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(54) APPAREL COMPRISING A WOUND THREAD LAYER AND METHODS OF MAKING THE SAME

(57) Articles of apparel (100,600) and methods of making articles of apparel comprising a base layer (110) and a thread layer (120,130,140,200,220,240,620,630,640,650) defined by a thread (202,222,242) having a plurality of thread lines (204,224,244) crossing over each other at points of overlap (247) between two or more of the thread lines. Each of the thread lines extends continuously across the thread layer. Each of the thread lines is directly bonded to a surface of the base layer along at least a portion of a length of the thread line. In some embodiments, the base layer and the thread layer can define a chamber or pocket for an article of apparel.

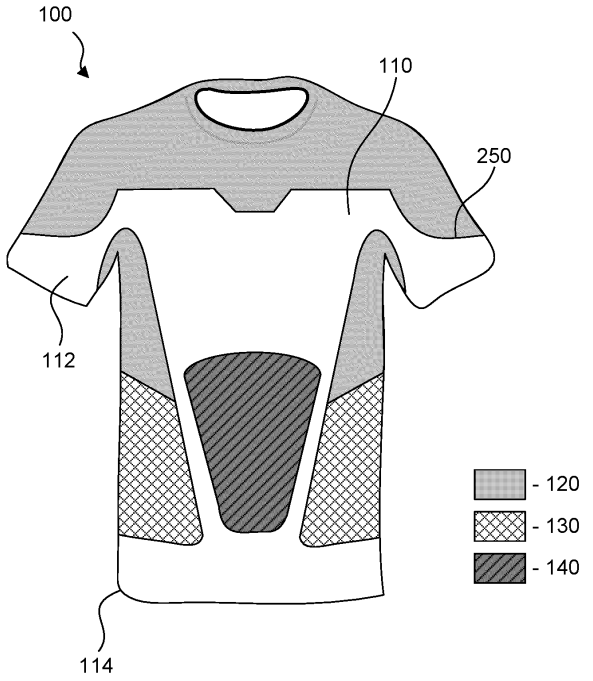

FIG. 1A

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Description

FIELD

[0001] The described embodiments generally relate to apparel and methods of making apparel. In particular, described embodiments relate to apparel comprising a layer made by winding one or more continuous threads around anchor points.

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 claimed invention is defined by the independent claims. Further embodiments of the claimed invention are described in the dependent claims.

[0004] Any "aspect", "embodiment" or "example" as well as any possible or preferable configuration described in the following and not falling within the scope of the claimed invention thus defined shall therefore be interpreted as background information not forming part of the claimed invention, but being provided to facilitate the understanding of the claimed invention.

[0005] A first embodiment (1) of the present application is directed to an article of apparel comprising a base layer; and a thread layer defined by a thread, the thread layer comprising a plurality of thread lines crossing over each other at points of overlap between two or more of the thread lines, wherein each of the thread lines extends continuously across the thread layer, wherein the thread lines are not woven or knitted threads, wherein the thread lines not embroidered threads stitched to the to the base layer, and wherein each of the thread lines is directly bonded to a surface of the base layer along at least a portion of a length of the thread line.

[0006] In a second embodiment (2), the thread layer according to the first embodiment (1) occupies a surface area defined by a thread border on the surface of the base layer, and each thread line comprises a first end disposed at the thread border and a second end disposed at the thread border.

[0007] In a third embodiment (3), the first end and the second end of each of the thread lines according to the second embodiment (2) are directly bonded to the surface of the base layer.

[0008] In a fourth embodiment (4), the thread layer according to any one of embodiments (1) - (3) occupies a surface area defined by a thread border on the surface of the base layer, and the base layer comprises a perimeter edge surrounding the thread border.

[0009] In a fifth embodiment (5), the base layer according to any one of embodiments (1) - (4) comprises a first piece of material and a second piece material adjacent to the first piece of material, and one or more of the thread lines extends across and is directly bonded to both the first piece of material and the second piece of material.

[0010] In a sixth embodiment (6), the article of apparel according to the fifth embodiment (5) further comprises a gap between the first piece of material and the second piece material, wherein the one or more of the thread lines extends across the gap.

[0011] In a seventh embodiment (7), the base layer according to any one of embodiments (1) - (4) comprises a first piece of material and a second piece material joined together at a seam, and one or more of the thread lines extends across the seam and is directly bonded to both the first piece of material and the second piece of material.

[0012] In an eighth embodiment (8), each the thread lines according to any one of embodiments (1) - (7) applies a compressive force on the surface of the base layer, the compressive force being applied along an axis extending from a first end to a second end of the thread line.

[0013] In a ninth embodiment (9), the article of apparel according to any one of embodiments (1) - (8) further comprises a second thread layer defined by a second thread, the second thread layer comprising a plurality of second thread lines crossing over each other at points of overlap between two or more of the second thread lines, wherein each of the second thread lines extends continuously across the second thread layer, wherein the second thread lines are not woven or knitted threads, wherein the second thread lines not embroidered threads stitched to the base layer, and wherein each of the second thread lines is directly bonded to a surface of the base layer along at least a portion of a length of the second thread line.

[0014] In a tenth embodiment (10), each of the thread lines according to any one of embodiments (1) - (8) are directly bonded to the surface of the base layer at a perimeter of the thread layer to define a pocket between the thread layer and the base layer.

[0015] In an eleventh embodiment (11), the article of apparel according to the tenth embodiment (10) further comprises an insert disposed within the pocket.

[0016] In a twelfth embodiment (12), the insert according to the eleventh embodiment (11) comprises a shin guard.

[0017] In a thirteenth embodiment (13), the base layer according to any one of embodiments (1) - (12) comprises a foam material.

[0018] In a fourteenth embodiment (14), the article of

apparel according to any one of embodiments (1) - (13) is provided and the base layer is a first base layer disposed below the thread layer, the article of apparel further comprises a second base layer disposed above the thread layer, and each of the thread lines is directly bonded to a surface of the second base layer along at least a portion of a length of the thread line.

[0019] In a fifteenth embodiment (15), the base layer according to the fourteenth embodiment (14) comprises a foam material and the second base layer according to the fourteenth embodiment (14) comprises a foam material.

[0020] A sixteenth embodiment (16) of the present application is directed to an article of apparel comprising a first thread layer comprising a first thread border and a first thread defining a plurality of first thread lines each extending from a first side of the first thread border to a second side of the first thread border and crossing over each other at points of overlap between two or more of the first thread lines; a second thread layer disposed over the first thread layer and comprising a second thread border and a second thread defining a plurality of second thread lines each extending from a first side of the second thread border to a second side of the second thread border and crossing over each other at points of overlap between two or more of the second thread lines; and a base layer disposed between the first thread layer and the second thread layer; wherein the first thread layer, the second layer, and the base layer are coupled together to form a chamber occupying a volume between the first thread layer and the second thread layer.

[0021] In a seventeenth embodiment (17), a portion of the base layer according to the sixteenth embodiment (16) defines a portion of the chamber.

[0022] In an eighteenth embodiment (18) the base layer, the first thread layer, and the second thread layer according to the sixteenth embodiment (16) or the seventeenth embodiment (17) are attached at a seam located at an edge of the chamber.

[0023] In a nineteenth embodiment (19) the plurality of first thread lines according to any one of embodiments (16) - (18) are directly bonded to a surface of the base layer.

[0024] In a twentieth embodiment (20), the article of apparel according to any one of embodiments (16) - (19) is provided and the base layer is a first base layer, and the article of apparel further comprises a second base layer disposed between the first base layer and the second thread layer, and a portion of the second base layer defines a portion of the chamber.

[0025] In a twenty-first embodiment (21), the first base layer, the second base layer, the first thread layer, and the second thread layer according to the twentieth embodiment (20) are attached at a seam located at an edge of the chamber.

[0026] In a twenty-second embodiment (22), the plurality of second thread lines according to the twentieth embodiment (20) or the twenty-first embodiment (21) are directly bonded to a surface of the second base layer.

[0027] In a twenty-third embodiment (23), the chamber according to any one of embodiments (16) - (22) is filled with insulation.

[0028] In a twenty-fourth embodiment (24), the chamber according to any one of embodiments (16) - (22) is filled with an insert.

[0029] In a twenty-firth embodiment (25), the chamber according to any one of embodiments (16) - (24) is a tubular chamber.

[0030] In a twenty-sixth embodiment (26), the article of apparel according to the twenty-fifth embodiment (25) comprises a pant leg, an arm sleeve, a knee sleeve, a waistband, an elbow sleeve, an ankle sleeve, a wrist sleeve, a collar, a double panel shirt, or a fully-fashioned tubular fabric.

[0031] A twenty-seventh embodiment (27) of the present application is directed to a method of making an article of apparel, the 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; and injecting foam around at least a portion of the thread layer.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0032]

FIGS. 1A and 1B shows an article of apparel according to some embodiments.

FIGS. 2A-2C show thread layers according to some embodiments.

FIG. 3 is an exemplary flowchart for methods according to some embodiments

FIG. 4 shows a machine for producing thread layers according to some embodiments.

FIG. 5 shows a heat press according to some embodiments.

FIG. 6 shows an article of apparel comprising a plurality of thread layers and a plurality of material pieces according to some embodiments.

FIG. 7 shows an article of apparel comprising a plurality of thread layers and a plurality of material pieces according to some embodiments.

FIG. 8 shows an article of apparel comprising a plurality of thread layers according to some embodiments.

FIG. 9 shows an article of apparel comprising a

plurality of thread layers according to some embodiments.

FIG. 10 shows an article of apparel comprising a thread layer according to some embodiments.

FIG. 11 shows an article of apparel comprising a thread layer defining a pocket according to some embodiments.

FIG. 12 shows a layered structure for articles apparel according to some embodiments.

FIG. 13 shows a cross-sectional view of a layered structure for articles of apparel according to some embodiments.

FIG. 14A shows a shaped material comprising a thread pattern according to some embodiments.

FIG. 14B is a cross-sectional view of FIG. 14A along the line B - B'.

FIG. 15 shows a mold assembly according to some embodiments.

FIG. 16 shows a thread layer comprising molded parts according to some embodiments.

FIG. 17 shows a mold assembly according to some embodiments.

FIG. 18 shows a thread layer comprising a molded part according to some embodiments.

FIG. 19 shows a layered structure for articles of apparel according to some embodiments.

FIG. 20A shows a thread layer on a stretched base layer according to some embodiments.

FIG. 20B shows the thread layer and base layer of FIG. 20A in a relaxed state.

FIG. 21A shows a cross-sectional view of FIG. 20A along line A - A'.

FIG. 21B shows a cross-sectional view of FIG. 20B along line B - B'.

FIG. 22A shows a thread layer on a stretched base layer according to some embodiments.

FIG. 22B shows the thread layer and base layer of FIG. 22A in a relaxed state.

FIG. 23A shows a cross-sectional view of FIG. 22A along line A - A'.

FIG. 23B shows a cross-sectional view of FIG. 22B along line B - B'.

DETAILED DESCRIPTION

[0033] 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.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] The articles of apparel described herein can be made by, or can comprise a layer 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.

[0038] 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 layer or 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.

[0039] 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 a thread pattern, and therefore provide different characteristics on the article of apparel.

[0040] 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).

[0041] In some embodiments, different thread layers or thread patterns can provide a first degree of a characteristic in one region of an article of apparel and a second degree of that characteristic in a second region of the article of apparel. In some embodiments, different thread layers or thread patterns can provide targeted characteristics to different regions of an article of apparel. In some embodiments, different thread layers or thread patterns can comprise thread lines oriented in different directions to provide targeted characteristics to different regions of an article of apparel.

[0042] 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.

[0043] In some embodiments, a thread layer or thread pattern can be bonded to the surface of one or more base layers. In some embodiments, a thread layer or thread pattern can be directly bonded to the surface of one or more base layers. In such embodiments, thread lines of the thread layer or thread pattern can be directly bonded to a surface of the base layer. Direct bonding to one or more base layers can impart unique characteristics on the base layer(s), and therefore the article of apparel. For example, direct bonding of a thread layer or thread pattern can impart desired mechanical or aesthetic properties to all or a portion of the article of apparel. In some embodiments, the direct bonding of a thread layer or thread pattern wound under tension can impart a compressive force on the surface of the base layer(s) once the thread pattern or thread layer is removed from anchor points. The compressive force can impart desired mechanical or aesthetic properties. For example, the compressive force can impart a desired shape to the article of apparel.

[0044] As used herein, two components (for example, a thread and a fabric) described as "bonded to" each other means the first component and second component are bonded to each other, either by direct contact and/or bonding between the two components or via an adhesive or bonding layer. Two components (for example, a thread and a fabric) described as "directly bonded to" each other means the two components are directly bonded to each other via a material of the first component, a material of the second component, or both. For example, where heat and/or pressure is utilized to directly bond the polymeric material of a thread to a base layer, the thread is directly bonded to the base layer via the polymeric material of thread. In such embodiments, the polymeric material can be thermally fused to the base layer.

[0045] In some embodiments, a thread layer or thread pattern as described herein can form a pocket or cham-

ber on an article of apparel. In such embodiments, the pocket or chamber can be filled with an insert or additional material, such as insulation.

[0046] In some embodiments, article of apparel as described herein can comprise one or more parts molded onto a thread layer or thread pattern. In some embodiments, the molded part(s) can encase all or a portion of a thread layer or thread pattern. In such embodiments, all or a portion of a thread layer or thread pattern can be embedded within the molded part(s). In some embodiments, the molded part(s) can comprise a concave or convex surface that provides a corresponding concave or convex shape to the thread layer or thread pattern. In some embodiments, the concave or convex shape can help shape an article of apparel to fit a wearer's body.

[0047] FIG. 1 illustrates an article of apparel 100 according to some embodiments. Apparel 100 can comprise one or more base layers 110 and one or more thread layers, for example, thread layers 120, 130, and 140. Thread layers 120, 130, 140 can be any exemplary thread layer described herein, for example, thread layers 200, 220, and 240. In some embodiments, a thread layer, for example thread layer 120, can comprise a plurality of thread layers (for example thread layer 200 and thread layer 220). In such embodiments, the thread layer can be referred to as a thread pattern comprising a plurality of thread layers.

[0048] Each thread layer 120, 130, 140 (or a thread pattern) can be defined by one or more threads comprising a plurality of thread lines crossing over each other at points of overlap between two or more of the thread lines. Each thread line of a thread layer extends continuously across the thread layer (or thread pattern). Thread lines extending continuously across the thread layer (or thread pattern) are not woven or knitted threads. Similarly, thread lines extending continuously across the thread layer (or thread pattern) are not embroidered threads stitched to a base layer 110. Rather, the thread lines, and therefore the thread layer(s) are formed by winding thread around anchor points as described herein.

[0049] In some embodiments, thread lines extending continuously across the thread layer (or thread pattern) can extend continuously without forming a knitted structure or a woven structure between opposing ends of the thread lines. In some embodiments, thread lines extending continuously across the thread layer (or thread pattern) can extend continuously without forming a knitted structure or a woven structure along a distance greater than or equal to at least 90% of the length of the thread lines measured between opposing ends of the thread lines. In some embodiments, thread lines extending continuously across the thread layer (or thread pattern) can extend continuously without forming an embroidered structure between opposing ends of the thread lines. In some embodiments, thread lines extending continuously across the thread layer (or thread pattern) can extend continuously without forming an embroidered structure along a distance greater than or equal to at least 90% of the length of the thread lines measured between opposing ends of the thread lines.

[0050] In some embodiments, thread lines of thread layer(s) 120, 130, 140 can be bonded to a surface 112 of a base layer 110 along at least a portion of a length of the thread line. In some embodiments, thread lines of thread layer(s) 120, 130, 140 can be directly bonded to a surface 112 of a base layer 110 along at least a portion of a length of the thread line. In some embodiments, surface 112 can be an exterior surface of base layer 110 facing away from a wearer's body during use. In some embodiments, surface 112 can be an interior surface of base layer 110 facing towards a wearer's body during use. In some embodiments, article of apparel 100 can comprise one or more thread layers bonded (or directly bonded) to an exterior surface of a base layer 110 and one or more thread layers bonded (or directly bonded) to an interior surface of the base layer 110.

[0051] Thread layers 120, 130, 140 can be bonded to different regions on surface 112 of a base layer 110. Article of apparel 100 can comprise any number of thread layers (or thread patterns) bonded to different regions of the article of apparel 100. For example, FIG. 6 illustrates an article of apparel 600 comprising a first thread layer 620 bonded to a first region on article of apparel 600, a second thread layer 630 bonded to a second region on article of apparel 600, a third thread layer 640 bonded to a third region on article of apparel 600, and a fourth thread layer 650 bonded to a fourth region on article of apparel 600. In such embodiments, the thread border 250 of each thread layer can define the respective regions on the article of apparel 100. In some embodiments, thread layers (or thread patterns) can overlap in an overlap region, for example overlap region 602 shown in FIG. 6. FIGS. 7-9 show additional articles of apparel comprising a plurality of thread layers according to some embodiments. Article of apparel 100 can comprise any of the thread layers as described in FIGS. 6-9.

[0052] In some embodiments, thread layers 120, 130, 140 (or a thread pattern comprising a thread layer 120, 130, 140) can wrap entirely around a portion of the article of apparel 100 to maintain the shape of the apparel 100 during use, as described herein with reference to FIG. 10.

[0053] In some embodiments, thread layers 120, 130, 140 (or a thread pattern comprising a thread layer 120, 130, 140) can comprise a molded part 1530 or 1730 as described herein with reference to FIGS. 15-18.

[0054] Thread layers (or thread patterns) applied to different regions of a base layer 110 can impart desired characteristics to the respective regions. Exemplary characteristics comprise, but are not limited to, strength, support, breathability, comfort (stretchability), aesthetics, abrasion resistance, water resistance, texture, tackiness, and haptics. In some embodiments, the material of a continuous thread used to wind a thread layer can impart the desired characteristics. For example, a thread layer wound using a hydrophobic thread can impart water resistance to a particular region on an article of apparel.

In some embodiments, the tension at which a continuous thread is wound can impart the desired characteristics. For example, a thread wound at high tension can impart a high degree of compression for a particular region on article of apparel.

[0055] Each thread layer 120, 130, 140 (or a thread pattern) can occupy a surface area defined by a thread border 250 (for example, border 250a, 250b, or 250c) on the surface 112 of a base layer 110. Each thread line within a thread layer (or thread pattern) can extend continuously across the layer and comprise a first end disposed at the thread border and a second end disposed at the thread border. In some embodiments, the first end and the second end of each thread line can be bonded to the surface 112 of the base layer 110. In some embodiments, the first end and the second end of each thread line can be directly bonded to the surface 112 of the base layer 110.

[0056] In some embodiments, a thread layer or thread pattern can be visibly exposed on surface 112 of article of apparel 100. In some embodiments, no lamination layer or supporting textile layer is disposed over a thread layer or thread pattern on the surface 112 of article of apparel 100. In some embodiments, a region on article of apparel 100 comprising a thread layer or thread pattern can be devoid of a lamination layer.

[0057] In some embodiments, the first end and the second end of each thread line bonded or directly bonded to the surface 112 of the base layer 110 can define the perimeter of a pocket (for example, pocket 1130) on apparel 100.

[0058] In some embodiments, the surface area of a first thread layer (or thread pattern) and the surface area of a second thread layer (or thread pattern) can partially overlap on the surface 112 of a base layer 110 in an overlap region. In such embodiments, the first thread layer (or thread pattern) and the second a thread layer (or thread pattern) can overlap partially on article of apparel 100. In some embodiments, the first thread layer (or thread pattern) and the second a thread layer (or thread pattern) can be bonded to each other at an area of overlap between first thread layer (or thread pattern) and the second a thread layer (or thread pattern). In some embodiments, the first thread layer (or thread pattern) and the second a thread layer (or thread pattern) can be directly bonded to each other at an area of overlap between first thread layer (or thread pattern) and the second a thread layer (or thread pattern). FIG. 6 shows an overlap region 602 for thread layers (or thread patterns) according to some embodiments.

[0059] In some embodiments, one or more of thread layers 120, 130, 140 (or a thread pattern) can occupy a surface area defined by a thread border that is the same a perimeter edge 114 of a base layer 110. In such embodiments, the one or more of thread layers 120, 130, 140 (or a thread pattern) can comprise a surface area occupying the entirety of a base layer 110. In some embodiments, one or more of thread layers 120, 130, 140 (or a thread pattern) can occupy a surface area defined by a thread border that is at least partially surrounded by perimeter edge 114 of a base layer 110. In such embodiments, perimeter edge 114 can define a surface area that at least partially includes the surface area defined by the thread border. In some embodiments, one or more of thread layers 120, 130, 140 (or a thread pattern) can occupy a surface area defined by a thread border that is surrounded by perimeter edge 114 of a base layer 110. In such embodiments, perimeter edge 114 can define a surface area that wholly includes the surface area defined by the thread border.

