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(54) **PROTECTIVE GARMENT FOR IMPROVED WELDING PROTECTION**

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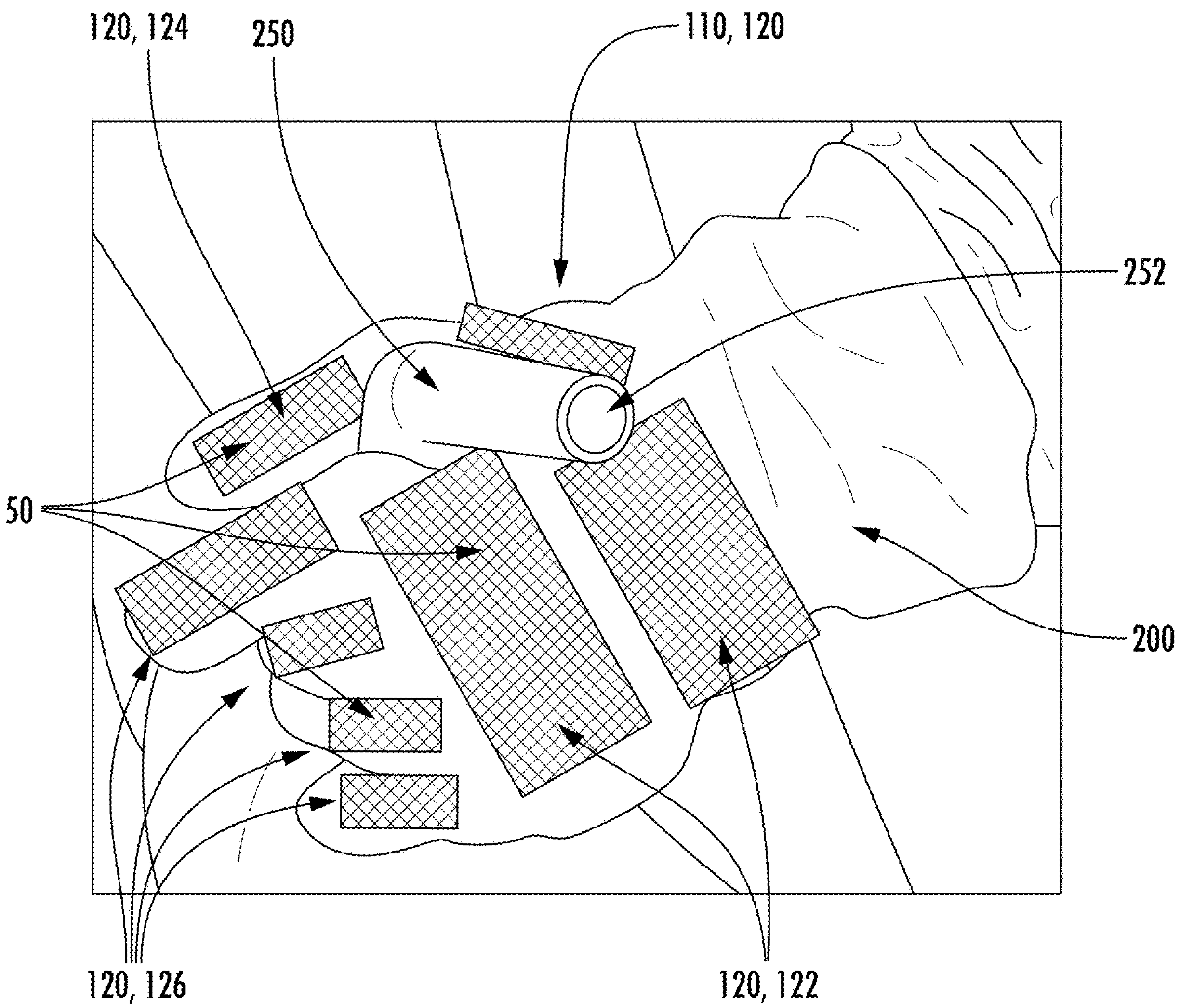
(57) **ABSTRACT**

A protective garment for providing improved safety and customization of personal protective equipment (PPE), and in particular, for welding protection from wire-sticks from exposed welding wires during welding. The protective garment includes a heat conducting composite made of one or more layers of a heat conducting material and one or more layers of a binder. The one or more heat conducting material layers may be a carbon fiber layer, such as a woven carbon-fiber layer, and the one or more binders may be an elastomeric binder, such as a polymer. As such, the heat conducting composite may be a carbon fiber reinforced polymer (CFRP) in which the elastomeric binder is used to hold the woven fibers and/or layers together. The heat conducting composite material may be used to form PPE, it may be formed into guards for use over PPE, or as an insert for use under PPE.



