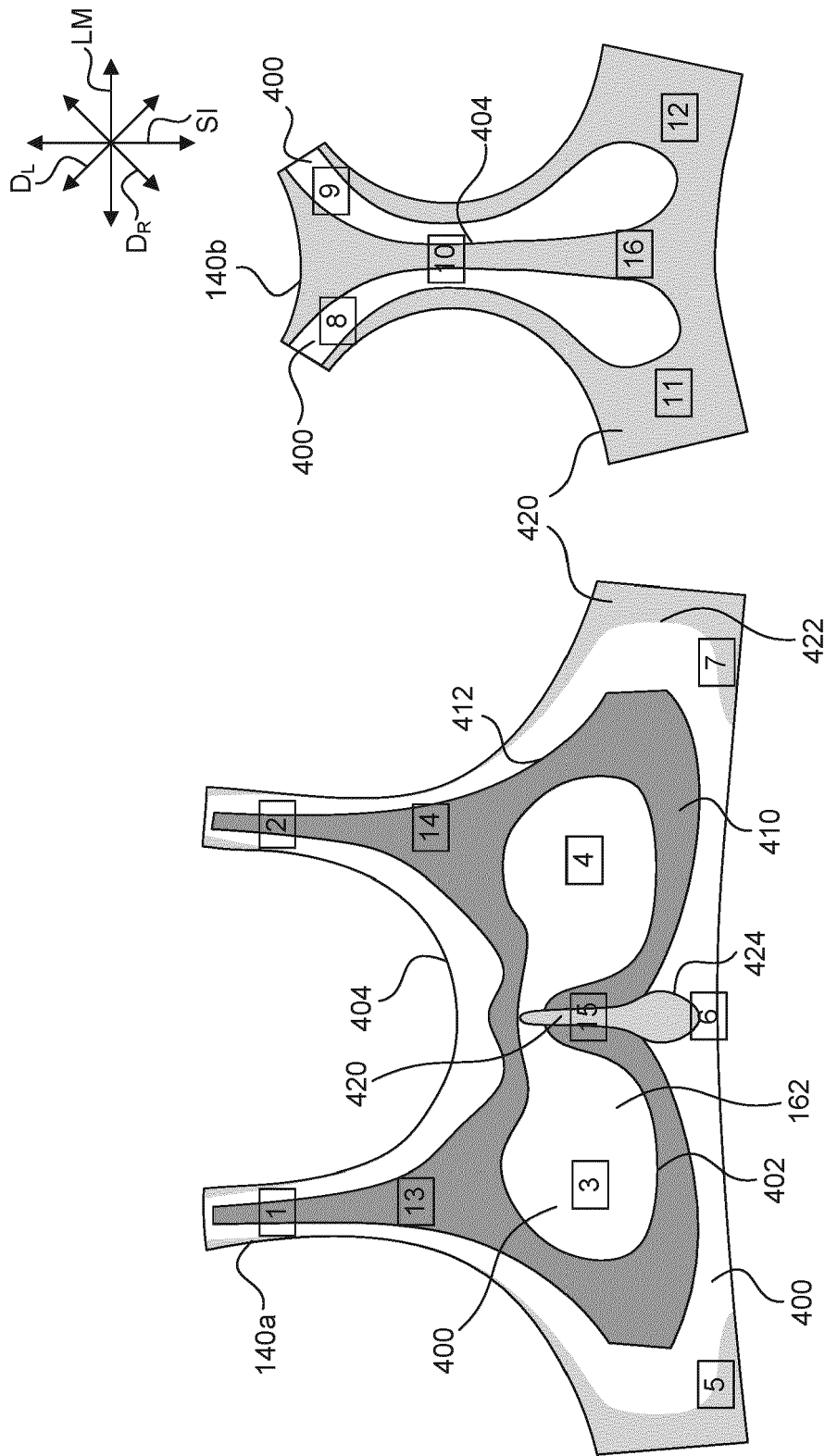
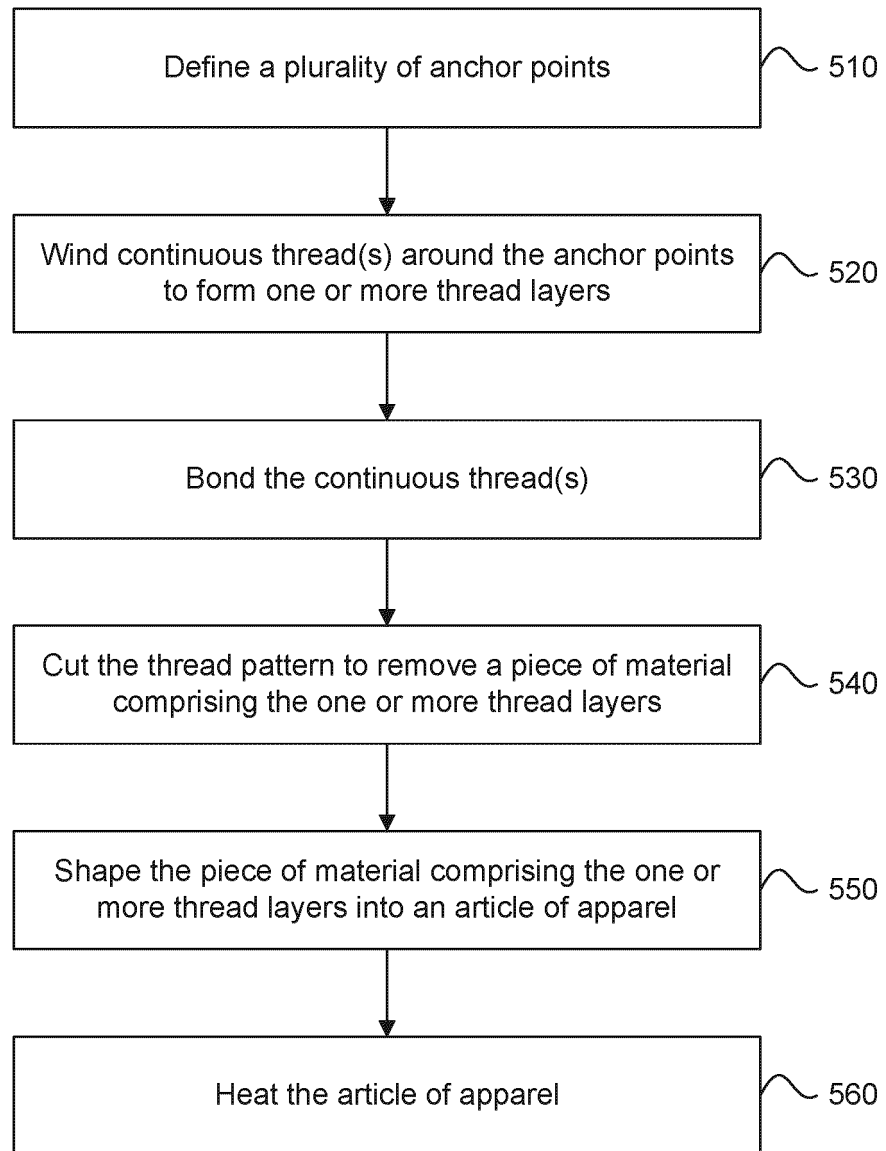