[0060] In some embodiments, thread lines of a thread layer (or thread pattern) can apply a compressive force on the surface 112 of the base layer 110, the compressive force being applied along an axis extending from a first end to a second end of the thread line. In such embodiments, the compressive force applied via each thread line can be configured to impart a desired shape on article of apparel as described herein with reference to, for example, FIGS. 14A-14B.

[0061] In some embodiments, the base layer 110 can comprise a single piece of material. In some embodiments, base layer 110 can comprise a plurality of pieces of material (for example, pieces 116). In such embodiments, base layer 110 can comprise a first piece of material and a second piece material adjacent to the first piece of material. Pieces of material located adjacent to each other can be disposed in a side-by-side relationship with the perimeter edge of the first piece adjacent to the perimeter edge of the second piece. In some embodiments, the first piece of material and a second piece material can be joined at a seam 150 as described herein. In some embodiments, the first piece of material and a second piece material may not be joined at a seam such that there is a gap 160 between the adjacent pieces of material. In either case, one or more of the thread lines for a thread layer 120, 130, 140 (or a thread pattern) can extend across and be bonded to both the first piece of material and the second piece of material. In some embodiments, one or more of the thread lines for a thread layer 120, 130, 140 (or a thread pattern) can extends across and be directly bonded to both the first piece of material and the second piece of material. FIGS. 6-9 illustrate thread layers extending across and bonded to multiple pieces of material according to some embodiments.

[0062] 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 attachment 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 stich, 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 com-

prise 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.

[0063] In some embodiments, base layer 110 can comprise three or more adjacent pieces of material. For example, base layer 110 can comprise three, four, five, six, seven, eight, nine, or ten pieces of material.

[0064] In some embodiments, base layer 110, or a piece of material defining base layer 110, can comprise a fabric material. In some embodiments, the fabric material can be a non-woven, woven, or knitted fabric material. In some embodiments, base layer 110, or a piece of material defining base layer can comprise a foam material. Exemplary fabric materials for base layer 110 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. In some embodiments, base layer 110, or a piece of material defining base layer 110, can comprise a polymeric sheet or film, for example, a TPU sheet or film. In some embodiments, base layer 110, or a piece of material defining base layer 110, can comprise a mesh material.

[0065] In some embodiments, base layer 110, or a piece of material defining base layer 110, can comprise a first base layer 110a disposed below a thread layer or thread pattern and a second base layer 110b disposed above the thread layer. In such embodiments, the thread layer or thread pattern can be sandwiched between the first base layer 110a and the second base layer 110b, as shown for example in FIG. 19. Also in such embodiments, thread lines of the thread layer or thread pattern can be (i) bonded to a surface 112 of the first base layer along at least a portion of a length of the thread line, (ii) bonded to a surface 112 of the second base layer along at least a portion of a length of the thread line, or (iii) both. In some embodiments, the thread lines can be directly bonded to the surface 112 of the first base layer 110a, directly bonded to a surface 112 of the second base layer 110b, or both.

[0066] In some embodiments, a thread layer 120, 130, 140 (or a thread pattern) can define a portion of a layered structure forming a chamber on article of apparel 100, for example, layered structure 1200.

[0067] Thread layers as described herein (for example, thread layers 200, 220, and 240) can each comprise a thread border 250 defined by the space in which thread lines of the thread layer are located. The thread border 250 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 border 250 and a second end located at a second side of the thread border 250. For example, thread lines 204 of thread layer 200 can comprise a first end 210 located at a first side of thread border 250 and a second end 212 located at a second side of thread border 250.

[0068] FIGS. 2A-2C illustrate thread borders 250a-c for thread layers 200, 220, and 240. For a thread pattern comprising a plurality of thread layers, the thread pattern can comprise a thread pattern border 250 defined by the space occupied by the combination of the individual thread layers. For example, a thread pattern comprising thread layers 200, 220, and 240 comprises a thread pattern border defined by the space occupied by the combination of border 250a and border 250c. Border 250b is wholly contained within border 250a.

[0069] As used herein, sides of a perimeter edge or a border refer to top, bottom, right, and left sides of a shape defined by the edge or border. 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 or border 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 or border located to the right of the geometrical center, and a left side defined by the portion of the edge or border located to the left of the geometrical center. The top and bottom sides do not overlap. Similarly, the left and right sides do not overlap. The top and left sides overlap at the portion of the edge or border located to the top-left of the geometrical center. The top and right sides overlap at the portion of the edge or border located to the top-right of the geometrical center. The bottom and left sides overlap at the portion of the edge or border located to the bottom-left of the geometrical center. The bottom and right sides overlap at the portion of the edge or border located to the bottom-right of the geometrical center. For purposes of determining the shape defined by the perimeter edge or border, the material having the edge or border is laid in a flat configuration with no portion of the material overlapping itself.

[0070] As used herein, a first side of a perimeter edge or border can be the top, bottom, right, or left side of the edge or border and a second side of the perimeter edge can be the top, bottom, right, or left side of the edge or border, provided that the first and second sides are not the same side. Similarly, a third side of a perimeter edge or border can be the top, bottom, right, or left side of the edge or border and a fourth side of the edge or border can be the top, bottom, right, or left side of the edge or border, provided that the third and fourth sides are not the same, and are not the same as the first or second sides.

[0071] In some embodiments, one or more thread layers (for example, thread layers 120, 130, 140) can comprise a thread defining (i) a plurality of thread lines

each extending from a first side of a thread border to a second side of the thread border 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 thread border to a fourth side of the thread border 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.

[0072] Thread layer 200 comprises a continuous thread 202 wound around anchor points 290. Thread layer 220 comprises a continuous thread 222 wound around anchor points 290. Thread layer 240 comprises a continuous thread 242 wound around anchor points 290. In some embodiments, anchor points 290 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 290. In such embodiments, separate thread layers can be wound over each other, with one thread layer disposed over one or more other thread layers.

[0073] 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. In some embodiments, 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.

[0074] 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 an anchor point'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.

[0075] Continuous thread 202 can be wrapped around a plurality of anchor points 290 and comprises a plurality of thread lines 204. Each thread line 204 extends between two respective anchor points 290.

[0076] Continuous thread 202 can be wrapped around a plurality of anchor points 290 in tension such that individual thread lines 204 are in tension when wrapped around anchor points 290. In some embodiments, the tension at which thread lines 204 are wound can range from 0 centinewtons (cN) to 25 cN, including subranges. For example, in some embodiments, the tension at which thread lines 204 are wound can range from 0.01 cN to 25 cN, from 0.1 cN to 25 cN, from 1 cN to 25 cN, from 5 cN to 25 cN, from 10 cN to 25 cN, or from 15 cN to 25 cN. In some embodiments, the tension at which thread lines 204 are wound can range from 2 cN to 10 cN. In some embodiments, the tension at which thread lines 204 are wound can range from 2 cN to 6 cN. In such embodiments, the tension can create the compressive force applied along thread lines as described herein. In some embodiments, the compressive force can range from 0 cN to 25 cN, including subranges. For example, in some embodiments, the compressive force can range from 0.01 cN to 25 cN, from 0.1 cN to 25 cN, from 1 cN to 25 cN, from 5 cN to 25 cN, from 10 cN to 25 cN, or from 15 cN to 25 cN. In some embodiments, the compressive force can range from 2 cN to 10 cN. In some embodiments, the compressive force can range from 2 cN to 6 cN.

[0077] Thread lines 204 directly bonded to surface 112 of base layer 110 can apply a compressive force on the surface 112 along an axis extending from a first end 210 to second end 212 of the thread line 204. This compressive force can be the result of the thread lines 204 being wound around anchor points under tension and being directly bonded to the surface while still under tension.

[0078] In some embodiments, different thread lines 204 can be wrapped around anchor points 290 at different tensions to impart desired characteristics to thread layer 200. In some embodiments, a first set of thread lines 204 can be wound at a first tension in any of the centinewton ranges described above and a second set of thread lines 204 can be wound at a second tension in any of the centinewton ranges described above, 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.

[0079] By winding continuous thread 202 in tension, thread layer 200 can be bonded while thread lines 204 are under tension such that thread lines 204 are in tension in a bonded thread layer or thread pattern. Bonding thread lines 204 while thread lines 204 are under tension

fixes the thread lines 204 in tension within a layer or pattern. Fixing thread lines 204 in tension will result in thread lines 204 wanting to contract when thread layer 200 is removed (for example, cut) from anchor points 290 used to wind thread layer 200. In cases where a portion of a thread line 204 is not bonded in a fully fixed position, the thread line 204 can contract when removed from anchor points. In such embodiments, the portion(s) of the thread line 204 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 204 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.

[0080] In embodiments where different thread lines 204 are wound at different tensions, different thread lines 204 of thread layer 200 will be under different values of tension in thread layer 200. The tension of thread lines 204 can be utilized to control characteristics of thread layer 200, and therefore an article of apparel comprising thread layer 200.

[0081] The number of thread lines 204 for thread layer 200 fixed at an anchor point 290 is defined by the "thread line communication number" of an anchor point 290. 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.

[0082] Similarly, the number of thread lines fixed at an anchor point 290 for a thread pattern comprising a plurality of thread layers is defined by the "thread line communication number" of an anchor point 290 for the thread pattern. For a thread pattern, the "thread line communication number" of an anchor point 290 is the total number of thread lines, for the plurality of layers, extending from an anchor point to different anchor points.

[0083] Anchor points 290 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 290 can have a thread line communication number of "X" or more. In some embodiments, all the anchor points 290 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.

[0084] A thread layer, for example thread layer 200, 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.

[0085] In some embodiments, thread lines 204 can be bonded at anchor points 290. In such embodiments, thread lines 204 can be bonded at anchor points 290 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 fasters, 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).

[0086] In some embodiments, thread lines 204 can be directly bonded together at anchor points 290. In some embodiments, thread lines 204 can be directly bonded together at anchor points 290 via a polymeric material of continuous thread 202. For example, heat and/or pressure can be applied to directly bond thread lines 204 at anchor points 290. In embodiments where heat and/or pressure is utilized to directly bond the polymeric material of thread lines 204, the thread lines 204 can be thermally fused together at one or more anchor points 290. In embodiments comprising direct bonding of thread lines 204 at anchor points 290, thread lines 204 can be directly bonded at anchor points 290 without the use of an adhesive or bonding layer.

[0087] In some embodiments, thread lines 204 can be bonded together via a bonding layer. In some embodiments, thread lines 204 can be bonded together at anchor points 290 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, a screen-printed layer, or a blown fiber layer. In some embodiments, the blown fiber layer can comprise polymeric fibers that can bond thread lines 204.

[0088] In some embodiments, thread lines 204 can be bonded together without the use of a bonding layer. For example, in some embodiments, thread lines 204 can be directly bonded together via, for example, but not limited to, direct local bonding via material(s) of thread lines 204, needle punching, hydro-entanglement, and ultrasonic/-vibratory entanglement.

[0089] In some embodiments, thread lines 204 can be bonded at points where two or more thread lines 204 overlap in thread layer 200 (i.e., intersection points 206). Thread lines 204 can be bonded at intersection points 206 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 fasters, 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 206 for thread lines can be referred to as "overlap points" or "points of overlap."

[0090] In some embodiments, thread lines 204 can be directly bonded together at intersection points 206. In some embodiments, thread lines 204 can be directly bonded together at intersection points 206 via the polymeric material of continuous thread 202. In embodiments comprising direct bonding of thread lines 204 at intersection points 206, thread lines 204 can be bonded at intersection points 206 without the use of an adhesive or bonding layer. For example, heat and/or pressure can be applied to thread layer 200 to directly bond thread lines 204 at intersection points 206. In embodiments where heat and/or pressure is utilized to directly bond the polymeric material of thread lines 204, the thread lines 204 can be thermally fused together at one or more intersection points 206.

[0091] In some embodiments, a bonding layer can bond thread lines 204 together at a plurality of intersection points 206 within thread layer 200. 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 blown fiber layer comprising polymeric fibers that can bond thread lines 204.

[0092] In some embodiments, continuous thread 202 can comprise overlaying thread lines 204. 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.

[0093] The thread lines 204 of thread layer 200 may not be woven or knitted together. In such embodiments, thread lines 204 can be referred to as "non-woven" and "non-knitted" thread lines. The thread lines 204 of thread layer 200 may not be embroidered threads stitched to a base layer. In such embodiments, thread lines 204 may be referred to as "non-embroidered" thread lines.

[0094] In some embodiments, continuous thread 202 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 202 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 202 with an activatable agent coating can comprise a robotic arm for activating the coating as continuous thread 202 is being wound around anchor points 290.

[0095] 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 202 can be a non-polymer thread composed of non-polymer materials, such as carbon fiber, cotton, wool, or silk. In some embodiments, continuous thread 202 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, poly-

mer yarn with non-melt core, and other similar types of yarn.

[0096] 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."

[0097] In some embodiments, continuous thread 202 can comprise an elastomeric thread. A suitable elastomeric material for an elastomeric continuous thread 202 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 from 100% to 300%, including subranges. For example, in some embodiments, the elastomeric thread can comprise a percent elongation in a range of from 100% to 300%, from 150% to 300%, from 200% to 300%, from 100% to 250%, or from 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).

[0098] In some embodiments, continuous thread 202 can be a plied thread. In some embodiments, the plied thread can be plied while winding thread 202. For example, a winding assembly used to wind thread 202 can ply the thread using thread from a plurality of thread spools (see for example, winding assembly 440). In some embodiments, the plied thread can be a pre-plied thread spooled around a thread spool.

[0099] 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.

[0100] 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.

[0101] In some embodiments, continuous thread 202 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.

[0102] In some embodiments, continuous thread 202 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 202 can be wound in a thread layer to provide areas of increased padding on an article of apparel.

[0103] In some embodiments, continuous thread 202 can be a dissolvable thread. Dissolvable threads can be dissolved after being wound in a thread layer by a solvent. In such embodiments, all or a portion of a thread layer can be removed by dissolving the dissolvable thread. In some embodiments, the dissolvable thread can be an acid-dissolvable thread and the solvent can be an acid solution that etches the thread.

[0104] In some embodiments, continuous thread 202 can be a conductive thread. In such embodiments, the conductive thread can be coupled to a power source configured to heat the conductive thread, and therefore an article of apparel comprising continuous thread 202.

[0105] In some embodiments, continuous thread 202 can be a reflective thread. In some embodiments, continuous thread 202 can be a tacky thread.

[0106] In some embodiments, continuous thread 202 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.

[0107] In some embodiments, continuous thread 202 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 dilatant material in a thread layer, the stiffness of the thread layer can change depending on the degree of strain 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.

[0108] In some embodiments, continuous thread 202 of thread layer 200 can have a denier in the range of from 1 denier to 3000 denier, including subranges. For example, continuous thread 202 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 202 can have a denier in the range of from 10 denier to 2500 denier, from 50 denier to 2000 denier, from 100 denier to 1900 denier,

from 200 denier to 1800 denier, from 300 denier to 1700 denier, from 400 denier to 1600 denier, from 500 denier to 1500 denier, from 600 denier to 1400 denier, from 700 denier to 1300 denier, from 800 denier to 1200 denier, from 900 denier to 1100 denier, or from 900 denier to 1000 denier.

[0109] 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 200, thread layer 220, and thread layer 240.

[0110] Continuous threads of any thread layer (for example, thread layers 220 and 240) can be wound around and extended between anchor points 290 in the same fashion as described above for continuous thread 202. Further, thread lines of the continuous threads of any thread layer (for example, thread layers 220 and 240) can be bonded in the same manner as described above for thread layer 200.

[0111] Like continuous thread 202, continuous thread for other thread layers (for example, threads 222 and 242) can comprise a plurality of thread lines (for example, thread lines 224 and 244) 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.

[0112] 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 200 can define a first layer of a thread pattern and second thread layer 220 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 200 can be disposed over second thread layer 220, or vice versa, in areas of overlap between the two thread layers.

[0113] 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, a screen-printed layer, or a blown fiber layer.

[0114] 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.

[0115] FIG. 2C illustrates a thread layer 240 comprising a continuous thread 242 with thread lines 244 extending tangential to a perimeter boundary according to some embodiments. Thread layer 240 comprises an edge 260. Edge 260 can be a portion of thread border 250c.

[0116] Thread lines 244 of continuous thread 242 can comprise a plurality of thread lines 244 extending between two respective anchor points 290 and extending tangential to edge 260. Thread lines 244 extending tangential to edge 260 can be referred to as "boundary-tangential thread lines." FIG. 2C shows a plurality of boundary-tangential thread lines 246.

[0117] Thread lines 244 of continuous thread 242 can also comprise a plurality of thread lines 244 extending between two respective anchor points 290 and not tangential to edge 260. Thread lines 244 not extending tangential to edge 260 can be referred to as "non-boundary-tangential thread lines." FIG. 2C shows a plurality of non-boundary-tangential thread lines 248.

[0118] In some embodiments, thread lines 246 extending tangential to edge 260 are not wound around an anchor point located at edge 260. In some embodiments, thread layer 240 can be devoid of anchor points located at edge 260.

[0119] Boundary-tangential thread lines 246 can comprise thread lines 246 that overlap each other at an overlap point 247 in thread layer 240. Any two thread lines 246 of thread layer 240 can overlap each other at an overlap point 247. For example, as shown in FIG. 2C, a first boundary-tangential thread line 246 can overlap a second boundary-tangential thread line 246 at overlap point 247.

[0120] Boundary-tangential thread lines 246 that overlap each other at an overlap point 247 can be disposed at an angle relative to each other. The relative angle of the

two thread lines 246 can be defined by the angle of intersection (θ) at an overlap point 247. Unless specified otherwise, the angle of intersection (θ) is the angle formed by the intersection of two thread lines 246 and is measured on the side of the thread lines 246 facing edge 260 (as shown in FIG. 2C).

[0121] In some embodiments, the angle of intersection (θ) at an overlap point 247 can be in the range of from 90° to 179°, including subranges. For example, θ may 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 from 90° to 179°, from 100° to 179°, from 110° to 179°, from 120° to 179°, from 130° to 179°, from 140° to 179°, from 150° to 179°, from 160° to 179°, or from 170° to 179°. In some embodiments, θ can be greater than 90°, greater than 120°, or greater than 150°.

[0122] Thread layer 240 can comprise any suitable number of boundary-tangential thread lines 246. In some embodiments, thread layer 240 can comprise four or more boundary-tangential thread lines 246. In some embodiments, thread layer 240 can comprise 10 or more boundary-tangential thread lines 246. In some embodiments, thread layer 240 can comprise 20 or more boundary-tangential thread lines 246. In some embodiments, thread layer 240 can comprise 30 or more boundary-tangential thread lines 246. In some embodiments, thread layer 240 can comprise 50 or more boundary-tangential thread lines 246. In some embodiments, thread layer 240 can comprise a number of boundary-tangential thread lines 246 in a range of from 2 to 50. For example, thread layer 240 can comprise from 2 to 50, from 4 to 50, from 10 to 50, from 20 to 50, or from 30 to 50 boundary-tangential thread lines 246.

[0123] In some embodiments, a plurality of adjacent anchor points 290 used to form thread layer 240 can each comprise a boundary-tangential thread line 246 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 may be located at the same distance from the anchor point. As an example, anchors points 290a and 290c are adjacent to anchor point 290b in FIG. 2C.

[0124] In some embodiments, boundary-tangential thread lines 246 overlapping at an overlap point 247 can be directly bonded to each other at the overlap point 247. In some embodiments, boundary-tangential thread lines 246 overlapping at an overlap point 247 can be directly bonded to each other via a polymeric material of the boundary-tangential thread lines 246.

[0125] In some embodiments, an anchor point 290 can comprise a boundary-tangential thread line 246 extending therefrom and a plurality of non-boundary-tangential thread lines 248 extending therefrom. In some embodiments, an anchor point 290 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 246 and the remainder of the thread lines can be non-boundary-tangential thread lines 248.

[0126] FIG. 3 shows a method 300 of making an article of apparel (for example, apparel 100) according to some embodiments. In step 310, a plurality of anchor points (for example, anchor points 290) on a support structure can be defined. In some embodiments, the support structure can be a support plate (for example, support plate 430, support plate 1502, or support plate 1702). In some embodiments, the support structure can be a mannequin. 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.

[0127] Unless stated otherwise, the steps of method 300 need not be performed in the order set forth herein. Additionally, unless specified otherwise, the steps of method 300 need not be performed sequentially. The steps can be performed in a different order or simultaneously. As one example, step 330 of method 300 need not be performed between steps 320 and 340. Rather, step 330 can be performed after step 340. As another example, step 360 need not be performed between steps 350 and 370. Rather, step 360 can be performed between steps 340 and 350. As another example, steps 340 and 350 can be performed simultaneously. Further, method 300 may not include all the steps illustrates. For example, method 300 may not include step 330.

[0128] In step 320, one or more continuous threads (for example, continuous thread 202) can be wound (wrapped) around the anchor points 290 such that individual thread lines (for example, thread lines 204) of the continuous thread(s) extend between two respective anchor points. Winding continuous thread(s) in step 320 forms one or more desired thread layers (for example, thread layer 200) and/or a thread pattern comprising a plurality of thread layers (for example, a thread pattern comprising thread layers 200, 220, and 240). During winding step 320, 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 members serve to support continuous thread(s) during winding step 320. 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. As another example, the anchor points can be projections extending from support plate (for example support plate 430).