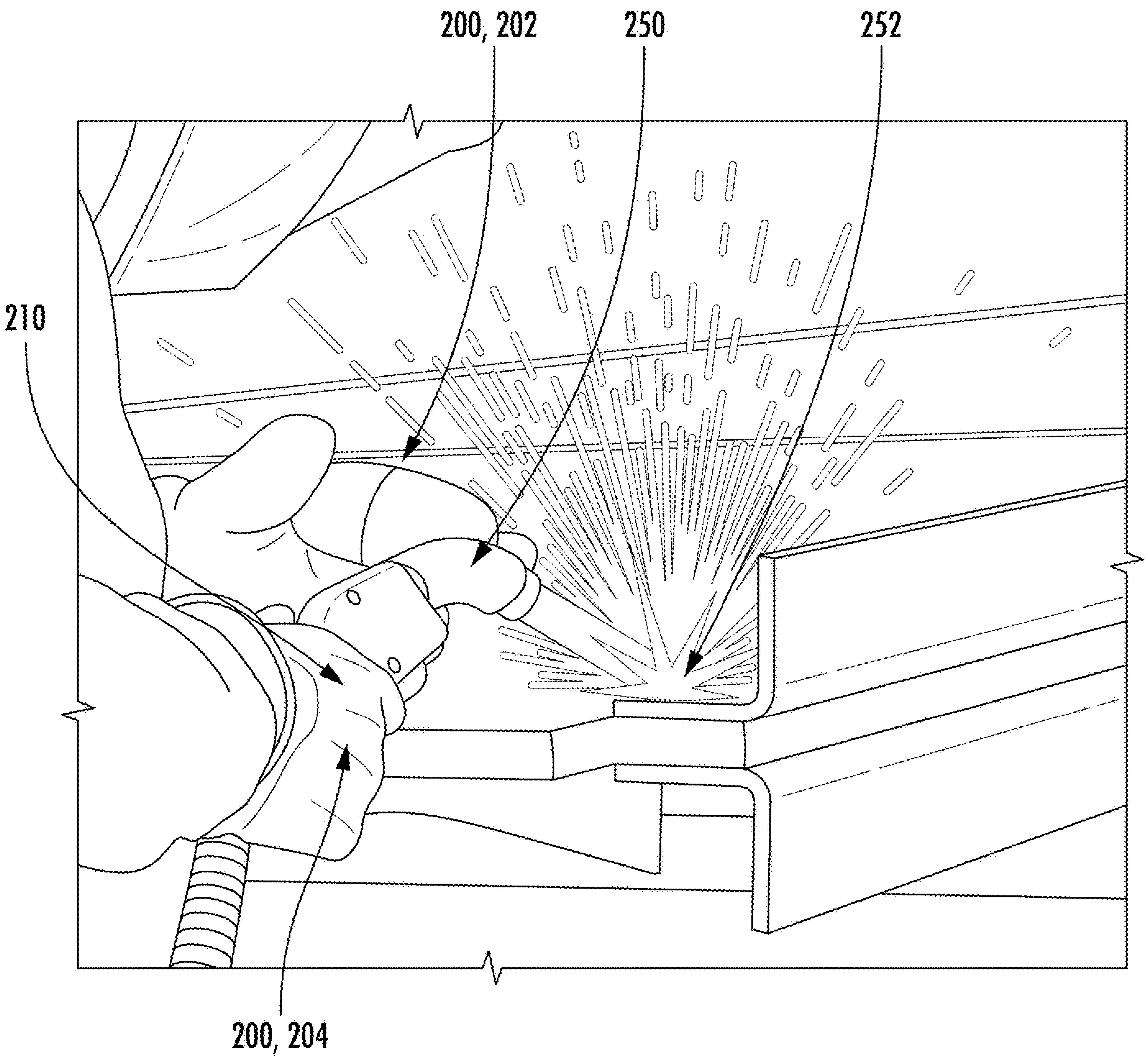



FIG. 1