FIG. 4

500**FIG. 5**

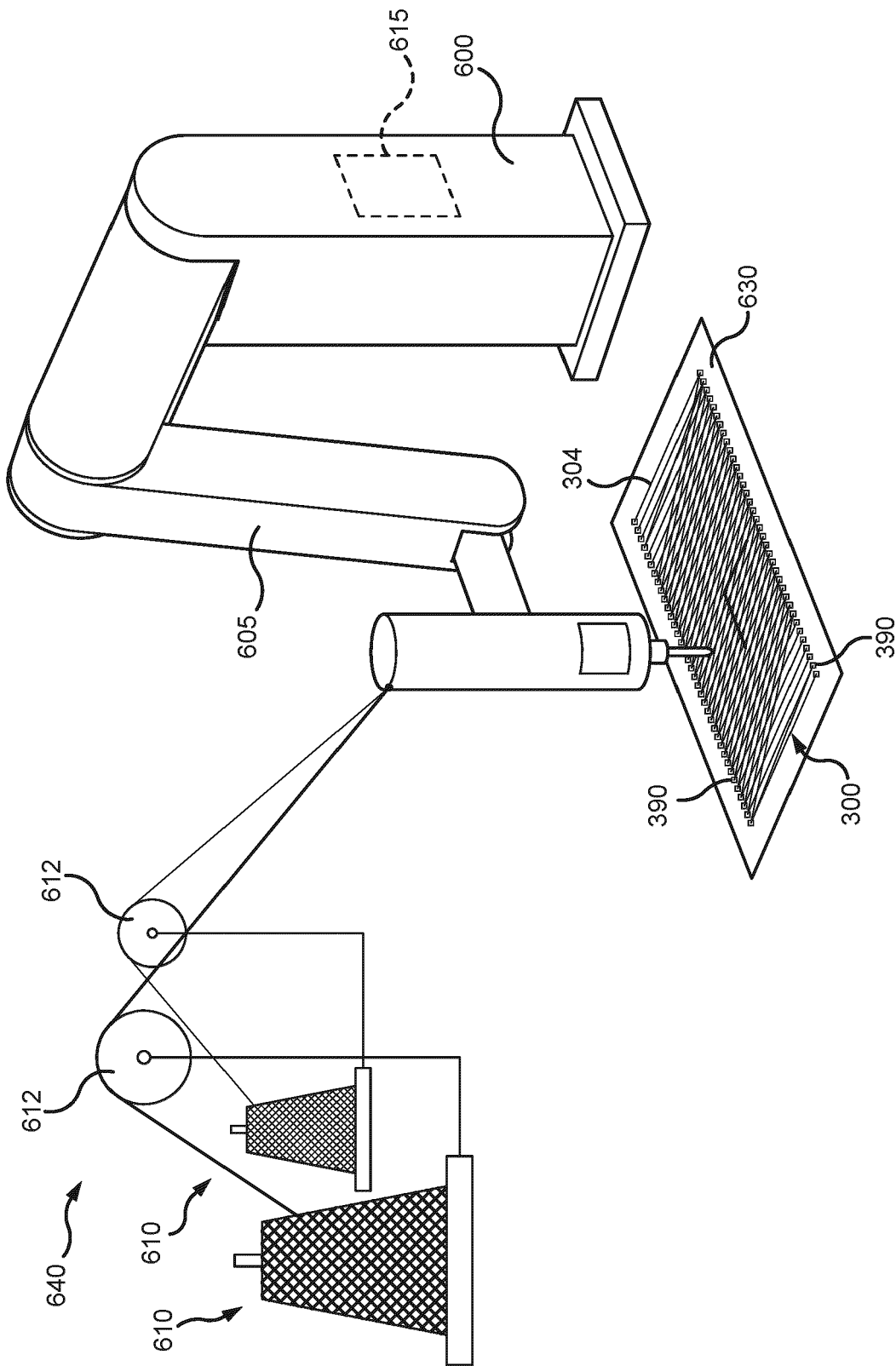


FIG. 6

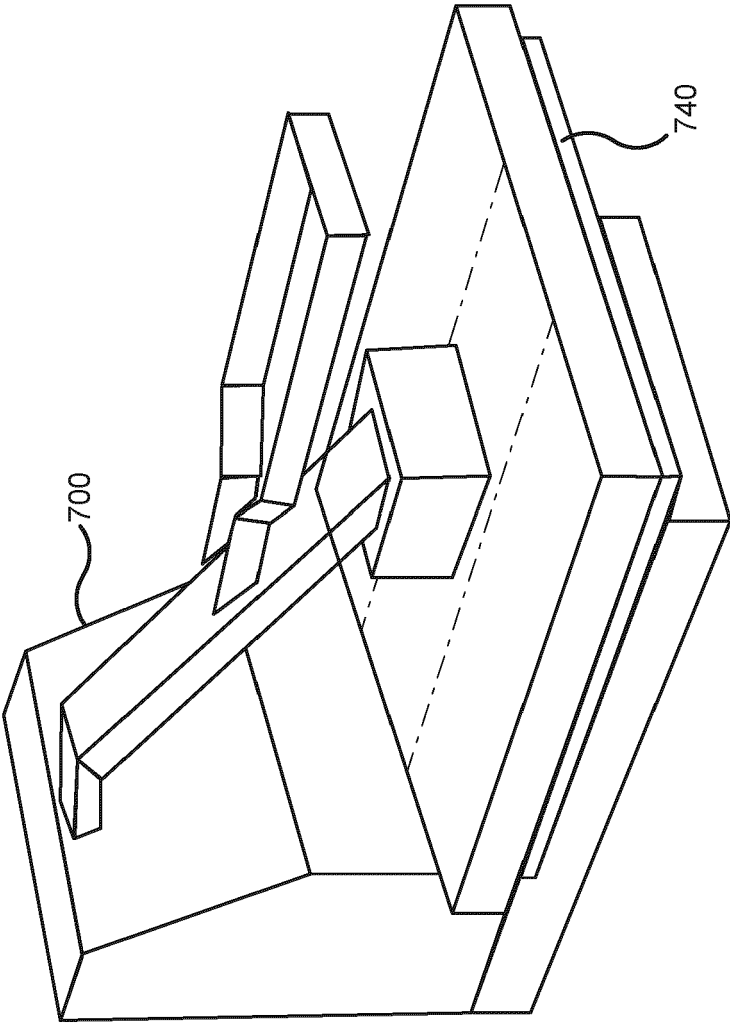


FIG. 7