[0129] 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.

[0130] In some embodiments, one or more continuous threads (for example, continuous thread 202) can be wound (wrapped) around the anchor points 290 over a base layer (for example, base layer 110). In such embodiments, base layer 110 can be disposed on a surface of the support structure comprising anchor points 290. For example, the base layer 110 can be disposed on a surface 432 of support plate 430.

[0131] In step 330, one or more parts can be molded onto a thread layer or thread pattern. For example, in some embodiments, one or more parts can be molded onto a thread layer or thread pattern as described herein with reference to FIGS. 15-18. In some embodiments, one or more parts can be molded by injecting a polymeric material (for example, a polymeric foam) around at least a portion of the thread layer or thread pattern.

[0132] In some embodiments, step 320 can be repeated after step 330 to form a thread layer (or thread pattern) over the one or more molded parts formed in step 330. In such embodiments, method 300 can form a thread pattern comprising a first thread layer with one or more molded parts and a second thread layer disposed over the first thread layer. In some embodiments, the second thread layer can be disposed over the one or more molded parts. In some embodiments, the second thread layer can be located between the one or more molded parts. In some embodiments, method 300 may not include step 330.

[0133] In step 340, 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 fasters, 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.

[0134] 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 fasters, 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.

[0135] In some embodiments, method 300 can comprise multiple winding steps 320 and multiple bonding steps 340. For example, a portion of a thread pattern can be wound in a first winding step 320 and then that portion can be bonded in a first bonding step 340. Then a second portion of a thread pattern can be wound in a second winding step 320 and that portion can be bonded in a second bonding step 340. In some embodiments, bonding step 340 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.

[0136] In some embodiments, steps 320 and 340 can be performed in the absence of a base layer (for example, base layer 110) disposed between the thread layer or thread pattern and a support structure comprising the anchor points.

[0137] In some embodiments, steps 320 and 340 can be performed in the presence of a base layer (for example, base layer 110) disposed between the thread layer or thread pattern and a support structure comprising the anchor points. In such embodiments, a thread layer or thread pattern can be bonded to the base layer in step 340. In such embodiments, steps 340 and 350 can be performed simultaneously.

[0138] In some embodiments, step 340 can comprise selectively heating all or a portion of a thread layer or thread pattern to form a solid part on the thread layer or thread pattern. For example, all or a portion of a thread layer or thread pattern can be heated to consolidate the thread lines into a solid part. Exemplary solid parts include, for example, a protective panel, such as an elbow pad or a shin guard. As a non-limiting example, thread layer 1120 shown in FIG. 11 can be consolidated to form a shin guard on article of apparel 1100.

[0139] In step 350, the thread layer or thread pattern formed in step 320 can be bonded to a base layer (for example base layer 110). In some embodiments, the thread layer or thread pattern can be bonded to the base layer via a laminated layer, an adhesive layer, a stitched layer, a cured layer, a screen-printed layer, a blown fiber layer, or a combination thereof. In some embodiments, the thread layer or thread pattern can be directly bonded to the base layer via for example, but not limited to, direct bonding via material(s) of thread lines and/or the base layer, needle punching, hydro-entanglement, and ultrasonic/vibratory entanglement.

[0140] In some embodiments, the thread layer or thread pattern formed in step 320 can be bonded to a

base layer (for example base layer 110) while the base layer is under tension. For example, the base layer can be held in a stretched position while the thread layer or thread pattern is bonded to a base layer. In such embodiments, bonding the thread layer or thread pattern to the base layer can lock portions of the base layer in tension, while leaving other portion free to contract one the applied tension is removed from the base layer. In such embodiments, the selective locking of portions of the base layer in tension can impart a desired shape to the article of apparel. For example, the selective locking of portions in tension can impart a shape as described in reference to FIGS. 14A-14B. As another example, the selective locking of portions of the base layer in tension can impart a corrugated or crimped structure as described in reference to FIGS. 20A-23B. In such embodiments, after bonding the thread layer or thread pattern to the base layer in the stretched position, the tension applied to the base layer can be removed such that the base layer is allowed to relax into a relaxed, un-stretched state. In some embodiments, the base layer held in the stretched position can have a flat shape.

[0141] In some embodiments, the base layer can be held in stretched position having a length and/or width that is from 5% to 50% of the un-stretched length and/or width of the base layer. In some embodiments, the tension force applied to the base layer in the length and/or width direction can be in a range from 0.03 N to 500 N.

[0142] In step 360, the thread layer or thread pattern can be cut. In some embodiments, cutting in step 360 can define all or a portion of a thread border 250 for thread layers of thread pattern and all or a portion of a thread pattern border 250. In some embodiments, a base layer 110 can be simultaneously cut with the thread layer or thread pattern. For example, in embodiments where step 350 is performed before step 360, the base layer and the thread layer or thread pattern can be cut simultaneously.

[0143] In step 370, the material comprising the base layer and the thread layer or thread pattern can be shaped into an article of apparel. In some embodiments, shaping the material can comprise joining the material to itself at a seam.

[0144] In some embodiments, shaping the material in step 370 can comprise attaching the material to one or more additional pieces of material to form an article of apparel. In some embodiments, attaching the material to the one or more additional pieces of material can comprise seaming the material to one or more of the additional pieces of material at one or more seams. In some embodiments, the one or more of the additional pieces of material can be made using method 300. In some embodiments, the one or more of the additional pieces of material can a piece of material without a thread layer or thread pattern as described herein.

[0145] FIG. 4 illustrates a computer numerical control (CNC) machine 400 for winding thread(s) in step 320 according to some embodiments. Machine 400 comprises a robot 405 for winding a thread layer (for example, thread layer 200) and/or a plurality of thread layers for a thread pattern comprising thread lines (for example, thread lines 204) around anchor points 290 on a support plate 430.

[0146] Robot 405 can comprise one or more thread spools 410 for threading and winding thread lines of one or more thread layers around anchor points 290. In some embodiments, CNC machine 400 can comprise a winding assembly 440 comprising a plurality of thread spools 410 for threading and winding a plurality of different threads.

[0147] In some embodiments, CNC machine 400 can comprise one or more thread tensioners 412 configured to apply a desired tension to thread(s) that are wound around anchor points 290. CNC machine 400 can comprise a controller 415 configured to wind one or more thread layers around anchor points 290 using a thread model and input data. In some embodiments, controller 415 can control tensioners 412 to wind thread(s) at desired tensions.

[0148] In some embodiments, CNC machine 400 can wind a plurality of threads from a plurality of thread spools 410 simultaneously when winding a thread layer. In some embodiments, machine 400 can be used to simultaneously wind overlaying thread lines from a plurality of thread spools 410.

[0149] In some embodiments, CNC machine 400 can comprise two or more robots 405 for winding a plurality of threads simultaneously. In such embodiments, the two or more robots 405 can wind different threads in different regions of a thread pattern simultaneously.

[0150] In some embodiments, robot 405 can ply two or more threads from different thread spools 410. In such embodiments, a thread layer or thread pattern can comprise 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.

[0151] In some embodiments, a tensioner 412 can be a mechanical tensioning device with digitally controlled impedance that is used to dynamically control how tight a thread is fed through machine 400. In some embodiments, the tension value for thread can be changed dynamically by adjusting the voltage in tensioner 412. In some embodiments, tensioner 412, can be a manually adjustable tensioner. In some embodiments, tensioner 412 can comprise a spring configured to adjust the amount of tension applied to thread(s). The spring can be manually controlled or digitally controlled.

[0152] In some embodiments, the tension at which a continuous thread for a thread layer is wound can range from 0 centinewtons (cN) to 25 cN, including subranges. For example, in some embodiments, the tension can range from 0.01 cN to 25 cN, from 0.1 cN to 25 cN, from 1 cN to 25 cN, from 5 cN to 25 cN, from 10 cN to 25 cN, or

from 15 cN to 25 cN. In some embodiments, the tension at which a continuous thread for a thread layer is wound can range from 2 cN to 10 cN. In some embodiments, the tension at which a continuous thread for a thread layer is wound can range from 2 cN to 6 cN.

[0153] In some embodiments, a first thread layer (for example, thread layer 200) can comprise a continuous thread 202 wound at a first tension and a second thread layer disposed over the first thread layer (for example, thread layer 220) can comprise a continuous thread 222 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.

[0154] FIG. 5 shows a heat press 500 for use in step 340, step 350, or both according to some embodiments. In step 340, heat press 500 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 step 350, heat press 500 can apply pressure and heat to a thread layer or thread pattern to bond continuous thread(s) to the base layer. In some embodiments, as shown for example in FIG. 5, heat press 500 can apply pressure and heat to a thread layer or thread pattern on support plate 430.

[0155] In some embodiments, heat press 500 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 500 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.

[0156] Heat can be applied to a thread layer or thread pattern in heat press 500 in one or more ways, such as but not limited to, radio frequency heat sealing (welding), high frequency heat sealing (welding), infrared welding, and steaming. Heat transfer between a thread layer or thread pattern and a heat press 500 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 500. In some embodiments, heat can be applied to both outer surfaces of a thread layer or thread pattern in heat press 500.

[0157] In some embodiments, heat can be uniformly applied to a thread layer or thread pattern within heat press 500. In such embodiments, the temperature at which a thread layer or thread pattern is bonded within heat press 500 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 500. In such embodiments, the temperature at which a thread layer or thread pattern is bonded within heat press 500 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 500, characteristics of the thread layer or thread pattern in different portions and/or regions of an article of apparel can be varied. In some embodiments, heat can be non-uniformly applied to a thread layer or thread pattern within heat press 500 to define a chamber or pocket as described herein.

[0158] In some embodiments, the heat applied to a thread layer or thread pattern can be controlled by controlling heat applied to heat press 500. In some embodiments, the heat applied to a thread pattern or thread layer can be additionally or alternatively controlled by one or more inserts 540 disposed between an interior surface of heat press 500 and the thread layer or thread pattern. In such embodiments, insert(s) 540 can control the heat applied by controlling the heat transfer between heat press 500 and the thread layer or thread pattern. In some embodiments, insert(s) 540 can serve to uniformly distribute heat across all or a portion of a thread layer or thread pattern within heat press 500. In some embodiments, insert(s) 540 can serve to vary the temperature of different portions and/or regions of a thread layer or thread pattern in heat press 500.

[0159] FIGS. 6 and 7 illustrate exemplary articles of apparel 600 and 660 comprising thread layers bonded to the surface 112 of a base layer 110 according to some embodiments. For purposes of discussion, FIGS. 6 and 7 illustrate thread layers 620, 630, 640, 650, 670, and 680 bonded to the articles of apparel 600 and 660. That said, as described herein, a thread pattern comprising a plurality of thread layers can also be bonded to the articles of apparel 600 and 660 in the same manner as thread layers 620, 630, 640, 650, 670, and 680.

[0160] As shown in FIG. 6, article of apparel 600 can comprise a base layer 110 comprising a plurality of pieces of material 116a-d. The pieces of material 116a-d can each define a portion of article of apparel 600. As a non-limiting example shown in FIG. 6, piece 116a can define all or part of a front portion of article of apparel 600, piece 116b can define all or part of a first sleeve of article of apparel 600, piece 116c can define all or part of a second sleeve of article of apparel 600, and piece 116d can define all or part of a back portion of article of apparel 600.

[0161] As shown in FIG. 7, article of apparel 660 can comprise a base layer 110 comprising a plurality of pieces of material 116a-116f. The pieces of material 116a-116f can each define a portion of article of apparel 660. As a non-limiting example shown in FIG. 7, the combination of piece 116a, second piece 116b, and third piece 116c can define first and second legs of article of apparel 660.

[0162] Each piece 116 comprises a shape defined by a perimeter edge 114.

[0163] In some embodiments a thread layer (for example, thread layer 620) can comprise a thread border 250 and a piece of base layer 110 (for example, piece 116a) can comprise a perimeter edge (for example, perimeter edge 114a) surrounding the thread border

250. In such embodiments, the area occupied by thread layer 620 on surface 112 can be less than the total surface area of surface 112 defined by perimeter edge 114a of base layer piece 116a.

[0164] In some embodiments, a thread layer (for example, thread layer 630) can comprise a thread border 250 that extends across multiple adjacent pieces of base layer 110 (for example, pieces 116a and 116b). In such embodiments, the area occupied by thread layer 630 on surface 112 can occupy a portion of the surface area of surface 112 defined by perimeter edge 114a of base layer piece 116a and a portion of the surface area of surface 112 defined by perimeter edge 114b of base layer piece 116b.

[0165] In embodiments comprising a thread layer (for example, thread layer 630) that comprises a thread border 250 extending across multiple adjacent pieces of base layer 110, one or more thread lines of the thread layer can extend from the first base layer piece to the second base layer piece. In such embodiments, one or more thread lines of the thread layer can be bonded to both the surface 112 of base layer 110 defined by the first piece (for example, piece 116a) and the surface 112 of base layer 110 defined by the second piece (for example, piece 116b). In some embodiments, one or more thread lines of the thread layer can be directly bonded to both the surface 112 of base layer 110 defined by the first piece and the surface 112 of base layer 110 defined by the second piece.

[0166] In some embodiments, a first thread layer (for example, thread layer 620) can comprise a thread border 250 that overlaps with the thread border of a second thread layer (for example, thread layer 630) in an overlap region 602. In such embodiments, the first thread layer can be bonded to the second thread layer in the overlap region 602. In some embodiments, first thread layer can be directly bonded to the second thread layer in the overlap region 602.

[0167] In some embodiments, as shown for example, in FIGS. 6 and 7, adjacent pieces of base layer 110 (for example, pieces 116a and 116b or pieces 116a and 116c) can be separated by a gap 160. In such embodiments, gap 160 can be defined by a space between the perimeter edges of the adjacent pieces of base layer 110. Also, in such embodiments, one or more of the thread lines of a thread layer (for example, thread layer 620) can extend across the gap 160 from the first price of material to the second piece of material. In some embodiments, all or a portion of gap 160 can be devoid of a seam 150. In embodiments comprising a gap 160 between adjacent pieces of base layer 110, thread lines of a thread layer can serve to attach adjacent pieces of base layer 110 together.

[0168] In some embodiments, gap 160 can comprise a minimum distance 162 between adjacent pieces 116. In some embodiments, minimum distance 162 can be greater than or equal to 1 millimeter. In some embodiments, minimum distance 162 can be greater than or equal to 2 millimeters. In some embodiments, minimum distance 162 can be greater than or equal to 1 centimeter. In some embodiments, minimum distance 162 can be greater than or equal to 2 centimeters.

[0169] In some embodiments, as shown for example in FIG. 7, a thread layer (for example thread layer 670) can extend across at least three pieces of a base layer 110. Thread layer 670 extends across first piece 116a, second piece 116b, and third piece 116c). In such embodiments, thread layer 670 can extend across multiple gaps 160 between the pieces of base layer 110.

[0170] In some embodiments, as shown for example in FIG. 7, a thread layer (for example thread layers 670 and 680) can extend across base layer 110 such that the thread border 250 of the thread layer occupies an area extending around the circumference of an article of apparel. In such embodiments, the thread layer can wrap entirely around a portion of the article of apparel. For example, the thread layer can wrap entirely around a pant leg, a sleeve, a waist, a torso portion, an abdomen portion, or a chest portion of the article of apparel. In some embodiments, a thread layer that wraps entirely around a portion of the article of apparel can be coupled to a tightening mechanism configured to adjust the tension in thread lines of the thread layer. Exemplary tightening mechanisms include, but are not limited to, a boa tightening mechanism and a ratchet tightening mechanism.

[0171] In some embodiments, as shown for example, in FIGS. 8 and 9, adjacent pieces of base layer 110 (for example, pieces 116a and 116b or pieces 116a and 116c) can be joined at a seam 150. In such embodiments, seam 150 can join the perimeter edges of the adjacent pieces of base layer 110 to form an article of apparel. Also, in such embodiments, one or more of the thread lines of a thread layer (for example, thread layer 820) can extend across the seam 150 from the first price of material to the second piece of material.

[0172] As shown in FIG. 8, article of apparel 800 can comprise a base layer 110 comprising a plurality of pieces of material 116a-d. The pieces of material 116a-d can each define a portion of article of apparel 800. As a non-limiting example shown in FIG. 8, piece 116a can define all or part of a front portion of article of apparel 800, piece 116b can define all or part of a first sleeve of article of apparel 800, piece 116c can define all or part of a second sleeve of article of apparel 800, and piece 116d can define all or part of a back portion of article of apparel 800.

[0173] Apparel 800 can comprise a first thread layer 820 bonded to a first region on article of apparel 800, a second thread layer 830 bonded to a second region on article of apparel 800, a third thread layer 840 bonded to a third region on article of apparel 800, and a fourth thread layer 850 bonded to a fourth region on article of apparel 800.

[0174] As shown in FIG. 9, article of apparel 860 can comprise a base layer 110 comprising a plurality of pieces of material 116a-116e. The pieces of material 116a-116f can each define a portion of article of apparel 860. As a

non-limiting example shown in FIG. 9, the combination of second piece 116b, third piece 116c, fourth piece 116d, and fifth piece 116e can define first and second legs of article of apparel 860.

[0175] Apparel 860 can comprise a first thread layer 870 bonded to a first region on article of apparel 860, a second thread layer 880 bonded to a second region on article of apparel 860, and a third thread layer 890 bonded to a third region on article of apparel 860.

[0176] In some embodiments, a seam 150 can join a first side of the perimeter edge for a piece of base layer to a second side of the perimeter edge for the piece of base layer. For example, as shown in FIG. 8, a seam 150 can join a first side of the perimeter edge 114b to a second side of the perimeter edge 114b for form a portion of a sleeve for an article of apparel.

[0177] In some embodiments, as shown for example in FIG. 9, a thread layer (for example thread layers 870, 880, or 890) can extend across base layer 110 such that the thread border 250 of the thread layer occupies an area extending across one or more seams 150 and entirely around a circumference of an article of apparel. In such embodiments, the thread layer can wrap entirely around a portion of the article of apparel. For example, the thread layer can be wrap entirely around a pant leg, a sleeve, a waist, a torso portion, an abdomen portion, or a chest portion of the article of apparel.

[0178] Seam(s) 150 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 150 comprise, but are not limited to, a Merrow stitch (tight overlock stitch), a gathered edge, a surge stitch, or an overlock stitch.

[0179] In some embodiments, a thread layer (or thread pattern) can wrap entirely around all or a portion of the article of apparel and provide a stiffness configured to maintain the shape of the article of apparel during use. For example, a thread layer (or thread pattern) can wrap entirely around all or a portion of the article of apparel to provide support for a wearer's joint during use.

[0180] FIG. 10 illustrates an article of apparel 1000 comprising an ankle sleeve and a thread layer 1020 that wraps entirely around the article of apparel 1000 to maintain the shape of the ankle sleeve. In some embodiments, thread layer 1020 can be directly bonded to surface 112 of a base layer 110 defining the shape of article of apparel 1000.

[0181] In some embodiments, thread layer 1020 directly bonded on surface 112 can provide a stiffness ranging from 20% to 90% as measured according to the Cusick drape test with a 30-centimeter test template diameter.

[0182] While FIG. 10 illustrates article of apparel 1000 comprising an ankle sleeve, other articles of apparel configured to wrap around a wearer's joint during use can comprise thread layer 1020. Additional exemplary articles configured to wrap around a wearer's joint during use comprise, but at not limited to, a pant leg, an arm sleeve, a knee sleeve, a waistband, an elbow sleeve, a wrist sleeve, or a shoulder wrap.

[0183] In some embodiments, the tension at which thread lines of thread layer 1020 are wound can be impart a compressive force on surface 112 that contributes to the stiffness provided by the thread layer 1020. In some embodiments, thread lines of thread layer 1020 can be wound at a tension value as described herein.

[0184] In some embodiments, the thread lines of a thread layer (or thread pattern) can be bonded to the surface 112 of a base layer 110 at only a perimeter region of the thread layer (or thread pattern) to define a pocket between the thread layer (or thread pattern) and the base layer 110. FIG. 11 illustrates an article of apparel 1100 comprising a pocket 1130 formed by a thread layer 1120 according to some embodiments.

[0185] Apparel 1100 comprises thread layer 1120 bonded to the surface 112 of a base layer 110 at a perimeter region 1122 of the thread layer 1120 to define a pocket 1130 according to some embodiments. Perimeter region 1122 can be a perimeter region of thread layer 1120 comprising thread border 250 for thread layer 1120. In some embodiments, thread layer 1120 can be directly bonded to the surface 112 of a base layer 110 at perimeter region 1122 of the thread layer 1120 to define a pocket 1130.