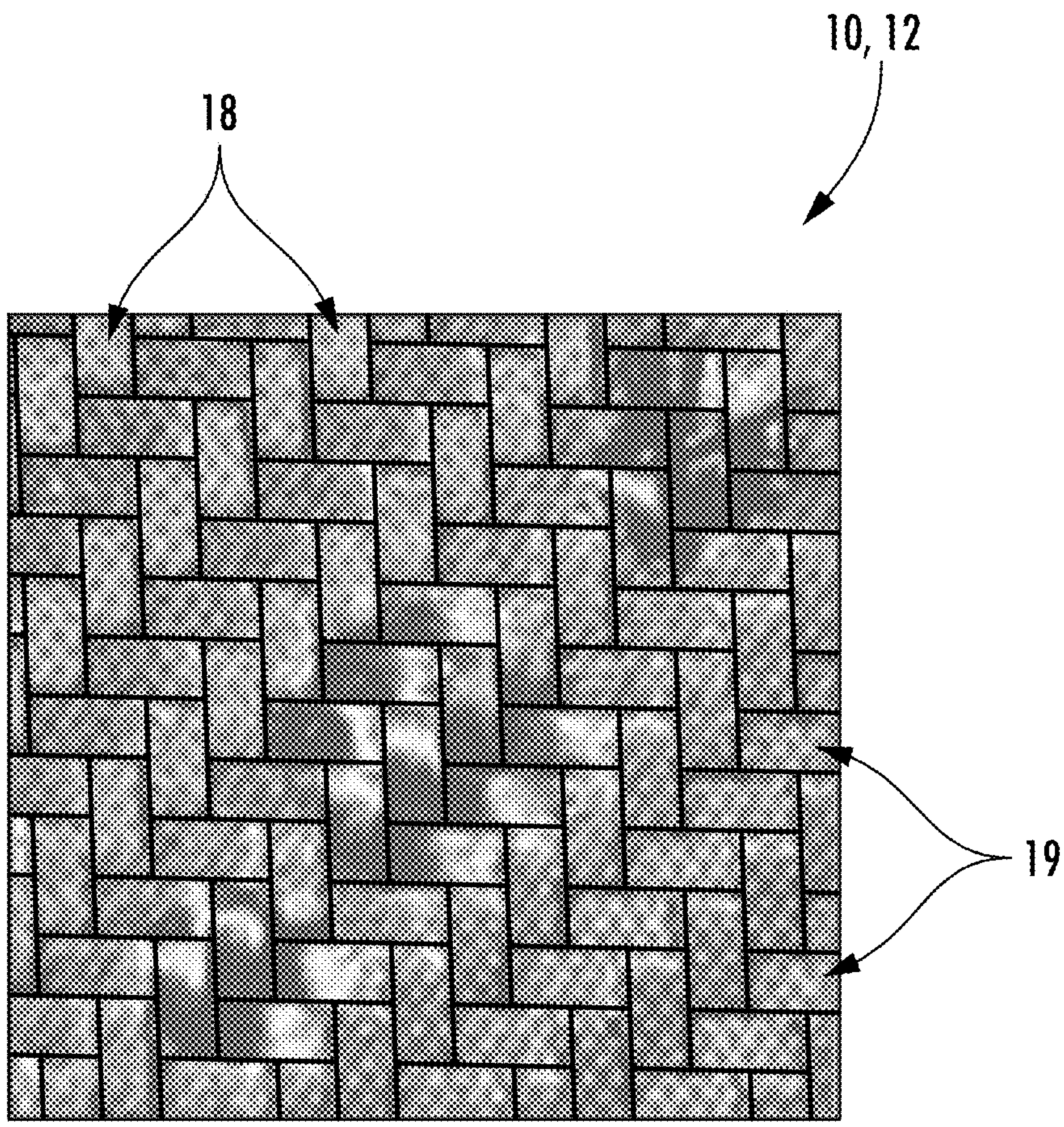



FIG. 2A