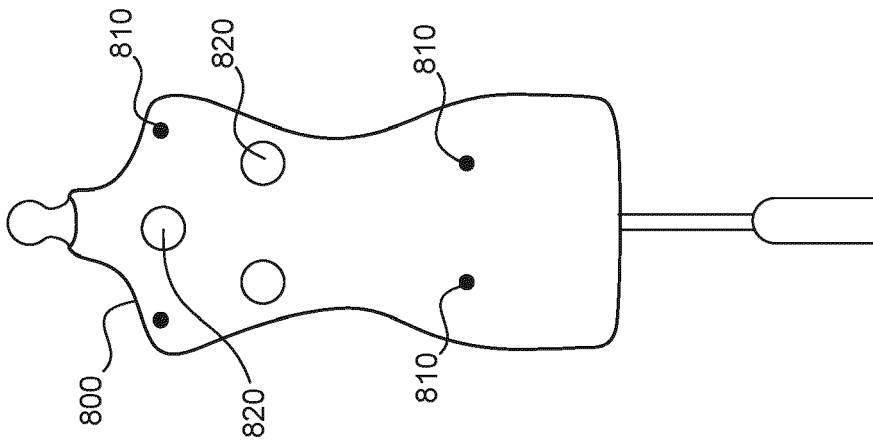


FIG. 8

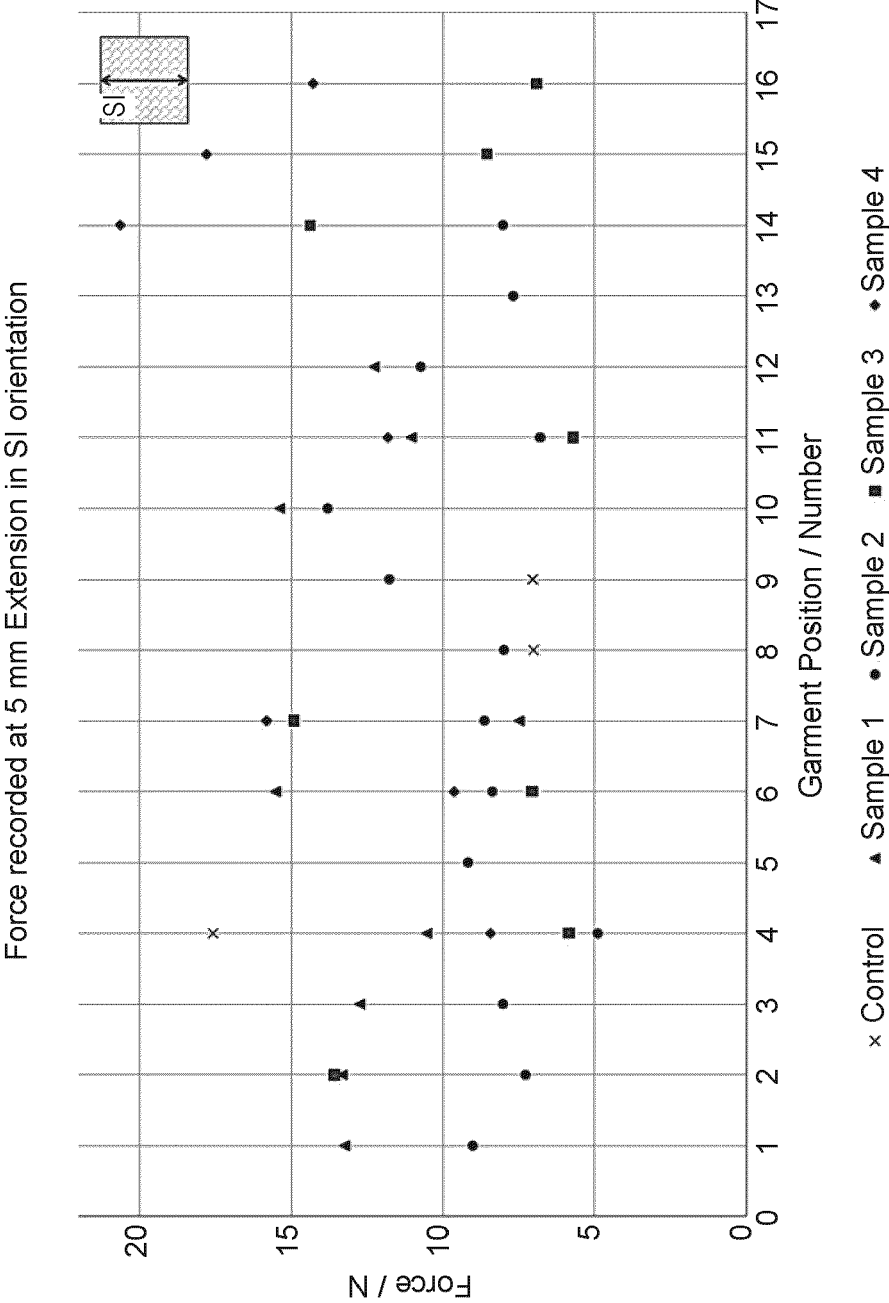


FIG. 9

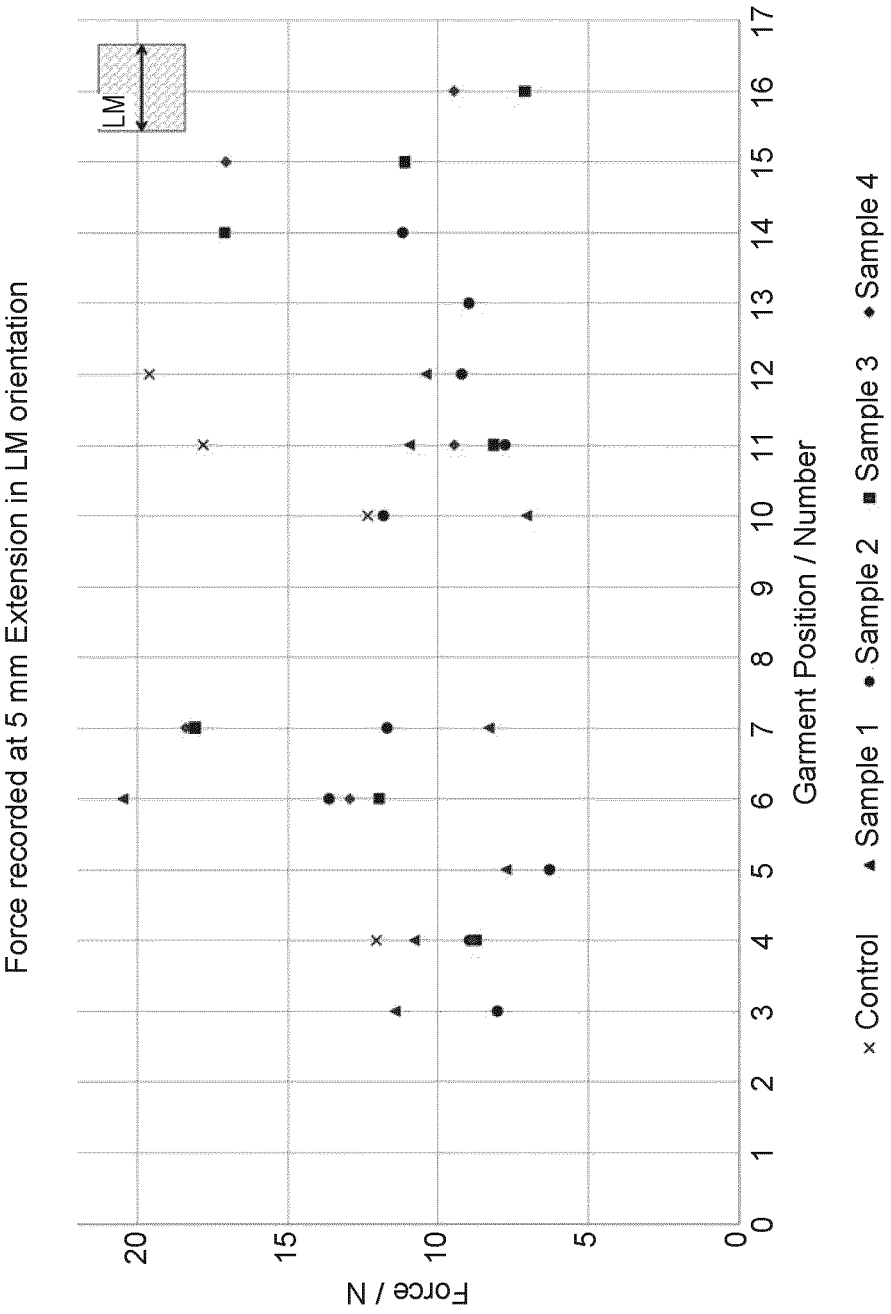