[0186] In some embodiments, thread layer 1120 can be bonded to the surface 112 around an entirety of perimeter region 1122. In some embodiments, thread layer 1120 can be bonded to the surface 112 around a portion of perimeter region 1122. For example, in some embodiments, all or a portion of a side 1123 of perimeter region 1122 may not be bonded to surface 112 to define an open perimeter portion 1124. In such embodiments, the open perimeter portion 1124 can provide an opening through which an insert 1140 can be inserted and removed from pocket 1130.

[0187] In some embodiments, pocket 1130 can be configured to receive an insert 1140. In some embodiments, pocket 1130 can comprise an insert 1140 disposed within the pocket 1130. In some embodiments, the insert 1140 can comprise a plate, for example, a shin guard or a padding plate. In some embodiments, the insert 1140 can comprise insulation.

[0188] As a non-limiting example, FIG. 11 shows an article of apparel 1100 comprising a sleeve with pocket 1130 defined by thread layer 1120 and comprising an insert 1140 in the form of a shin guard.

[0189] In some embodiments, articles of apparel as described herein (for example article of apparel 100) can comprise thread layers or thread patterns coupled together in a layered structure to form a chamber on the article of apparel. In such embodiments, the chamber can be filled with a material, such as an insulation material.

[0190] FIGS. 12 and 13 illustrate a layered structure 1200 according to some embodiments. For purposes of

discussion, FIGS. 12 and 13 illustrate a thread layers 1210 and 1250. That said, thread patterns comprising a plurality of thread layers can form a layered structure in the same manner as thread layers 1210 and 1250.

[0191] Layered structure 1200 can comprise a thread layer 1210 comprising a thread border 1212 and a thread 1220 defining a plurality of first thread lines 1222 each extending from a first side 1214 of the thread border 1212 to a second side 1216 of the thread border 1212 and crossing over each other at points of overlap between two or more of the thread lines 1222. Layered structure 1200 can also comprise a second thread layer 1250 disposed over the first thread layer 1210 and comprising a thread border 1252 and a second thread 1260 defining a plurality of thread lines 1262 each extending from a first side 1254 of the thread border 1252 to a second side 1256 of the thread border 1252 and crossing over each other at points of overlap between two or more of the thread lines 1262.

[0192] Thread layer 1210 and layer 1250 can be coupled together to form a chamber 1280 occupying a volume 1282 between the thread layer 1210 and thread layer 1250.

[0193] In some embodiments, thread layer 1210 and thread layer 1250 can be coupled at a seam 1290 located at an edge 1284 of chamber 1280. Seam 1290 can comprise any suitable attachment region for joining thread layer 1210 and thread layer 1250 along edge 1284. Exemplary attachment regions comprise, but are not limited to, stitched attachment 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 stich, a Merrow stitch (tight overlock stitch), a gathered edge, a surge stitch, an overlock stitch, and an interlocking seam construction.

[0194] In some embodiments, layered structure 1200 can comprise a base layer 1230 disposed between the first thread layer 1210 and the second thread layer 1250 such that a portion of the base layer 1230 defines a portion of chamber 1280. In such embodiments, base layer 1230, first thread layer 1210, and second thread layer 1250 can be coupled together to form chamber 1280. Also in such embodiments, base layer 1230, first thread layer 1210, and second thread layer 1250 can be attached at seam 1290 located at edge 1284 of chamber 1280. In some embodiments comprising base layer 1230, thread lines 1222 of first thread layer 1210 can be bonded to a surface 1232 of base layer 1230. For example, thread lines 1222 of first thread layer 1210 can be directly bonded to surface 1232 of base layer 1230 in the same manner as described above for a thread layer and base layer 110.

[0195] In some embodiments, layered structure can comprise a base layer 1270 disposed between the first thread layer 1210 and the second thread layer 1250 such that a portion of the base layer 1270 defines a portion of chamber 1280. In such embodiments, base layer 1270, first thread layer 1210, and second thread layer 1250 can be coupled together to form chamber 1280. Also in such embodiments, base layer 1270, first thread layer 1210, and second thread layer 1250 can be attached at seam 1290 located at edge 1284 of chamber 1280. In some embodiments comprising base layer 1270, thread lines 1262 of second thread layer 1250 can be bonded to a surface 1272 of base layer 1270. For example, thread lines 1262 of second thread layer 1250 can be directly bonded to surface 1272 of base layer 1270 in the same manner as described above for a thread layer and base layer 110.

[0196] In some embodiments, layered structure 1200 can comprise both base layer 1230 and base layer 1270. In such embodiments, base layer 1230, base layer 1270, first thread layer 1210, and second thread layer 1250 can be attached at seam 1290.

[0197] In some embodiments, chamber 1280 can be filled with a material or insert 1286. In some embodiments, chamber 1280 the material can be insulation.

[0198] Base layers 1230 and 1270 can be the same as base layer 110. In some embodiments, base layers 1230 and 1270 can comprise multiple pieces 116 of material as described herein for base layer 110.

[0199] In some embodiments, chamber 1280 can be a tubular chamber. In such embodiments, layered structure 1200 can form all or a portion of an article of apparel configured to wrap around a portion of a wearer's body during use. For example, layered structure 1200 can form all of a portion of a pant leg, an arm sleeve, a knee sleeve, a waistband, an elbow sleeve, an ankle sleeve, a wrist sleeve, a collar, a double panel shirt, or a fully-fashioned tubular fabric.

[0200] In some embodiments, an article of apparel, or a portion therefore, can comprise a thread layer (or thread pattern) configured to impart a desired shape on the article of apparel. FIGS. 14A and 14B illustrate a shaped material 1400 for an article of apparel according to some embodiments. FIGS. 20A - 23A illustrate shaped materials 2000 and 2200 for an article of apparel according to some embodiments.

[0201] Material 1400 comprises a base layer 110 and a thread layer 1420 comprising thread lines 1424 wound tangential to an edge 260 defining the edge of a shaped area 1410 on base layer 110. Thread lines 1424 can be wound tangential to edge 260 as described herein with reference to thread layer 240 in FIG. 2C. As described herein, the tension under which the thread lines 1424 are wound and bonded to base layer, the tension under which base layer 110 is held while bonding to thread layer 1420, or a combination thereof can create shaped area 1410. Thread lines 1424 of thread layer 1420 can apply a compressive force on the surface 112 of the base layer 110 along an axis extending from a first end 1426 to a second end 1428 of the thread lines 1424.

[0202] Shaped area can comprise a curved shape relative to the shape base layer 110 surrounding edge 260. In some embodiments, the curved shape can have a

maximum height 1412 and a maximum length 1414. In some embodiments, a ratio of maximum height 1412 to maximum length 1414 can range from 5:1 to 1:20, including subranges. For example, the ratio can range from 5:1 to 1:20, from 5:1 to 1:15, from 5:1 to 1:10, from 5:1 to 1:5, from 5:1 to 1:4, from 5:1 to 1:3, from 5:1 to 1:2, from 5:1 to 1:1, from 5:1 to 2:1, from 5:1 to 3:1, from 5:1 to 4:1, from 4:1 to 1:20, from 3:1 to 1:20, from 2:1 to 1:20, from 1:1 to 1:20, from 1:2 to 1:20, from 1:3 to 1:20, from 1:4 to 1:20, from 1:5 to 1:20, from 1:10 to 1:20, or from 1:15 to 1:20. Unless specified otherwise, maximum height 1412 is measured relative to a flat surface 1450 on which material 1400 is placed with the portion of base layer 110 surrounding edge 260 laid flat on the surface 1450 as shown in FIG. 14B. Other than forces applied to position material 1400 on surface 1450 as shown in FIG. 14B, no external load is applied to material 1400 for purposes of measuring height 1412. Unless specified otherwise, maximum length 1414 is defined by the largest lateral dimension measured in a straight line along surface 1450 between opposing sides of edge 260. Other than forces applied to position material 1400 on surface 1450 as shown in FIG. 14B, no external load is applied to material 1400 for purposes of measuring length 1414.

[0203] In some embodiments, material 1400 can comprise a plurality of shaped areas 1410 on base layer 110. In some embodiments, the plurality of shaped areas can provide a desired texture for an article of apparel comprising material 1400.

[0204] In some embodiments, thread layers (or thread patterns) as described herein can comprise one or more molded parts. In some embodiments, a thread layer (or thread pattern) can comprise a plurality of molded parts. In some embodiments, a molded part can comprise a curved shape.

[0205] With reference to FIGS. 20A - 21B, material 2000 comprises a base layer 110 and a thread layer 2020 comprising thread lines 2024 disposed in a pattern with adjacent thread lines extending linearly relative to each other such that adjacent thread lines 2024 do not overlap. In some embodiments, the adjacent thread lines 2024 can extend parallel to each other. FIGS. 20A and 21A show material 2000 with base layer 110 in a stretched position under tension. FIGS. 20B and 21B show material 2000 with base layer 110 in a relaxed position with no tension applied.

[0206] In some embodiments, thread lines 2024 of thread layer 2020 can apply a compressive force on the surface 112 of the base layer 110 along an axis extending from a first end 2026 to a second end 2028 of the thread lines 2024. In some embodiments, thread lines 2024 of thread layer 2020 may not apply a compressive force on the surface 112 of the base layer 110 along an axis extending from a first end 2026 to a second end 2028 of the thread lines 2024. In some embodiments, thread lines 2024 of thread layer 2020 can comprise overlaying thread lines.

[0207] As shown in FIGS. 20A and 21A, adjacent thread lines 2024 can be spaced apart on surface 112 of base layer 110 by a spacing length 2025 when base layer 110 is in the stretched position. In some embodiments, the spacing length 2025 between adjacent thread lines 2024 can be constant across thread layer 2020. In some embodiments, spacing length 2025 between adjacent thread lines 2024 can vary across thread layer 2020. In such embodiments, spacing length 2025 can vary in the same way as described below for spacing lengths 2225a, 2225b.

[0208] As shown in FIGS. 20B and 21B, the spacing between adjacent thread lines 2024 changes when base layer 110 in a relaxed position with no tension applied. The spacing can change due to the thread lines 2024 being bonded to portions of base layer 110 while other portions of the base layer 110 between the thread lines 2024 are free to contract when the tension is removed.

[0209] Material 2000 with the tension removed can comprise a corrugated or crimped structure comprising a plurality of ridges 2010 and a plurality of groves 2018. Ridges 2010 and grooves 2018 can be disposed in an alternating fashion with grooves 2018 disposed between two ridges 2010 and ridges 2010 disposed between two grooves 2018. Grooves 2018 can comprise a concave shape formed by surface 112 of base layer 110. Ridges 2010 can comprise a convex shape formed by surface 112 of base layer 110. Thread lines 2024 can be located within grooves 2018 on surface 112 of base layer 110.

[0210] As illustrated in FIGS. 20A - 21B, the spacing between adjacent thread lines 2024 reduces from spacing length 2025 to create ridges 2010 comprising a base length 2014. Unless specified otherwise, base length 2014 is defined by the maximum lateral dimension of ridges 2010 measured in cross-section in a straight line between opposing interior surfaces of ridges 2010 and between adjacent thread lines 2024. Base length 2014 is measured parallel to a flat surface 2050 as illustrated in FIG. 21B. Other than forces applied to position material 2000 on surface 2050 as shown in FIG. 21B, no external load is applied to material 2000 for purposes of measuring base length 2014.

[0211] In some embodiments, base length 2014 can be "zero," meaning that opposing interior surfaces of ridges 2010 are in contact on material 2000. In some embodiments, the base length 2014 for ridges 2010 can range from 0.5 centimeters (cm) to 10 cm, including subranges. For example, base length 2014 can range from 0.5 cm to 10 cm, from 0.5 cm to 5 cm, from 0.5 cm to 4 cm, from 0.5 cm to 3 cm, or from 0.5 cm to 2 cm. The base length 2014 for a plurality of ridges 2010 can be defined by an average base length 2014 for the ridges 2010.

[0212] In some embodiments, ridges 2010 can comprise a maximum length 2016 greater than base length 2014. In some embodiments, a ratio of base length 2014 to maximum length 2016 can range from 1:1.2 to 1:10, including subranges. For example, the ratio can range from 1:1.2 to 1:10, from 1:1.2 to 1:8, from 1:1.2 to 1:6, from 1:1.2 to 1:5, from 1:1.2 to 1:4, from 1:1.2 to 1:2, from

1:1.2 to 1:1, or from 1:1.2 to 1:1.5. Unless specified otherwise, maximum length 2016 is defined by the maximum lateral dimension of ridges 2010 measured in cross-section in a straight line between opposing interior surfaces of ridges 2010. Like base length 2014, maximum length 2016 is measured parallel to flat surface 2050 as illustrated in FIG. 21B. The maximum length 2016 for a plurality of ridges 2010 can be defined by an average maximum length 2016 for the ridges 2010.

[0213] In some embodiments, ridges 2010 can comprise a maximum height 2012 ranging from 0.5 cm to 10 cm, including subranges. For example, maximum height 2012 can range from 0.5 cm to 10 cm, from 0.5 cm to 5 cm, from 0.5 cm to 4 cm, from 0.5 cm to 3 cm, or from 0.5 cm to 2 cm. The maximum height 2012 for a plurality of ridges 2010 can be defined by an average maximum height 2012 for the ridges 2010. Unless specified otherwise, maximum height 2012 is measured relative to flat surface 2050 as shown in FIG. 21B. Other than forces applied to position material 2000 on surface 2050 as shown in FIG. 21B, no external load is applied to material 2000 for purposes of measuring height 2012.

[0214] In some embodiments, a ratio of maximum height 2012 to base length 2014 can range from 20:1 to 1:5, including subranges. For example, the ratio can range from 20:1 to 1:5, from 20:1 to 1:2, from 20:1 to 1:1, 20:1 to 2:1, from 20:1 to 5:1, from 20:1 to 10:1, from 20:1 to 15:1, from 15:1 to 1:5, from 10:1 to 1:5, from 5:1 to 1:5, from 2:1 to 1:5, from 1:1 to 1:5, or from 1:2 to 1:5.

[0215] With reference to FIGS. 22A - 22B, material 2200 comprises a base layer 110 and a thread layer 2220 comprising thread lines 2224 disposed in a pattern with thread lines 2224 overlapping each other at intersection points 2227. Interesting thread lines 2224 can bound a plurality of quadrilateral areas 2230 that are shaped when the tension applied to base layer 110 is removed and base layer 110 is in a relaxed state. While FIGS. 22A and 22B show quadrilateral areas 2230 in the shape of diamonds, interesting thread lines 2224 can bound any quadrilateral shape, including squares, rhombuses, rectangles, parallelograms, trapezoids, and kites. FIGS. 22A and 23A show material 2200 with base layer 110 in a stretched position under tension. FIGS. 22B and 23B show material with base layer 110 in a relaxed position with no tension applied.

[0216] In some embodiments, thread lines 2224 of thread layer 2220 can apply a compressive force on the surface 112 of the base layer 110 along an axis extending from a first end 2226 to a second end 2228 of the thread lines 2224. In some embodiments, thread lines 2224 of thread layer 2220 may not apply a compressive force on the surface 112 of the base layer 110 along an axis extending from a first end 2226 to a second end 2228 of the thread lines 2224. In some embodiments, thread lines 2224 of thread layer 2220 can comprise overlaying thread lines.

[0217] As shown in FIGS. 22A and 23A, adjacent thread lines 2224 can be spaced apart on surface 112 of base layer 110 by a spacing length 2225 when base layer 110 is in the stretched position. In some embodiments, the spacing length 2225 between adjacent thread lines 2024 can be constant across thread layer 2220. In some embodiments, spacing length 2225 between adjacent thread lines 2224 can vary across thread layer 2220. In such embodiments, the spacing length 2225 for a first plurality of thread lines 2224 can comprise a first spacing length 2225a and the spacing length for a second plurality of thread lines 2224 can comprise a second spacing length 2225b. In some embodiments, the first spacing length 2225a can be at least 10% greater than or less than the second spacing length 2225b. By varying the spacing length 2225 between adjacent thread lines 2224, the size of ridges 2210 and grooves 2218 can vary on material 2200.

[0218] As shown in FIGS. 22B and 23B, the spacing between adjacent thread lines 2224 changes when base layer 110 in a relaxed position with no tension applied. The spacing can change due to the thread lines 2224 being bonded to portions of base layer 110 while other portions of the base layer 110 between the thread lines 2224, and in particular portions of the base layer 110 in quadrilateral areas 2230, are free to contract when the tension is removed.

[0219] Material 2200 with the tension removed can comprise a corrugated or crimped structure comprising a plurality of ridges 2210 and a plurality of groves 2218. Ridges 2210 and grooves 2218 can be disposed in an alternating fashion with grooves 2218 disposed between two ridges 2210 and ridges 2210 disposed between two grooves 2218. Grooves 2218 can comprise a concave shape formed by surface 112 of base layer 110. Ridges 2210 can comprise a convex shape formed by surface 112 of base layer 110. Thread lines 2224 can be located within grooves 2218 on surface 112 of base layer 110.

[0220] As illustrated in FIGS. 22A - 23B, the spacing between adjacent thread lines 2224 reduces from spacing length 2225 to create ridges 2210 comprising a base length 2214. Unless specified otherwise, base length 2214 is defined by the maximum lateral dimension for ridges 2210 measured in cross-section in a straight line between opposing interior surfaces of ridges 2210 and between adjacent thread lines 2224. Base length 2214 is measured relative to surface 2250 in the same way as described above for base length 2014.

[0221] In some embodiments, base length 2214 can be "zero," meaning that opposing interior surfaces of ridges 2210 are in contact on material 2200. In some embodiments, the base length 2214 for ridges 2210 can be any value or within any range as described above for base length 2014 of ridges 2010. The base length 2214 for a plurality of ridges 2210 can be defined by an average base length 2214 for the ridges 2210.

[0222] In embodiments comprising varying spacing length 2225, ridges 2210 can comprise varying base lengths 2214. In such embodiments, the base length for a first plurality of ridges 2210 can comprise a first

base length 2214a and the base length for a second plurality of ridges 2210 can comprise a second base length 2214b. In some embodiments, the first base length 2214a can be at least 10% greater than or less than the second base length 2214b. In some embodiments, ridges 2210 can comprise a maximum length 2216 greater than base length 2214. In some embodiments, a ratio of base length 2214 to maximum length 2216 can be within any of the ranges described above for the ratio of base length 2014 and maximum length 2016. Maximum length 2216 is measured the same way as described above for maximum length 2016.

[0223] Ridges 2210 can comprise a maximum height 2212. Maximum height 2212 can be any value or within any range as described above for maximum height 2012 of ridges 2010. Maximum height 2212 is measured the same way as described above for maximum height 2012. In some embodiments, a ratio of maximum height 2212 to base length 2214a and/or base length 2214b can be in any of the ranges described above for the ratio of maximum height 2012 and base length 2014.

[0224] FIG. 15 illustrates a molding assembly 1500 for molding parts on a thread layer 1520 according to some embodiments. Mold assembly 1500 can comprise a support plate 1502 for supporting a thread layer 1520. In some embodiments, support plate 1502 can comprise anchor points 1590 around which thread layer 1520 can be wound. Anchor points 1590 can be, for example, pins or projections extending from a surface 1506 of support plate 1502.

[0225] As shown in FIG. 15, thread layer 1520 can be disposed over support plate 1502 such that at least a portion of thread layer 1520 is located within an opening 1504 defined by support plate 1502.

[0226] Mold assembly 1500 can also comprise one or more molds 1510 configured to mold a part (for example part 1530) on thread layer 1520 within opening 1504. In some embodiments, mold assembly 1500 can comprising a plurality of molds 1510.

[0227] Mold(s) 1510 can comprise a first mold plate 1512 and a second mold plate 1514 defining a mold cavity 1516. During use, material can be flowed into mold cavity 1516 through a port (for example port 1518) to mold parts 1530 on or around a portion of thread layer 1520. In some embodiments, a material can be injected into mold cavity 1516 through port 1518.

[0228] As shown in FIG. 15, a portion of thread layer 1520 can be disposed between a first mold plate 1512 and a second mold plate 1514 such that the portion of thread layer 1520 is located within mold cavity 1516. The portion of thread layer 1520 located within mold cavity 1516 can be fully or partially be embedded within a material molded with mold 1510.

[0229] FIG. 16 illustrates thread layer 1520 comprising molded parts 1530 according to some embodiments. In some embodiments, a portion of thread layer 1520 can be fully or partially embedded within each molded part 1530. In some embodiments, each molded part 1530 can be a separate part molded on a different portion of thread layer 1520.

[0230] In some embodiments, thread layer 1520 can define a first thread layer for a thread pattern comprising thread layer 1520 and a second thread layer 1522 disposed over the first thread layer 1520. In some embodiments, the second thread layer 1522 can be disposed over the molded parts 1530. In some embodiments, the second thread layer 1522 can be bonded to thread layer 1520. In some embodiments, the second thread layer 1522 can be directly bonded to thread layer 1520. In some embodiments, the second thread layer 1522 can be bonded to the molded parts 1530. In some embodiments, the second thread layer 1522 can be directly bonded to the molded parts 1530.

[0231] FIG. 17 illustrates a molding assembly 1700 for molding a curved part on a thread layer 1720 according to some embodiments. Mold assembly 1700 can comprise a support plate 1702 for supporting a thread layer 1720. In some embodiments, support plate 1702 can comprise anchor points 1790 around which thread layer 1720 can be wound. Anchor points 1790 can be, for example, pins or projections extending from a surface 1706 of support plate 1702.

[0232] As shown in FIG. 17, thread layer 1720 can be disposed over support plate 1702 such that at least a portion of thread layer 1720 is located within an opening 1704 defined by support plate 1702.

[0233] Mold assembly 1700 can also comprise one or more molds 1710 configured to mold a part (for example part 1730) on thread layer 1720 within opening 1704. In some embodiments, mold assembly 1700 can comprising a plurality of molds 1710.

[0234] Mold(s) 1710 can comprise a first mold plate 1712 and a second mold plate 1714 defining a mold cavity 1716. During use, material can be flowed into mold cavity 1716 through a port (for example port 1718) to a mold part 1730 on a portion of thread layer 1720. In some embodiments, a material can be injected into mold cavity 1716 through port 1718.

[0235] In some embodiments, first mold plate 1712 can comprise a curved surface 1713. In some embodiments, curved surface 1713 can comprise a convex curvature. In some embodiments, curved surface 1713 can comprise a concave curvature. In use, curved surface can be pressed against thread layer 1720 within opening 1704 such that a portion of thread layer 1720 takes on the shape of the curved surface. In such embodiments, mold 1710 can mold a part 1730 on thread layer 1720 having a desired concave or convex shape. And in such embodiments, the molded part 1730 can impart a desired shape to the portion of thread layer 1720 pressed against surface 1713 during molding.

[0236] In some embodiments, second mold plate 1714 can comprise a curved surface 1715. In some embodiments, curved surface 1715 can comprise a convex curvature. In some embodiments, curved surface 1715 can comprise a concave curvature

[0237] As shown in FIG. 17, a portion of thread layer 1720 can be disposed between a first mold plate 1712 and a second mold plate 1714 such that the portion of thread layer 1720 is located within mold cavity 1716 and pressed against surface 1713. The portion of thread layer 1720 located within mold cavity 1716 can be fully or partially be embedded within a material molded with mold 1710.

[0238] FIG. 18 illustrates thread layer 1720 comprising a curved molded part 1730 according to some embodiments. In some embodiments, a portion of thread layer 1720 can be fully or partially embedded within molded part 1730. Molded part 1730 comprises a first surface 1732 and a second surface 1734 opposite the first surface 1732. In some embodiments, first surface 1732 can be a curved surface comprising a convex curvature or a concave curvature. In some embodiments, second surface 1734 can be a curved surface comprising a convex curvature or a concave curvature.

[0239] In some embodiments, a portion of thread layer 1720 can be fully or partially embedded in second surface 1734. In such embodiments, thread layer 1720 comprises a first portion fully or partially embedded in second surface 1734 and a second portion not embedded in second surface 1734.

[0240] In some embodiments, thread layer 1720 can define a first thread layer for a thread pattern comprising thread layer 1720 and a second thread layer 1722 disposed over the first thread layer 1720. In some embodiments, the second thread layer 1722 can be disposed over molded part 1730. In some embodiments, the second thread layer 1722 can be bonded to thread layer 1720. In some embodiments, the second thread layer 1722 can be directly bonded to thread layer 1720. In some embodiments, the second thread layer 1722 can be bonded to surface 1732 of molded part 1730. In some embodiments, the second thread layer 1522 can be directly bonded to surface 1732 of molded part 1730.

[0241] Suitable materials for molding with mold 1510, 1710 comprise, but are not limited to, polymer materials, such as polymeric foams. Suitable polymeric foams comprise, but are not limited to an ethyl vinyl acetate (EVA) foam, a polyurethane (PU) foam, or expanded thermoplastic polyurethane (eTPU).

[0242] In some embodiments, molded parts 1530, 1730 can be padding, for example bra cups or padding plates. In some embodiments, molded parts 1530, 1730 can be rigid parts, such as shin guards or protective panels. In some embodiments, molded parts 1530, 1730 can be insulation, for example insulation panels.

[0243] While articles of apparel (for example, article of apparel 100) discussed herein may be described or illustrated in the context of a particular article (for example, a shirt), 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 headband, a wristband, or a tape.

[0244] 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.

[0245] 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.

[0246] 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.

[0247] 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.

Claims

1. An article of apparel (100, 600), comprising:

a base layer (110); and

a thread layer (120, 130, 140, 200, 220, 240, 620, 630, 640, 650) defined by a thread (202, 222, 242), the thread layer comprising a plurality of thread lines (204, 224, 244) crossing over each other at points of overlap (247) between two or more of the thread lines,

wherein each of the thread lines extends continuously across the thread layer,

wherein the thread lines are not woven or knitted threads,

wherein the thread lines are not embroidered threads stitched to the base layer, and

wherein each of the thread lines is directly bonded to a surface (112) of the base layer along

at least a portion of a length of the thread line.

2. The article of apparel of claim 1, wherein the thread layer occupies a surface area defined by a thread border (250) on the surface of the base layer,
wherein each of the thread lines comprises a first end (210) disposed at the thread border and a second end (212) disposed at the thread border; in particular wherein the first end and the second end of each of the thread lines are directly bonded to the surface of the base layer.

3. The article of apparel of claim 1 or 2, wherein the thread layer occupies a surface area defined by a thread border on the surface of the base layer, wherein the base layer comprises a perimeter edge (114) surrounding the thread border.

4. The article of apparel according to one of claims 1 to 3, wherein the base layer comprises a first piece of material and a second piece material adjacent to the first piece of material, and
wherein one or more of the thread lines extends across and is directly bonded to both the first piece of material and the second piece of material, in particular further comprising a gap between the first piece of material and the second piece material, wherein the one or more of the thread lines extends across the gap.

5. The article of apparel according to one of claims 1 to 3, wherein the base layer comprises a first piece of material and a second piece material joined together at a seam, and
wherein one or more of the thread lines extends across the seam and is directly bonded to both the first piece of material and the second piece of material.

6. The article of apparel according to one of claims 1 to 5, wherein each of the thread lines applies a compressive force on the surface of the base layer, the compressive force being applied along an axis extending from a first end to a second end of the thread line.

7. The article of apparel according to one of claims 1 to 6, further comprising a second thread layer defined by a second thread, the second thread layer comprising a plurality of second thread lines crossing over each other at points of overlap between two or more of the second thread lines,

wherein each of the second thread lines extends continuously across the second thread layer,
wherein the second thread lines are not woven or knitted threads,
wherein the second thread lines not embroidered threads stitched to the base layer, and
wherein each of the second thread lines is directly bonded to a surface of the base layer along at least a portion of a length of the second thread line.

8. The article of apparel according to one of claims 1 to 6, wherein each of the thread lines are directly bonded to the surface of the base layer at a perimeter of the thread layer to define a pocket between the thread layer and the base layer, in particular further comprising an insert disposed within the pocket, wherein the insert in particular comprises a shin guard.

9. The article of apparel according to one of claims 1 to 8, wherein the base layer comprises a foam material.

10. The article of apparel according to one of claims 1 to 9, wherein:

the base layer is a first base layer disposed below the thread layer,
the article of apparel further comprises a second base layer disposed above the thread layer, and
wherein each of the thread lines is directly bonded to a surface of the second base layer along at least a portion of a length of the thread line, in particular wherein the base layer comprises a foam material and the second base layer comprises a foam material.

11. An article of apparel, comprising:

a first thread layer (120, 130, 140, 200, 220, 240, 620, 630, 640, 650, 1210, 1250) comprising a first thread border and a first thread defining a plurality of first thread lines each extending from a first side of the first thread border to a second side of the first thread border and crossing over each other at points of overlap between two or more of the first thread lines;
a second thread layer (120, 130, 140, 200, 220, 240, 620, 630, 640, 650, 1210, 1250) disposed over the first thread layer and comprising a second thread border and a second thread defining a plurality of second thread lines each extending from a first side of the second thread border to a second side of the second thread border and crossing over each other at points of overlap between two or more of the second thread lines; and
a base layer (110) disposed between the first thread layer and the second thread layer;
wherein the first thread layer, the second layer, and the base layer are coupled together to form a chamber (1280) occupying a volume (1282) between the first thread layer and the second

thread layer.

12. The article of apparel of claim 11, wherein a portion of the base layer defines a portion of the chamber.

13. The article of apparel of claim 11 or 12, wherein the base layer, the first thread layer, and the second thread layer are attached at a seam located at an edge of the chamber.

14. The article of apparel according to one of claims 11 to 13, wherein the plurality of first thread lines are directly bonded to a surface of the base layer.

15. A method of making an article of apparel, the method comprising:
winding (320) 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; and
injecting (330) foam around at least a portion of the thread layer.