FIG. 10

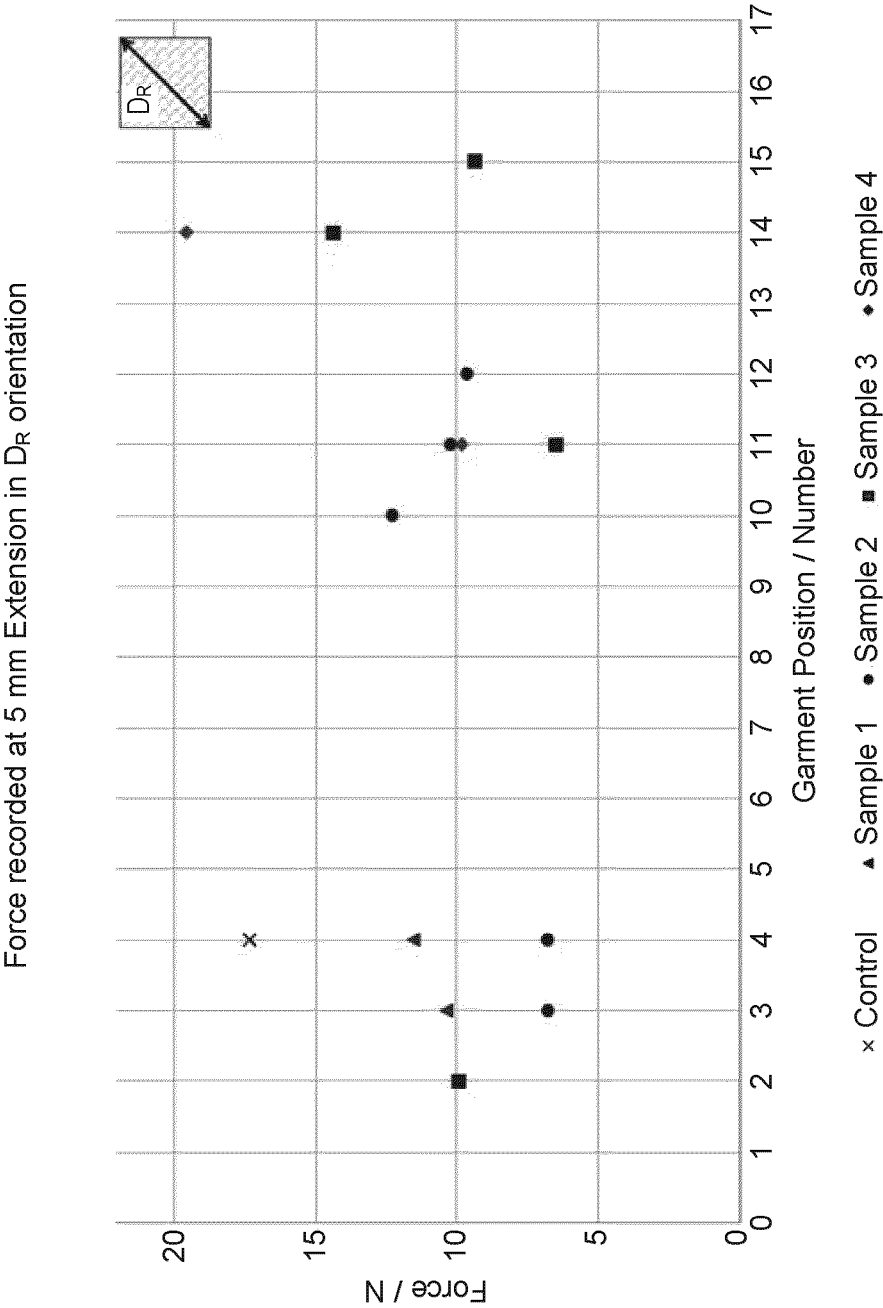


FIG. 11

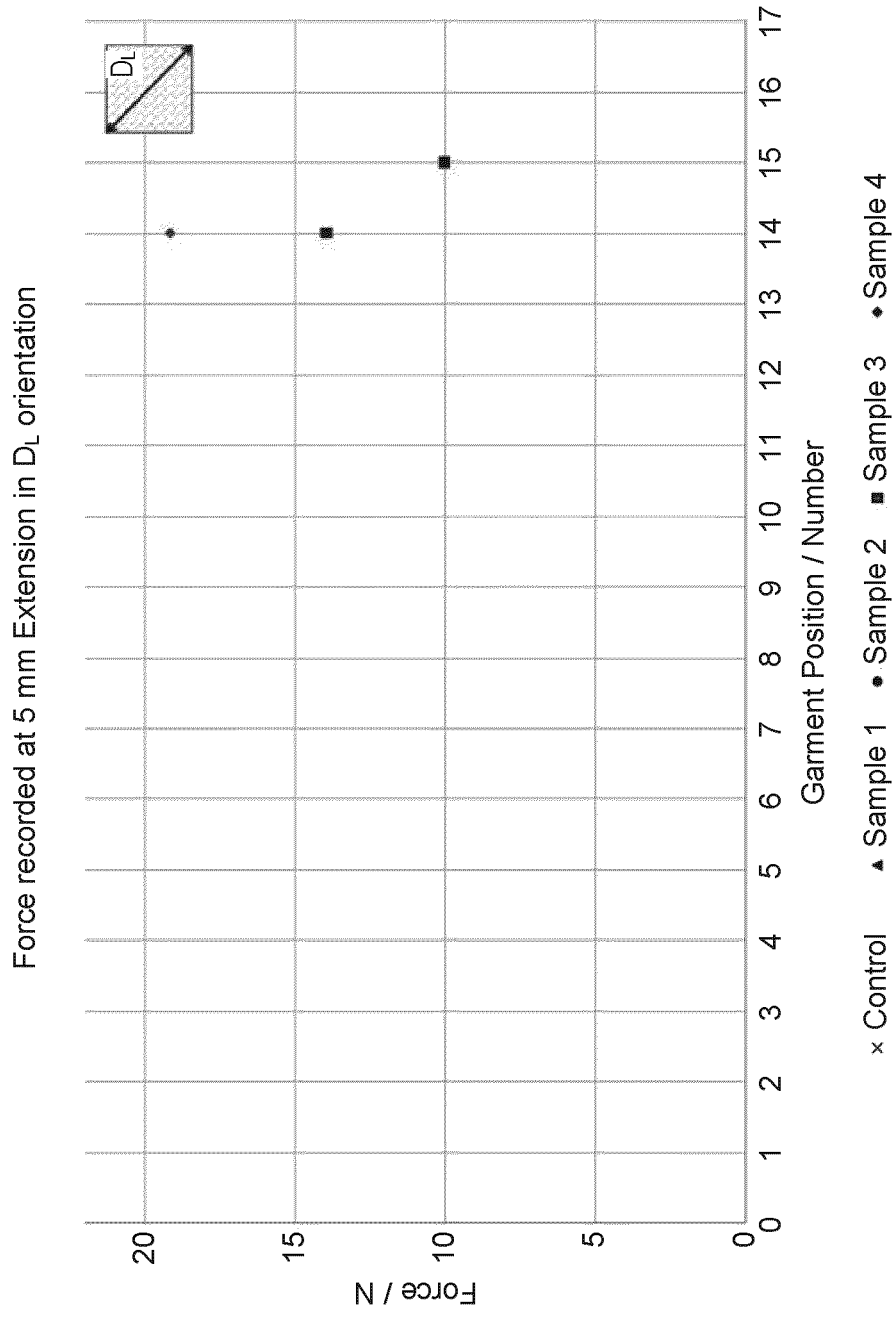


FIG. 12