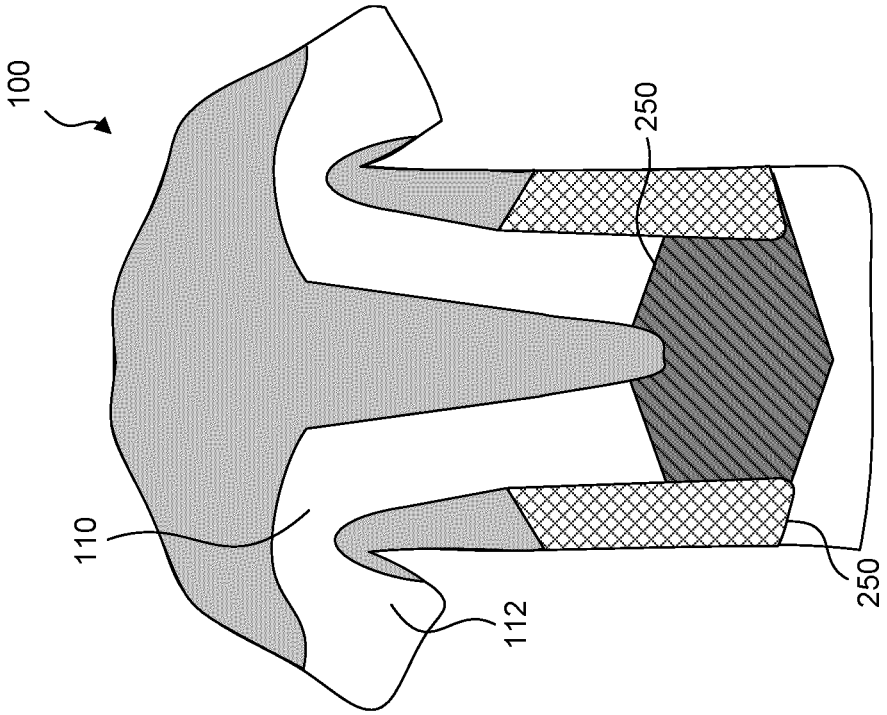

FIG. 1B

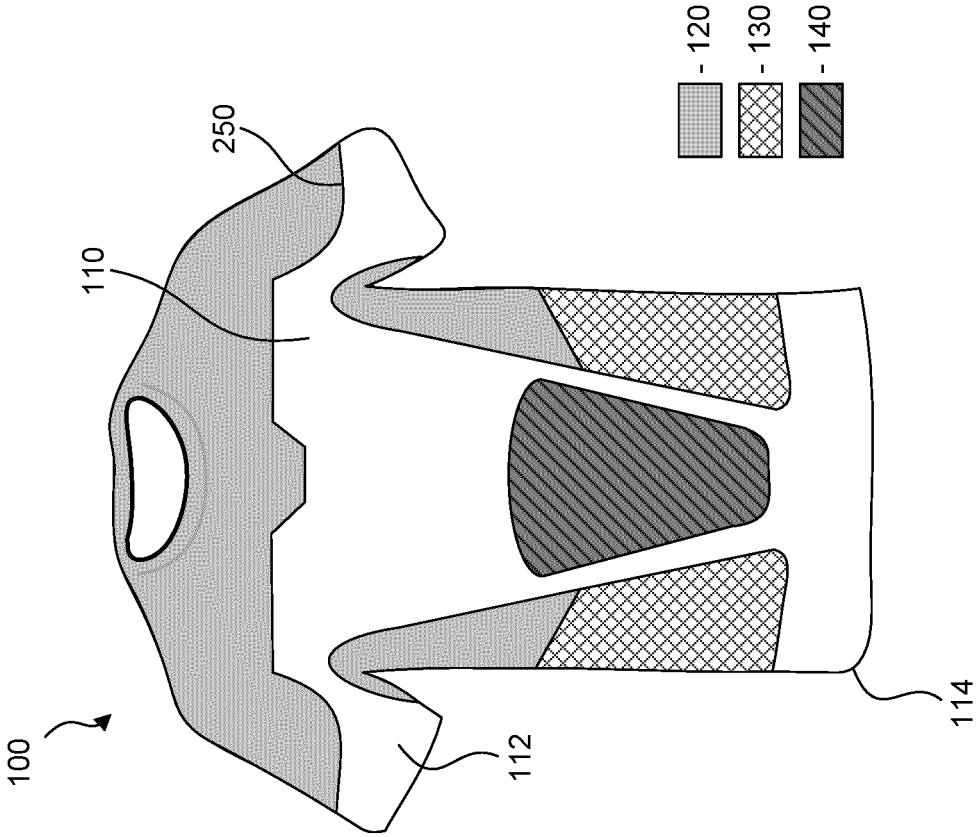

FIG. 1A

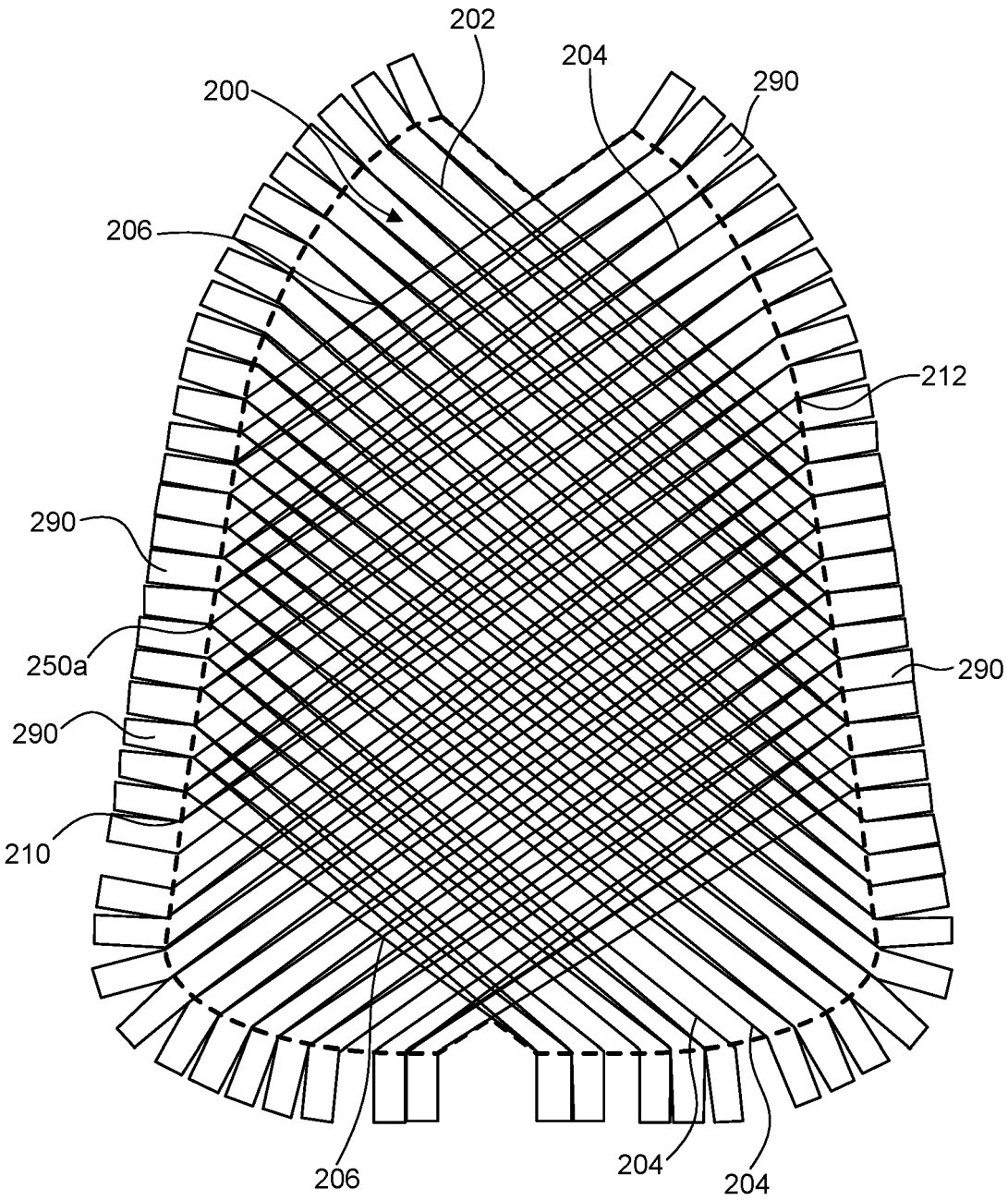

FIG. 2A

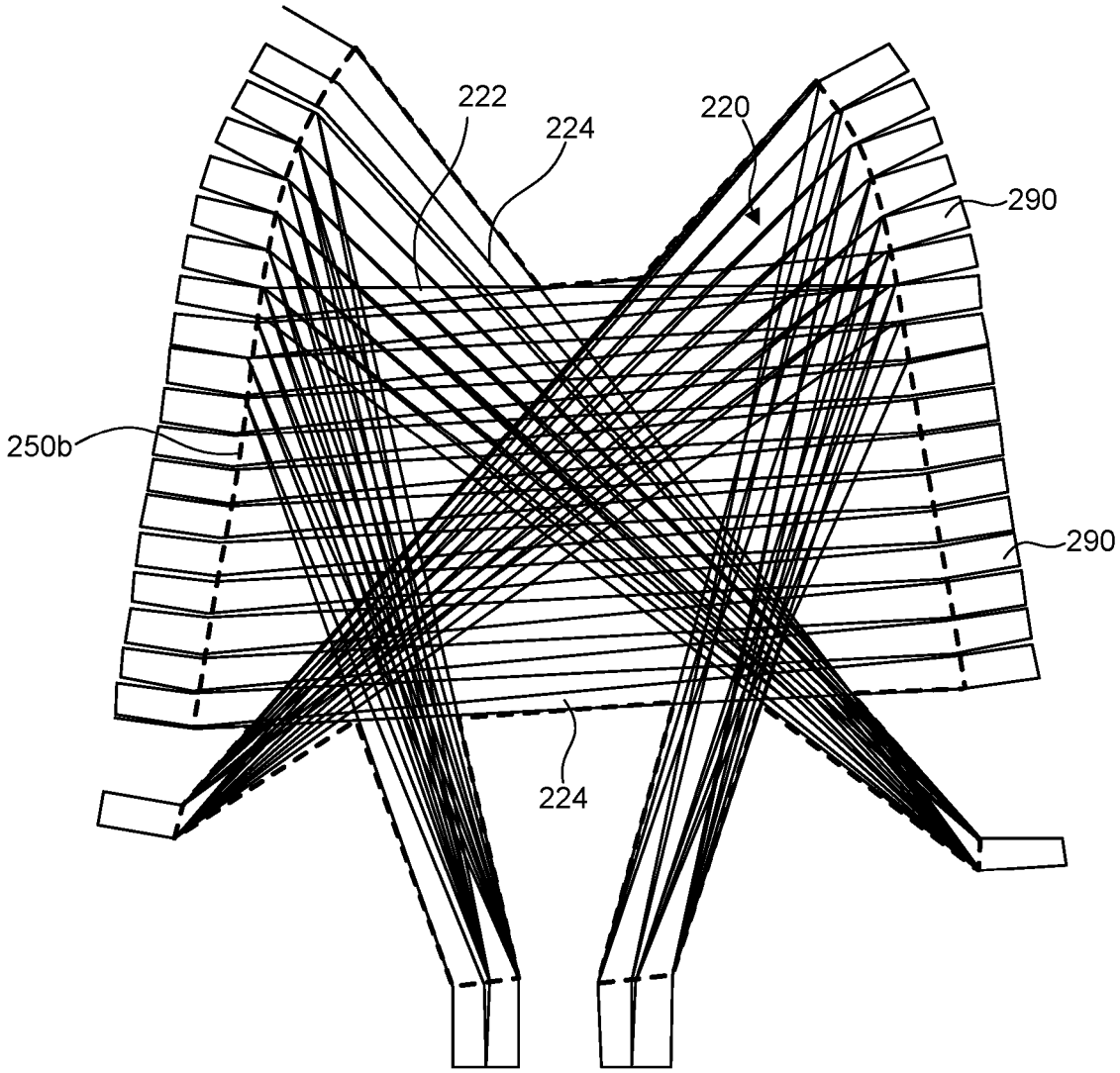

FIG. 2B

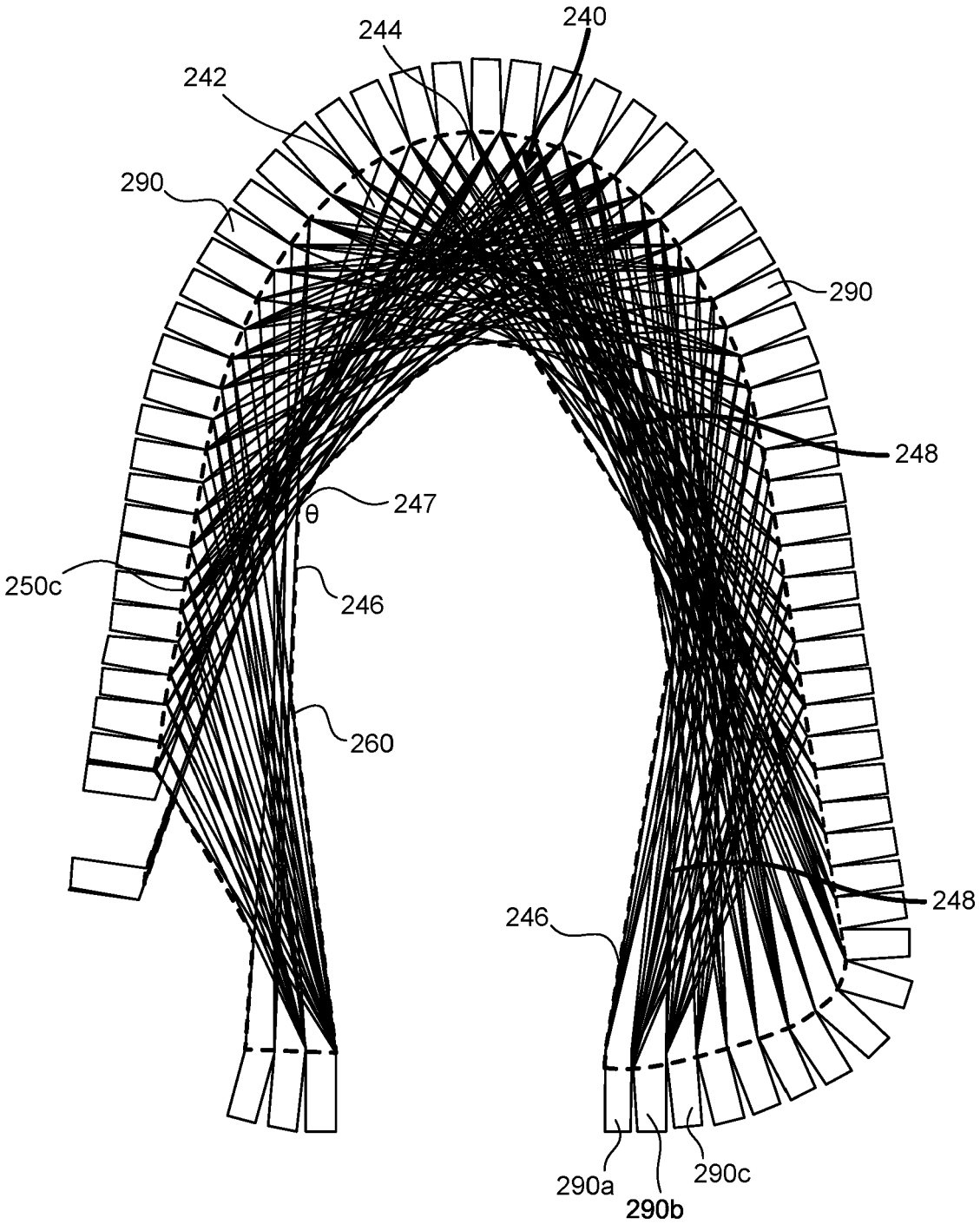
240
244
242
290
290
248
θ
247
250c
246
260
248
246
290a
290b
290c

FIG. 2C

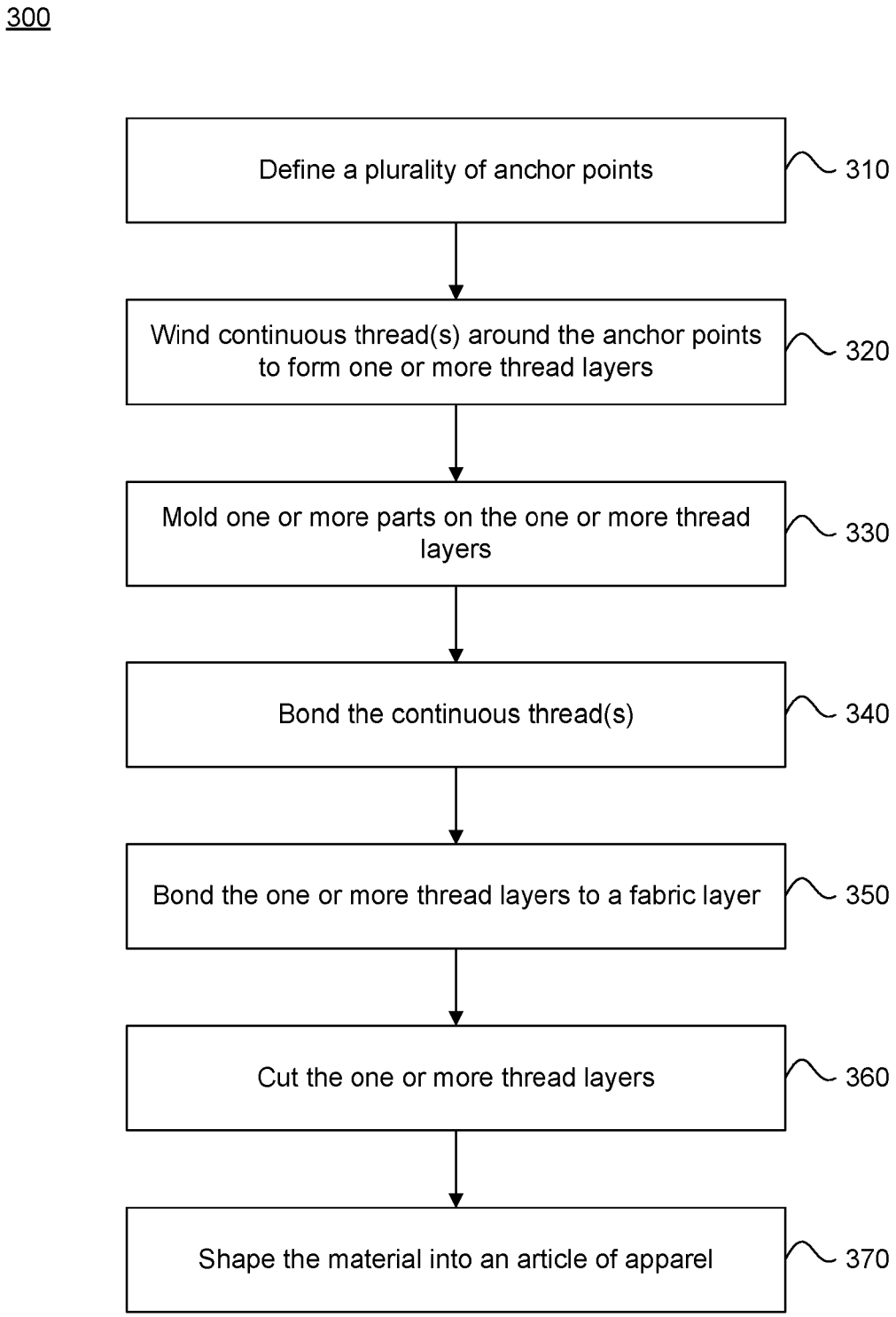
300
Define a plurality of anchor points
310
Wind continuous thread(s) around the anchor points to form one or more thread layers
320
Mold one or more parts on the one or more thread layers
330
Bond the continuous thread(s)
340
Bond the one or more thread layers to a fabric layer
350
Cut the one or more thread layers
360
Shape the material into an article of apparel
370

FIG. 3

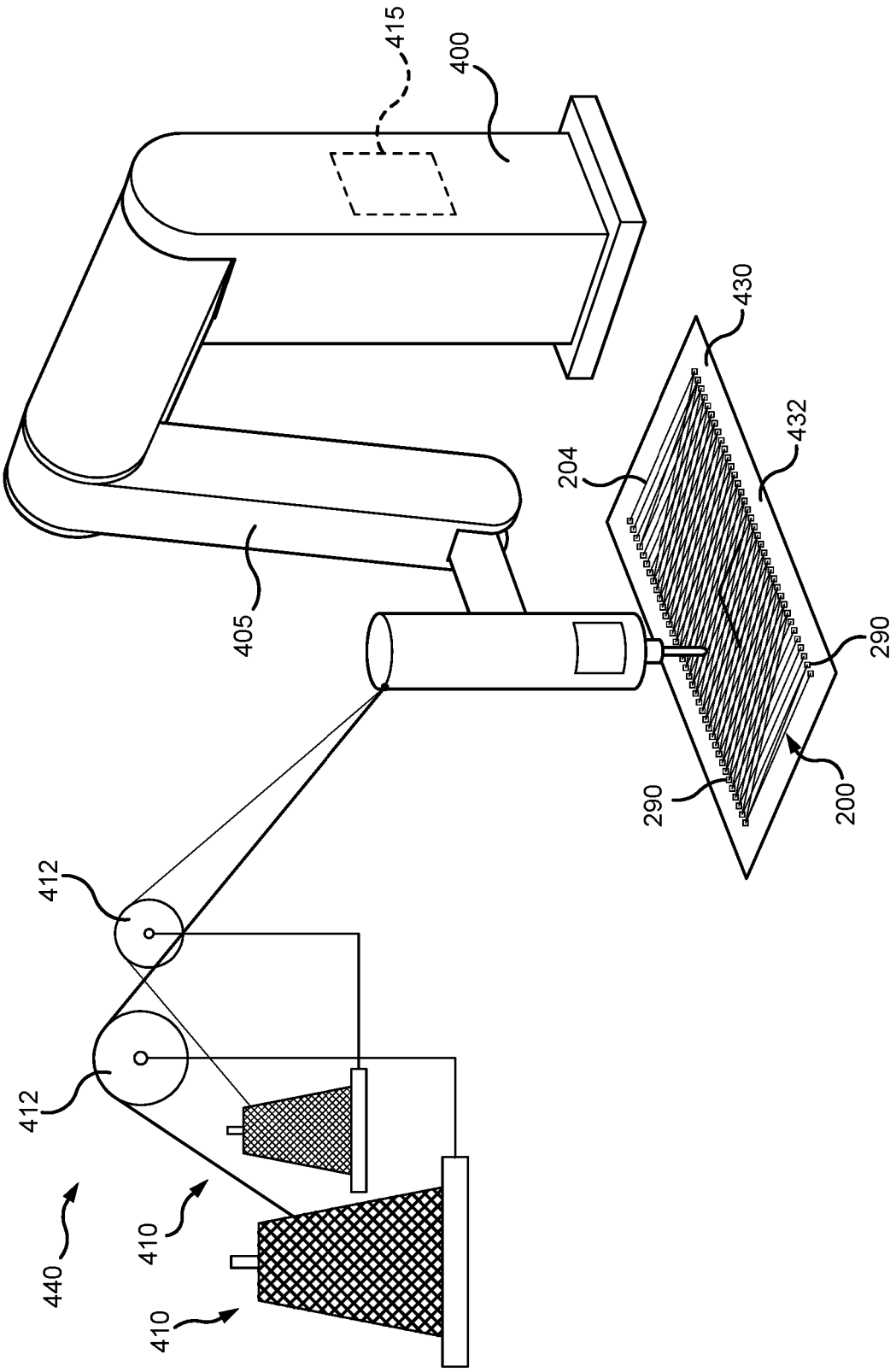

FIG. 4

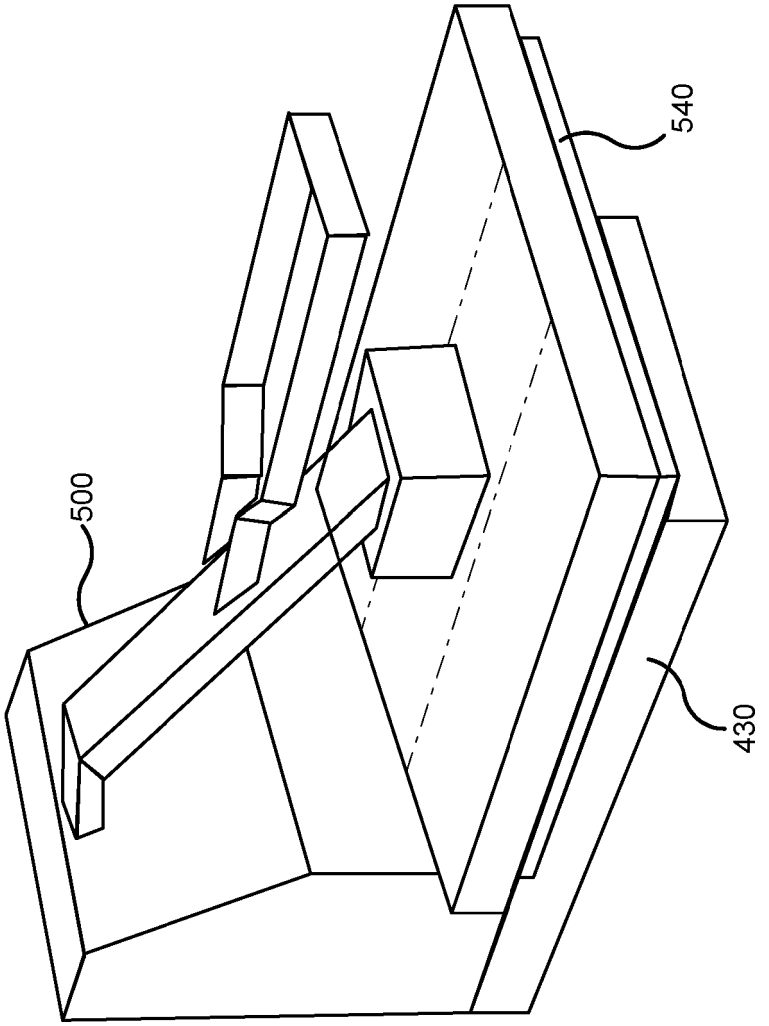

FIG. 5

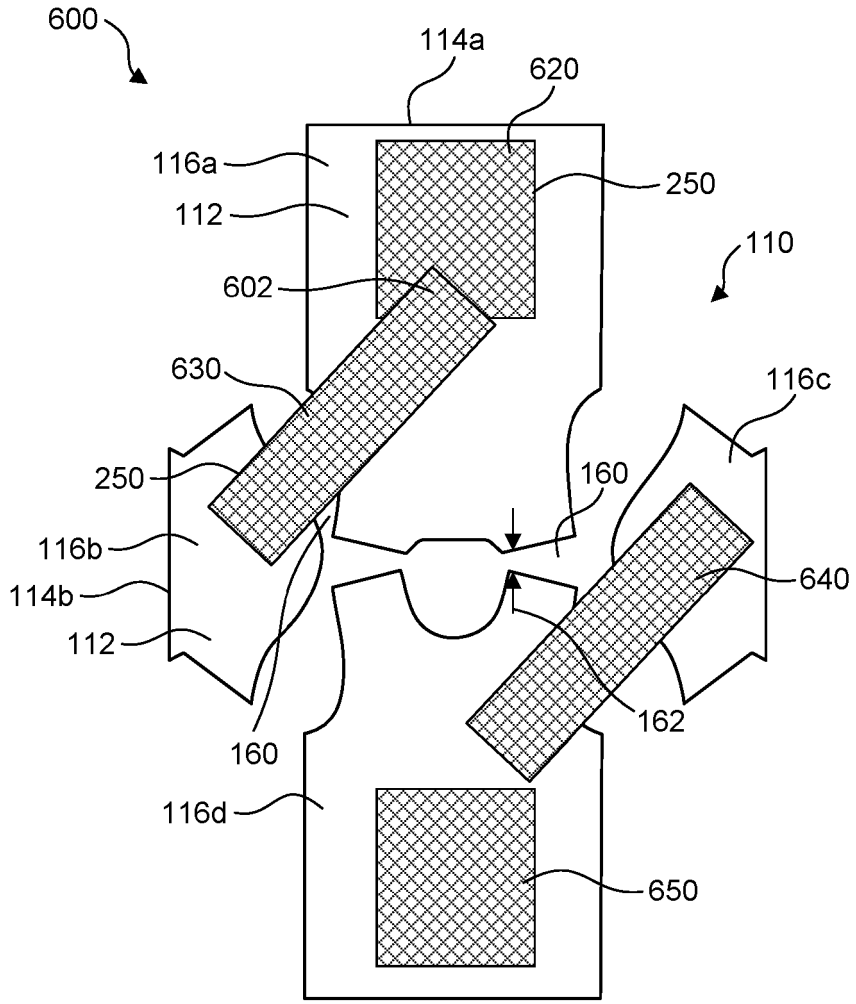
600
114a
620
116a
250
112
110
602
630
116c
250
160
116b
640
114b
112
162
160
116d
650

FIG. 6

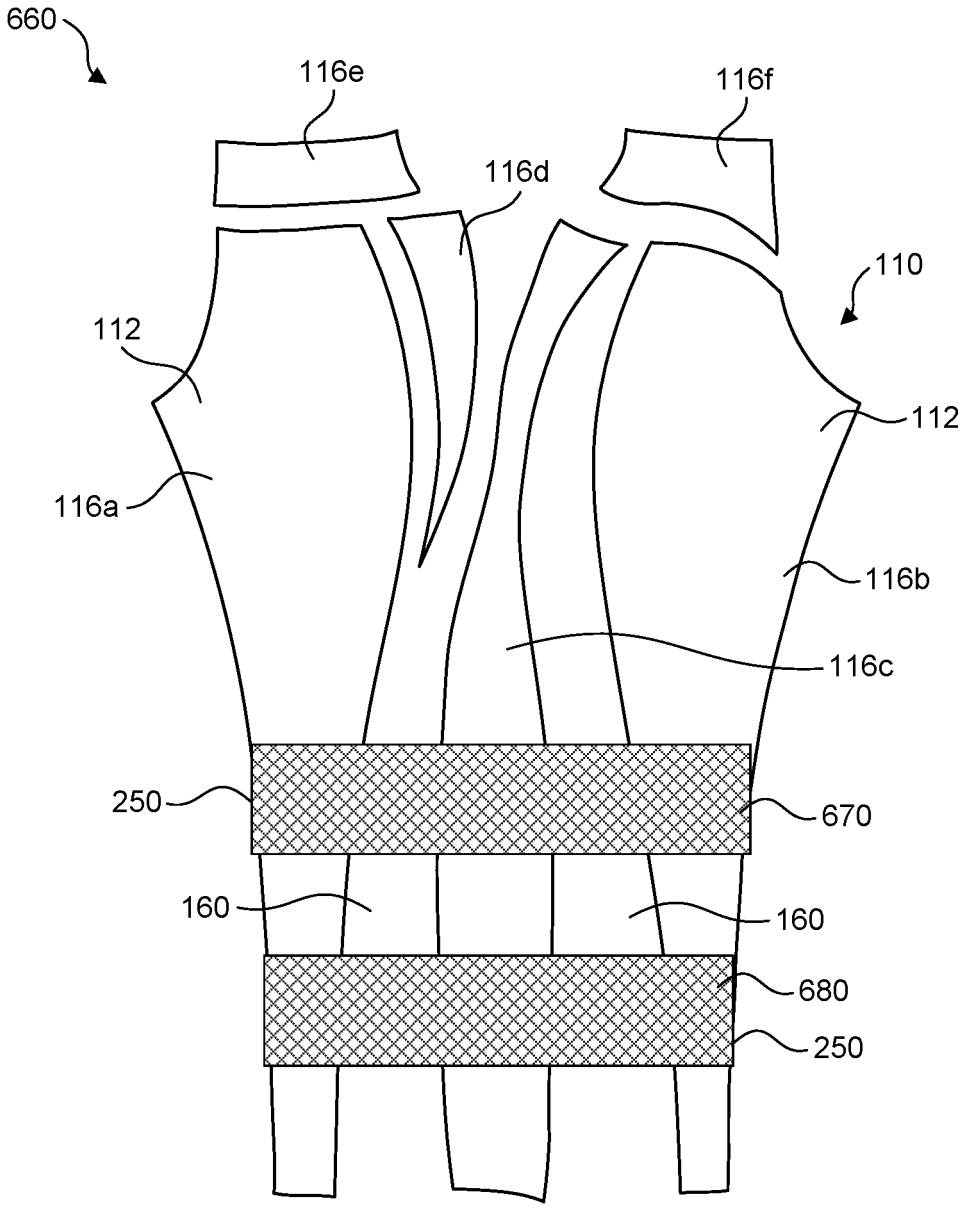
660
116e
116f
116d
110
112
112
116a
116b
116c
250
670
160
160
680
250

FIG. 7

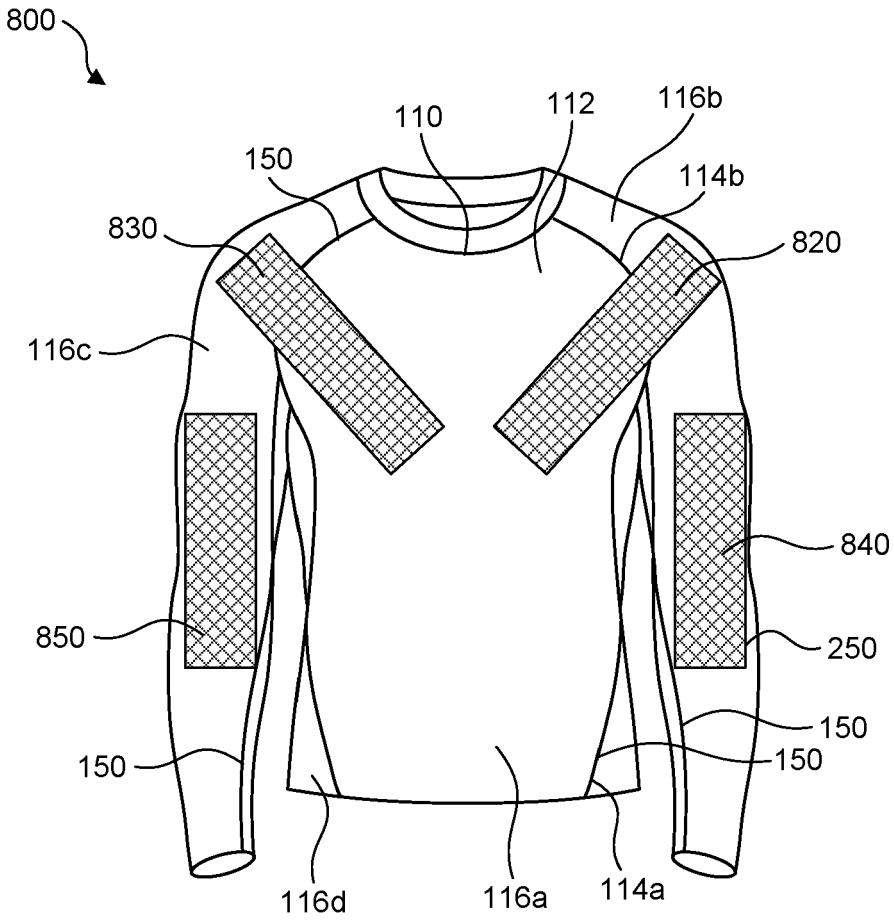
800
110
112
116b
150
114b
830
820
116c
840
850
250
150
150
150
116d
116a
114a

FIG. 8

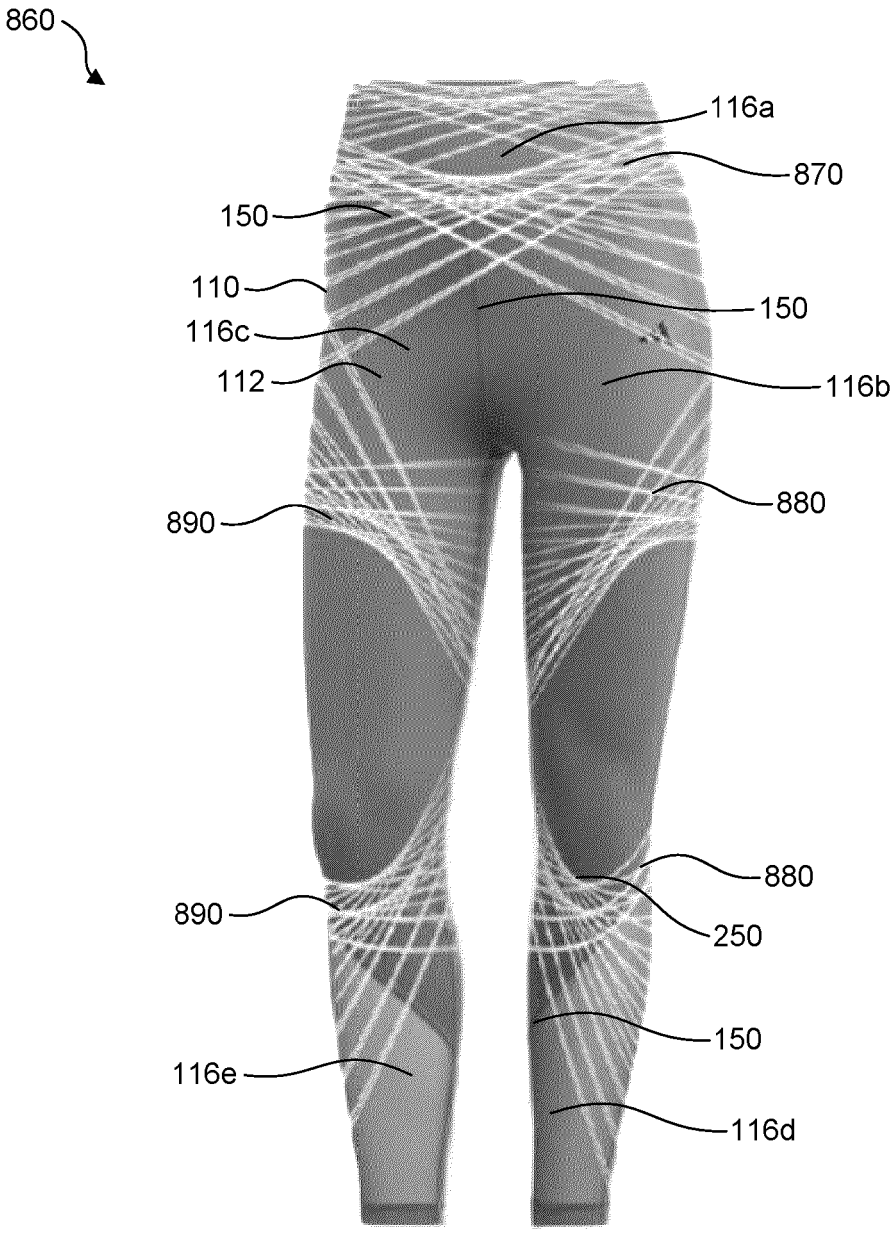
860
116a
870
150
110
150
116c
112
116b
880
890
880
890
250
150
116e
116d

FIG. 9

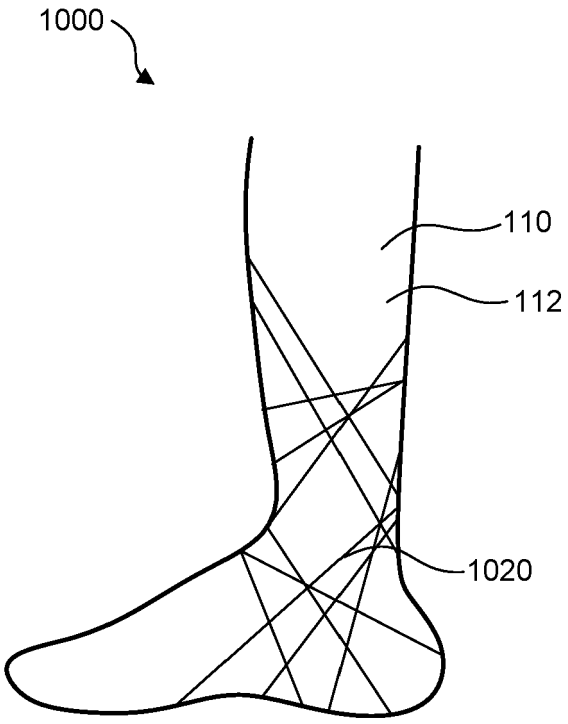

FIG. 10

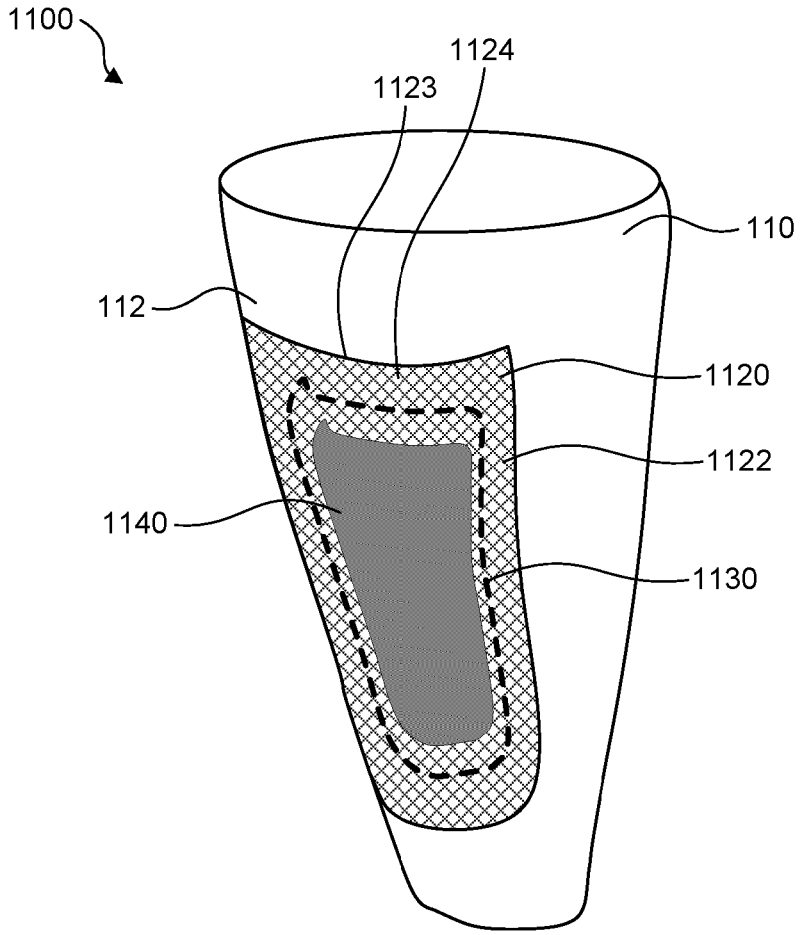

FIG. 11

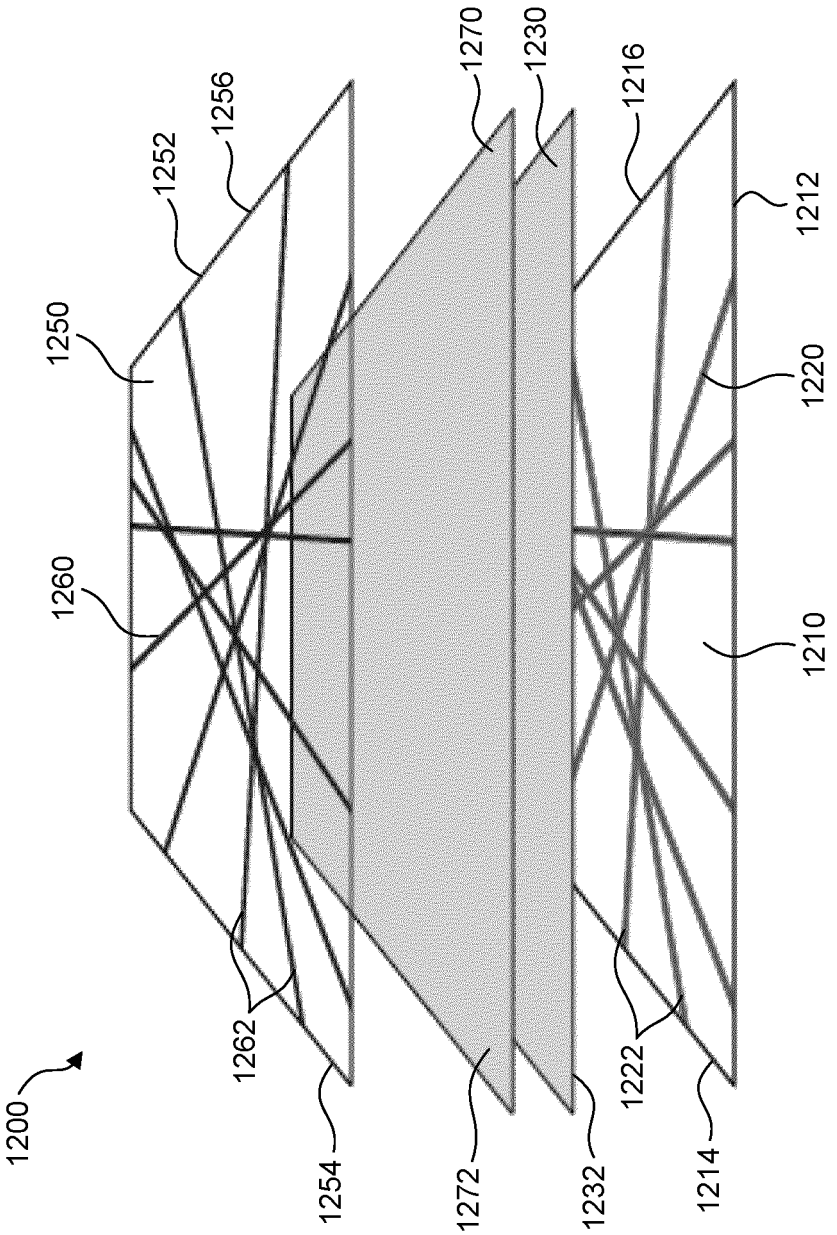
1200
1250
1252
1256
1260
1262
1254
1270
1272
1230
1232
1216
1222
1214
1212
1220
1210

FIG. 12

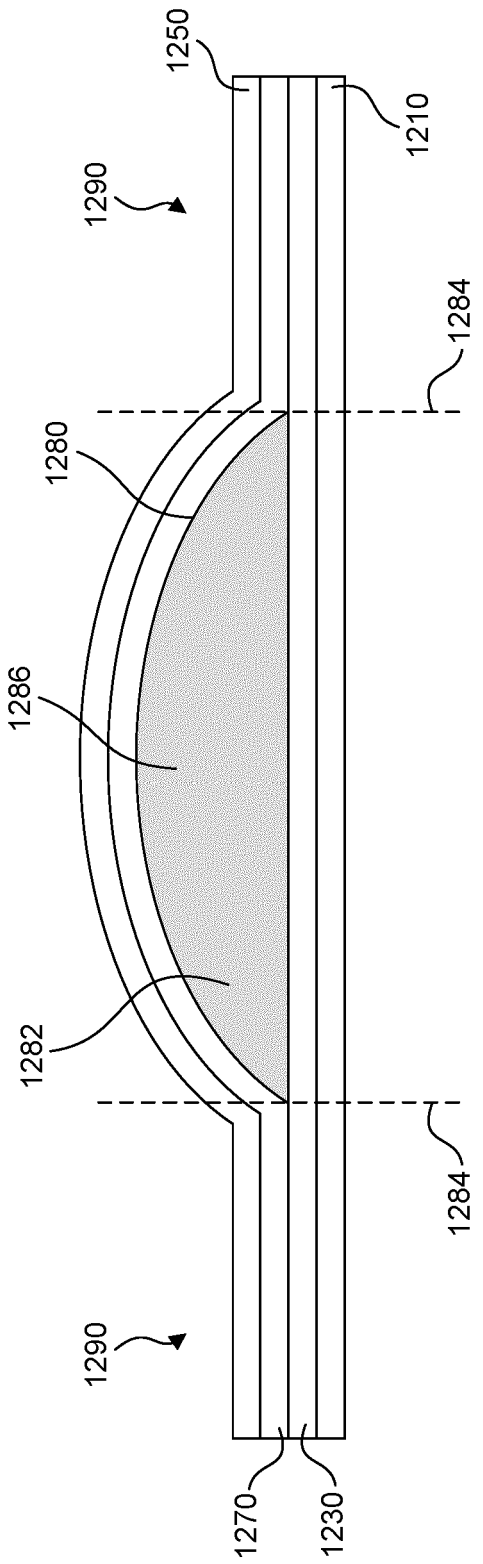

FIG. 13

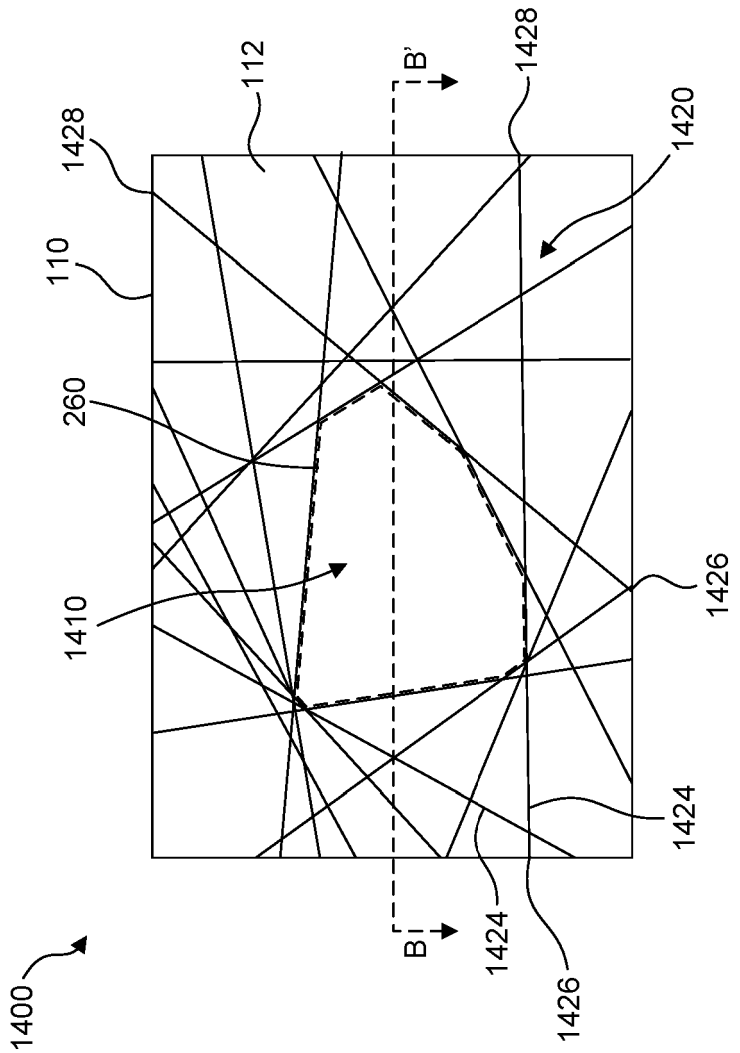

FIG. 14A

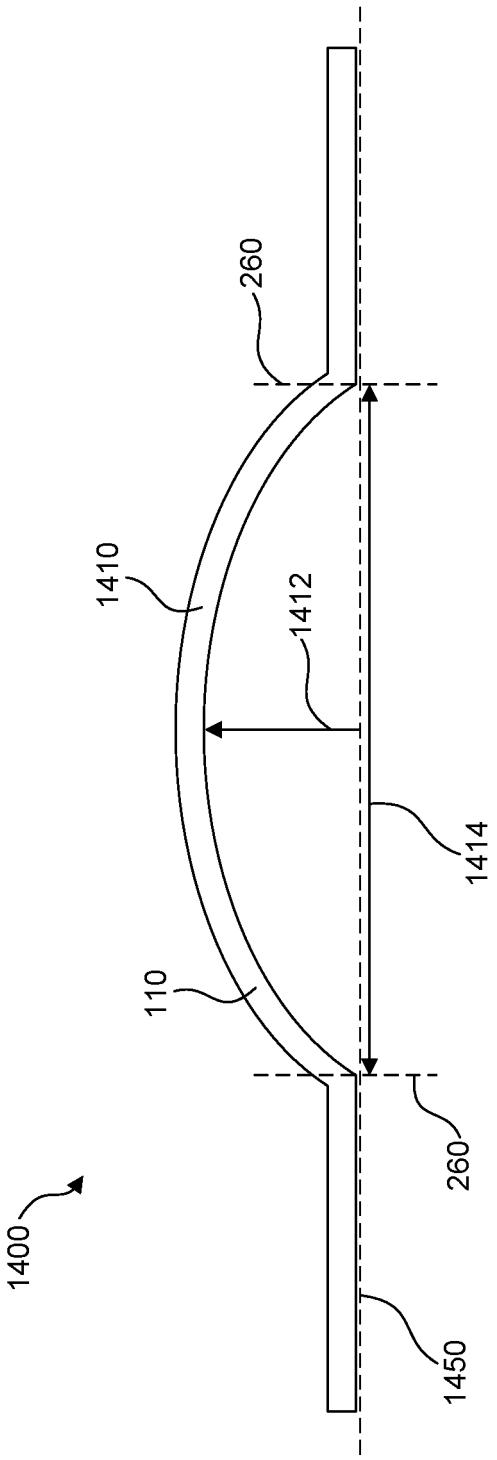

FIG. 14B

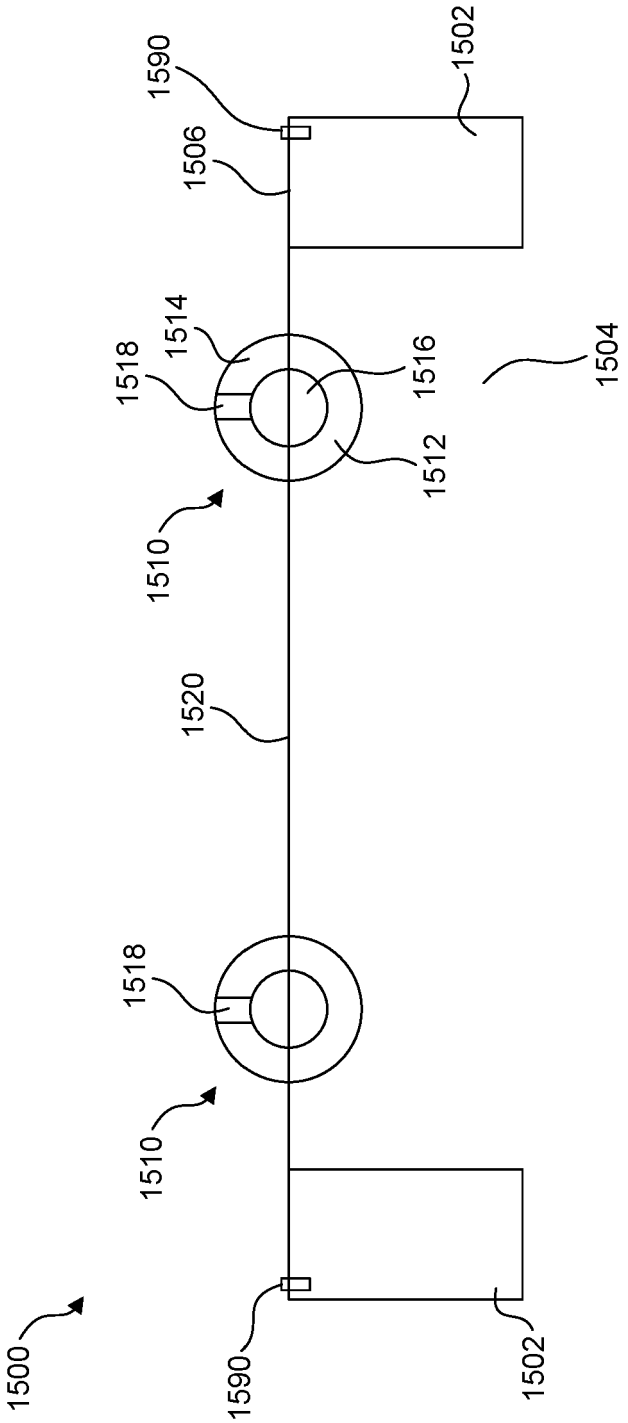
1500
1590
1502
1506
1514
1518
1516
1504
1512
1510
1520
1518
1510
1590
1502