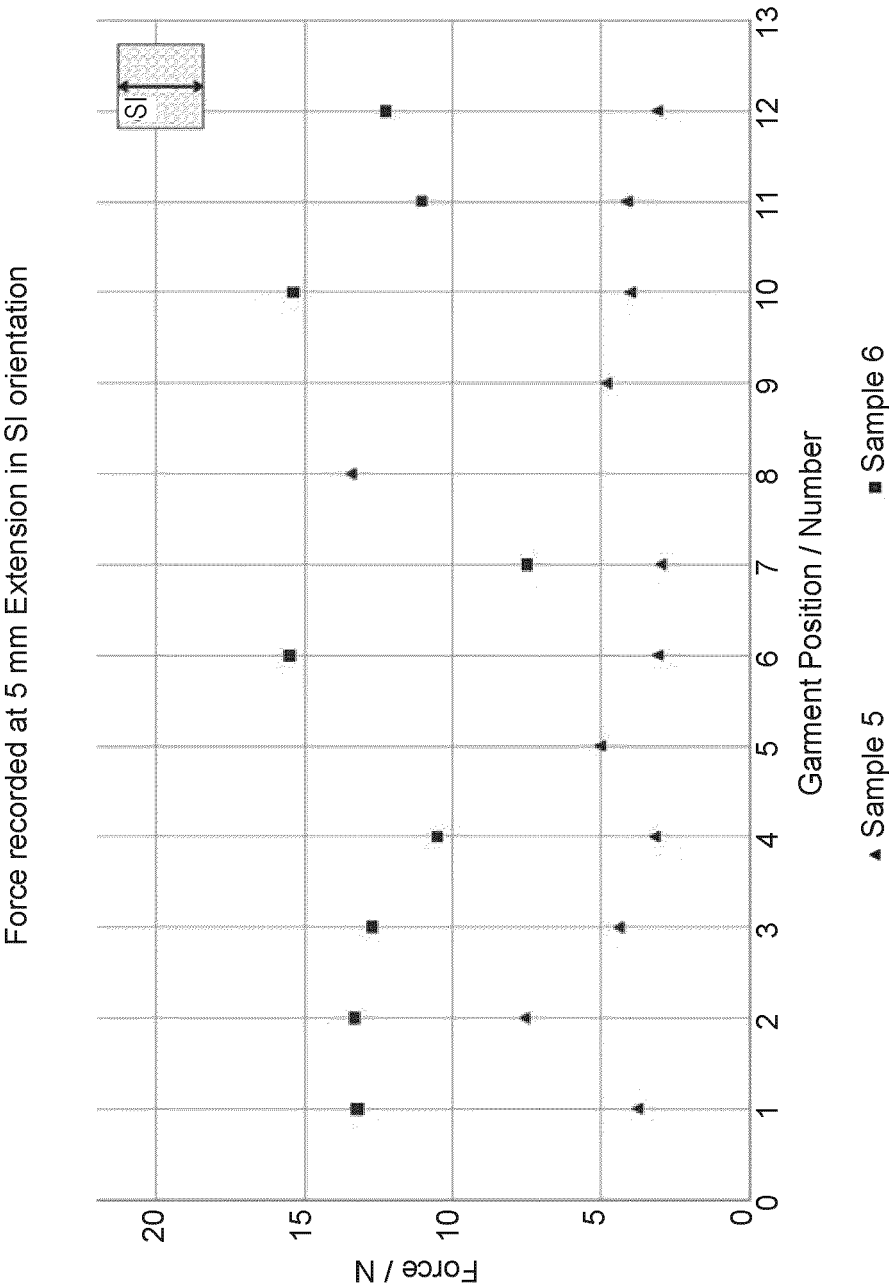


FIG. 13

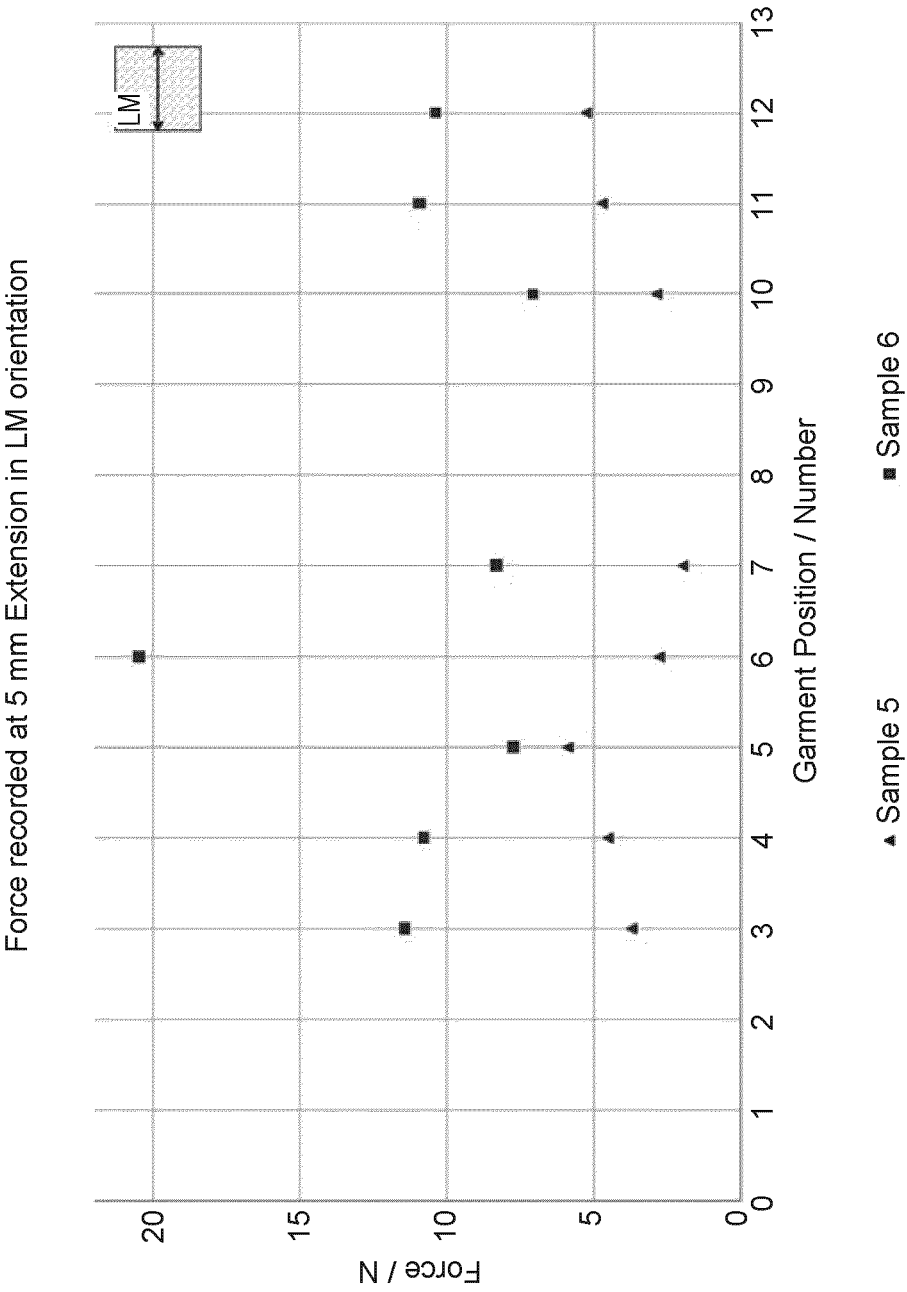


FIG. 14

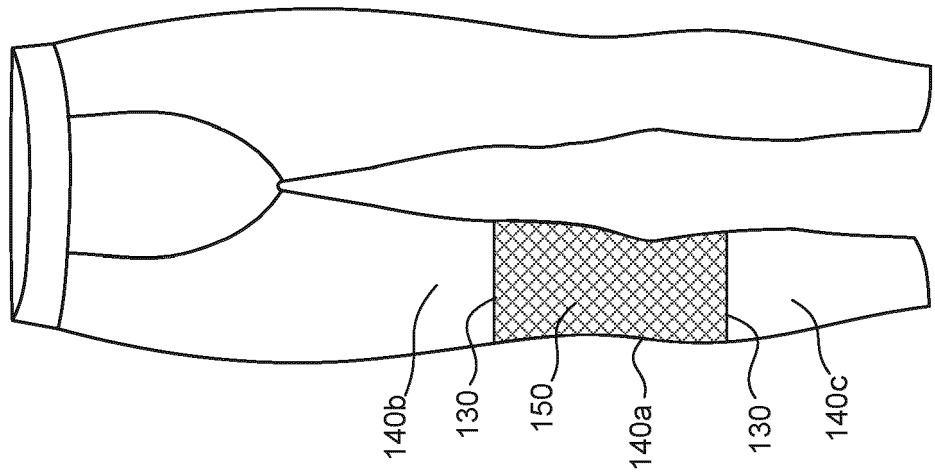