FIG. 15

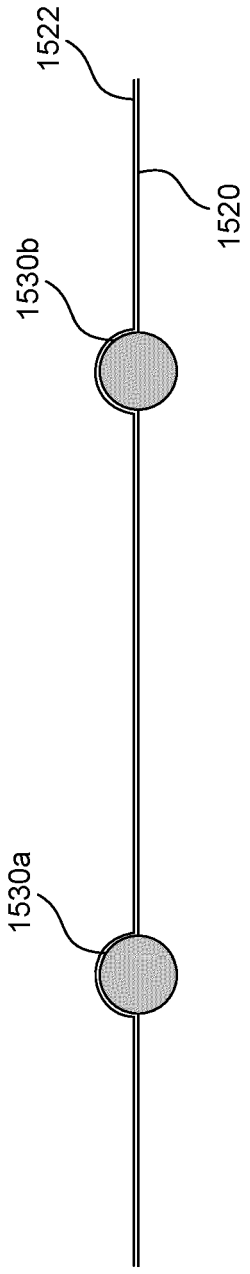

FIG. 16

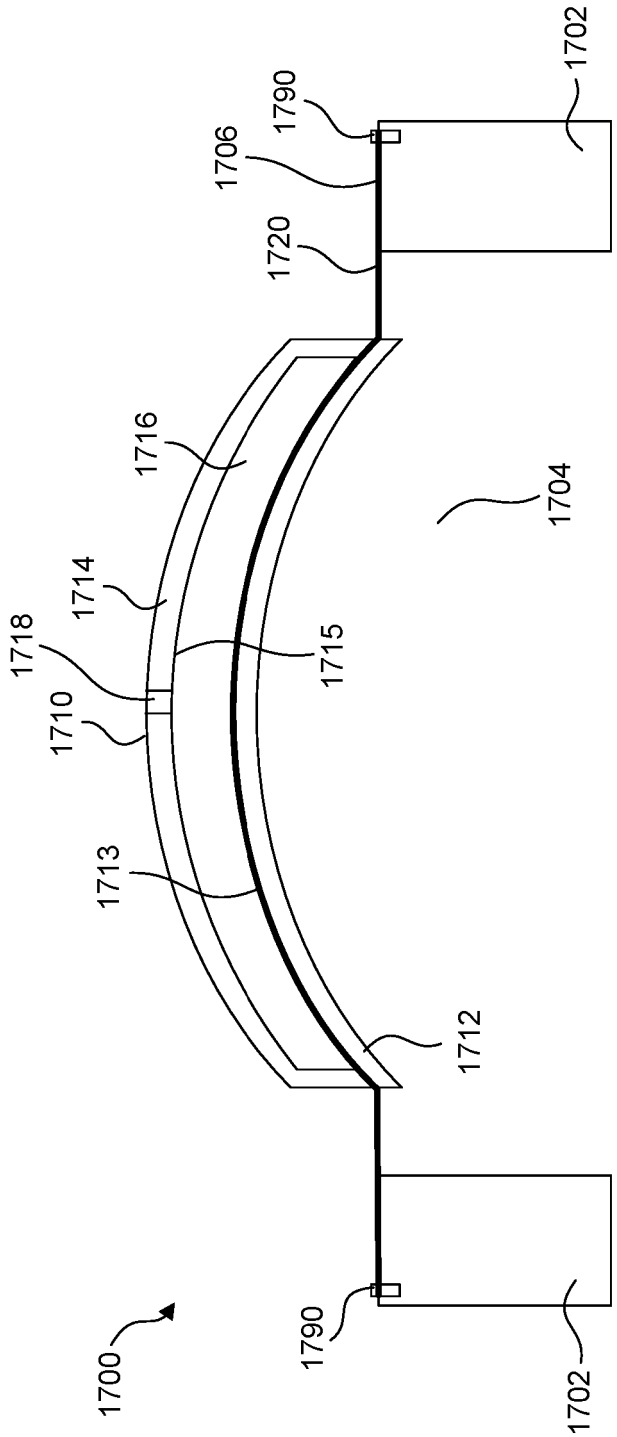
1700
1790
1702
1706
1720
1716
1704
1714
1718
1715
1710
1713
1712
1790
1702

FIG. 17

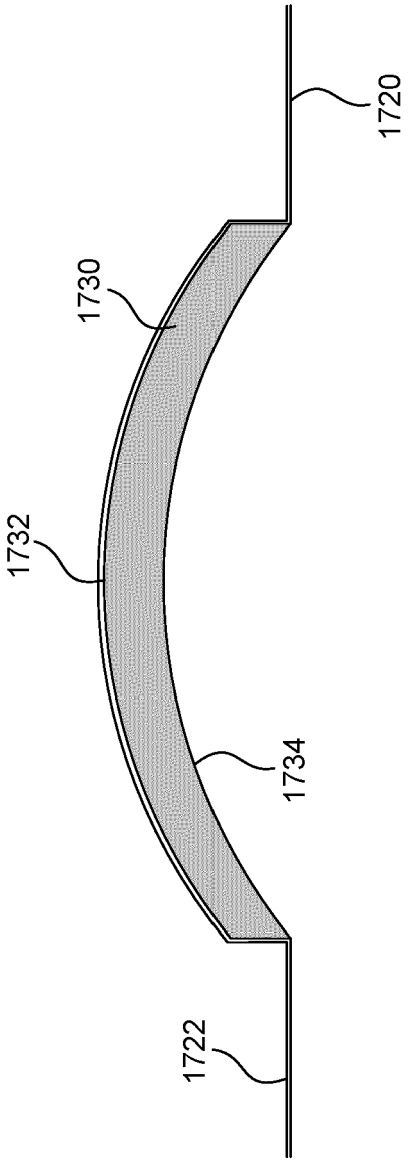

FIG. 18

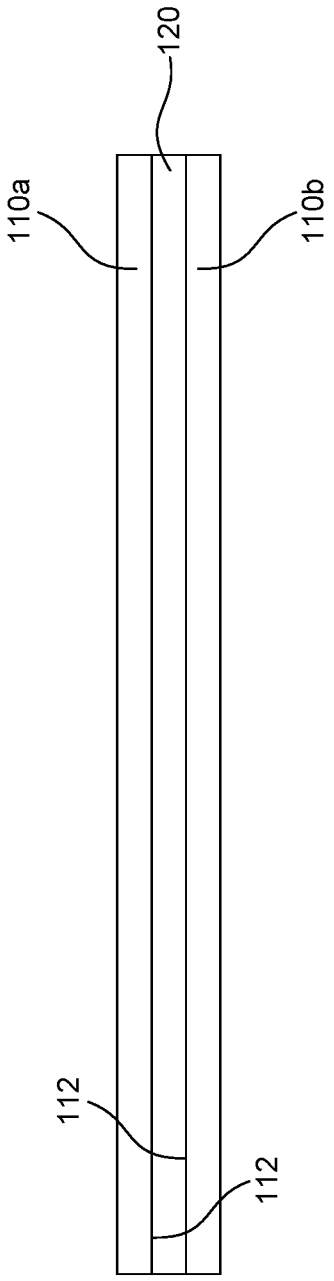

FIG. 19

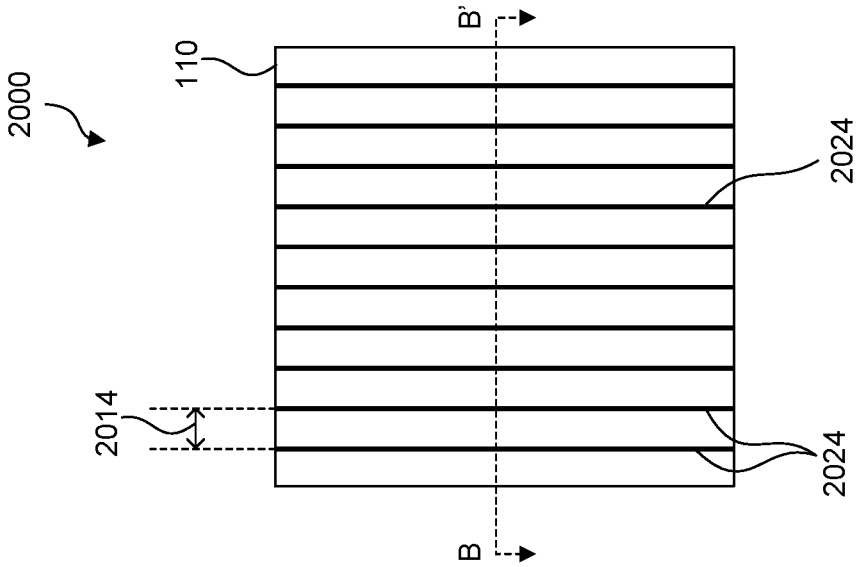

FIG. 20B

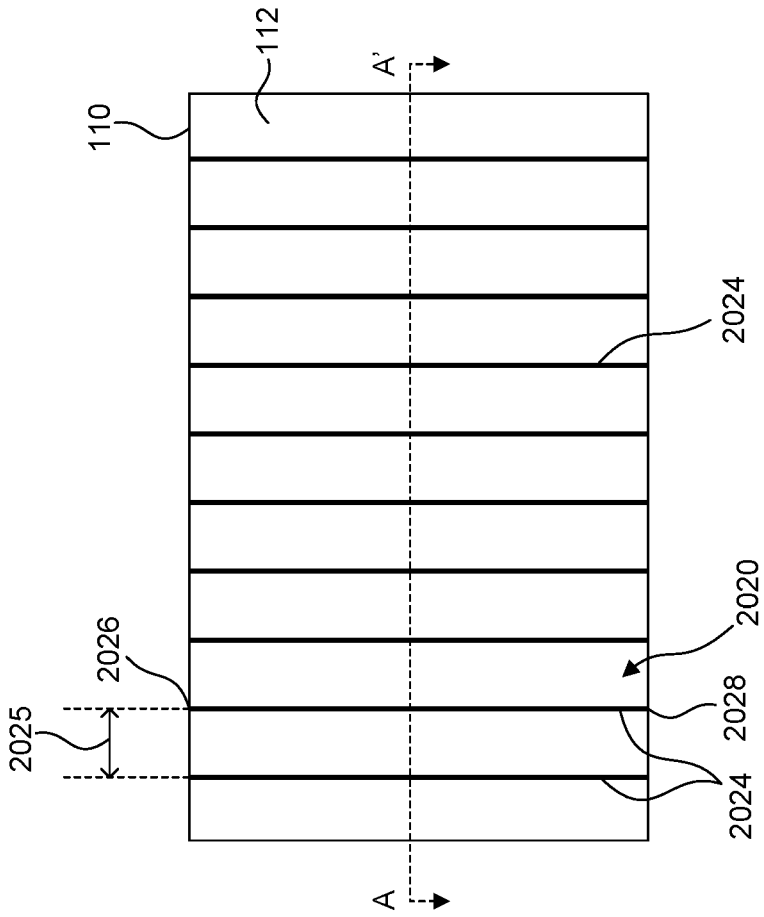

FIG. 20A

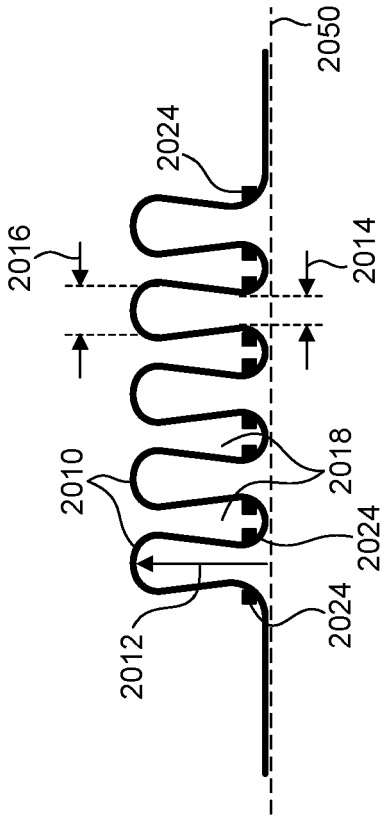

FIG. 21B

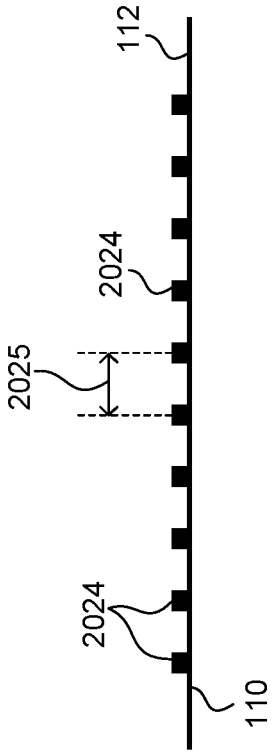

FIG. 21A

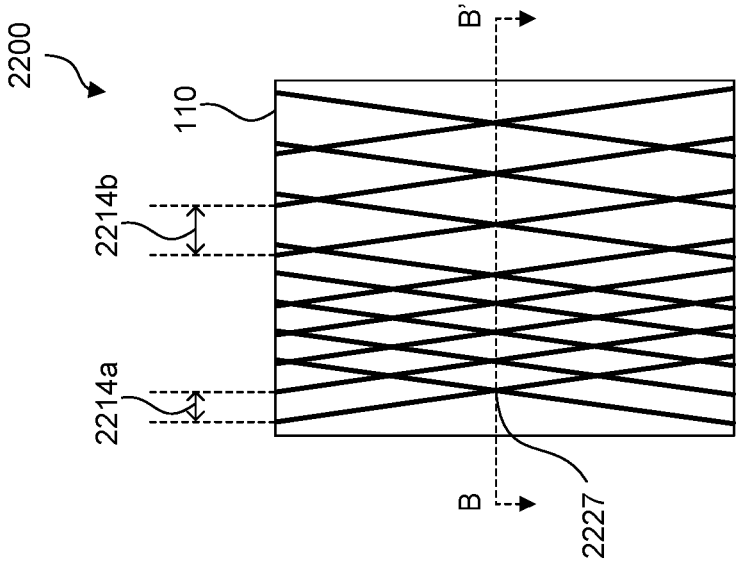

FIG. 22B

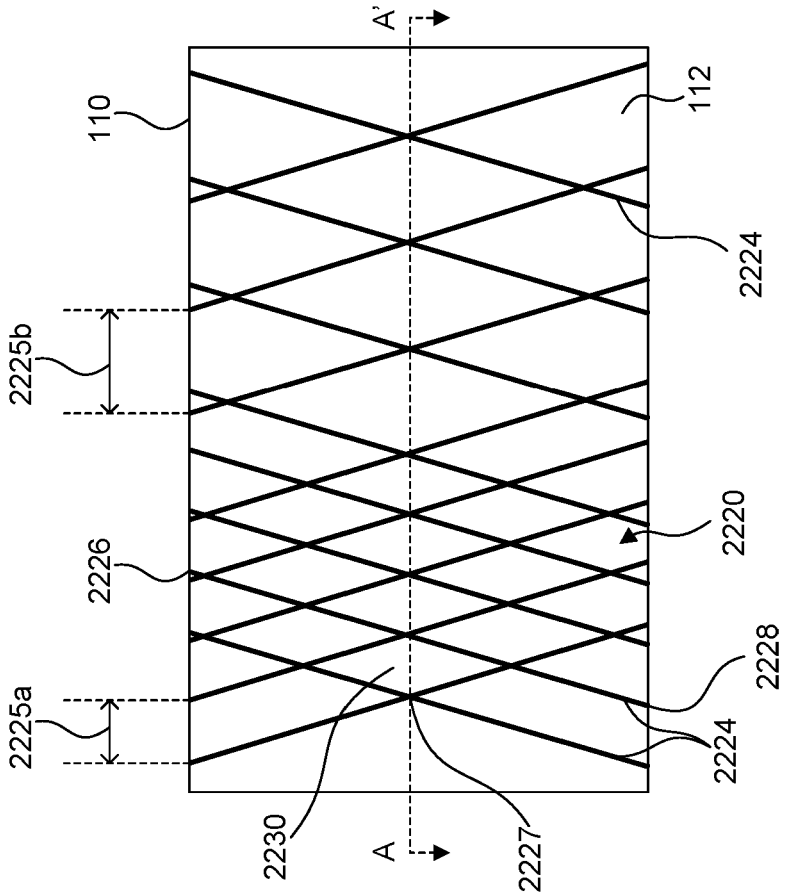

FIG. 22A

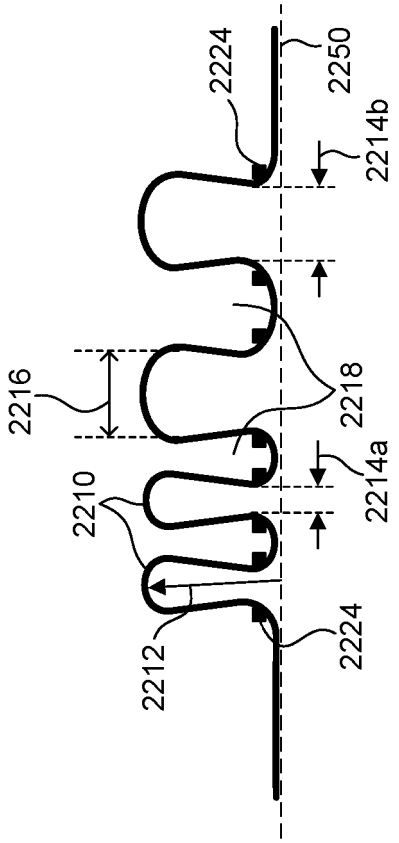

FIG. 23B

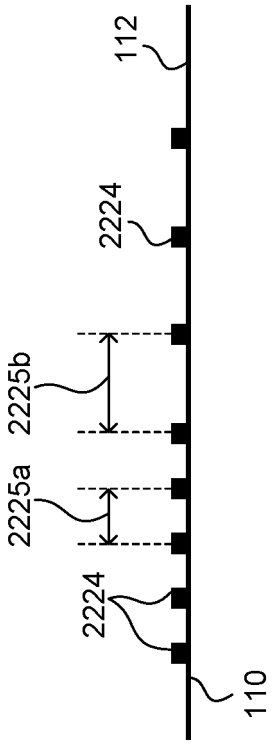

FIG. 23A