FIG. 16

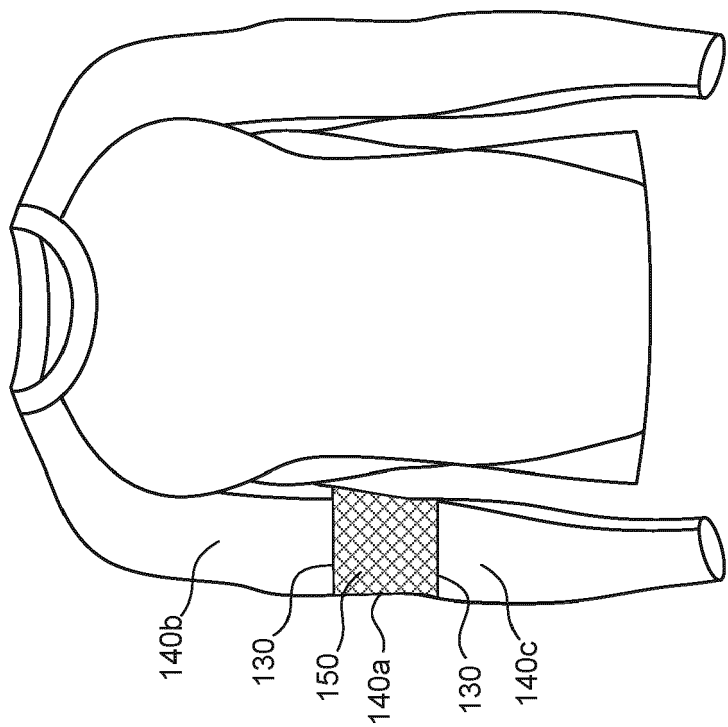


FIG. 15



EUROPEAN SEARCH REPORT

Application Number

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			A41C D04H A41D
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 28 June 2024	Examiner van Voorst, Frank
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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