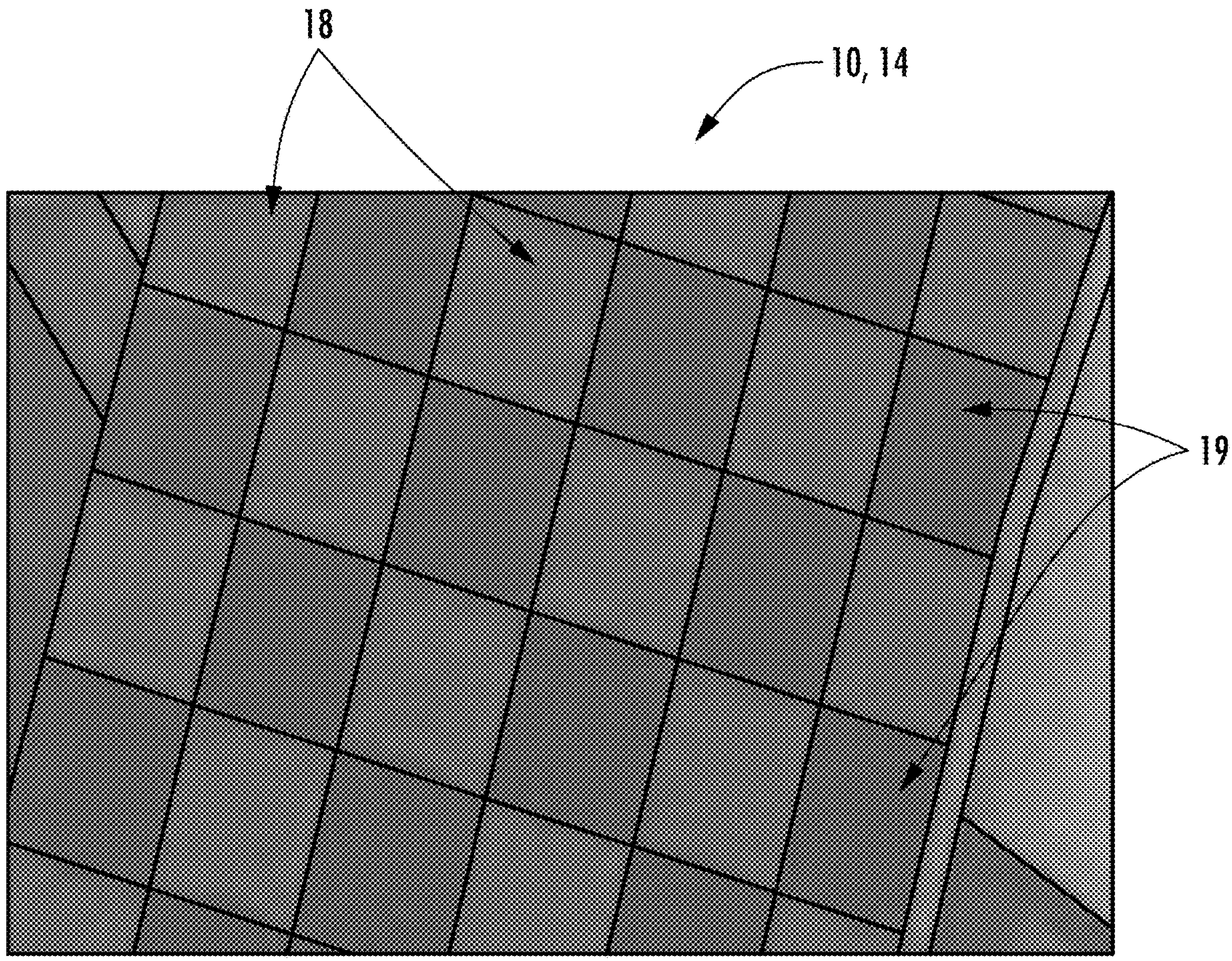



FIG. 2B

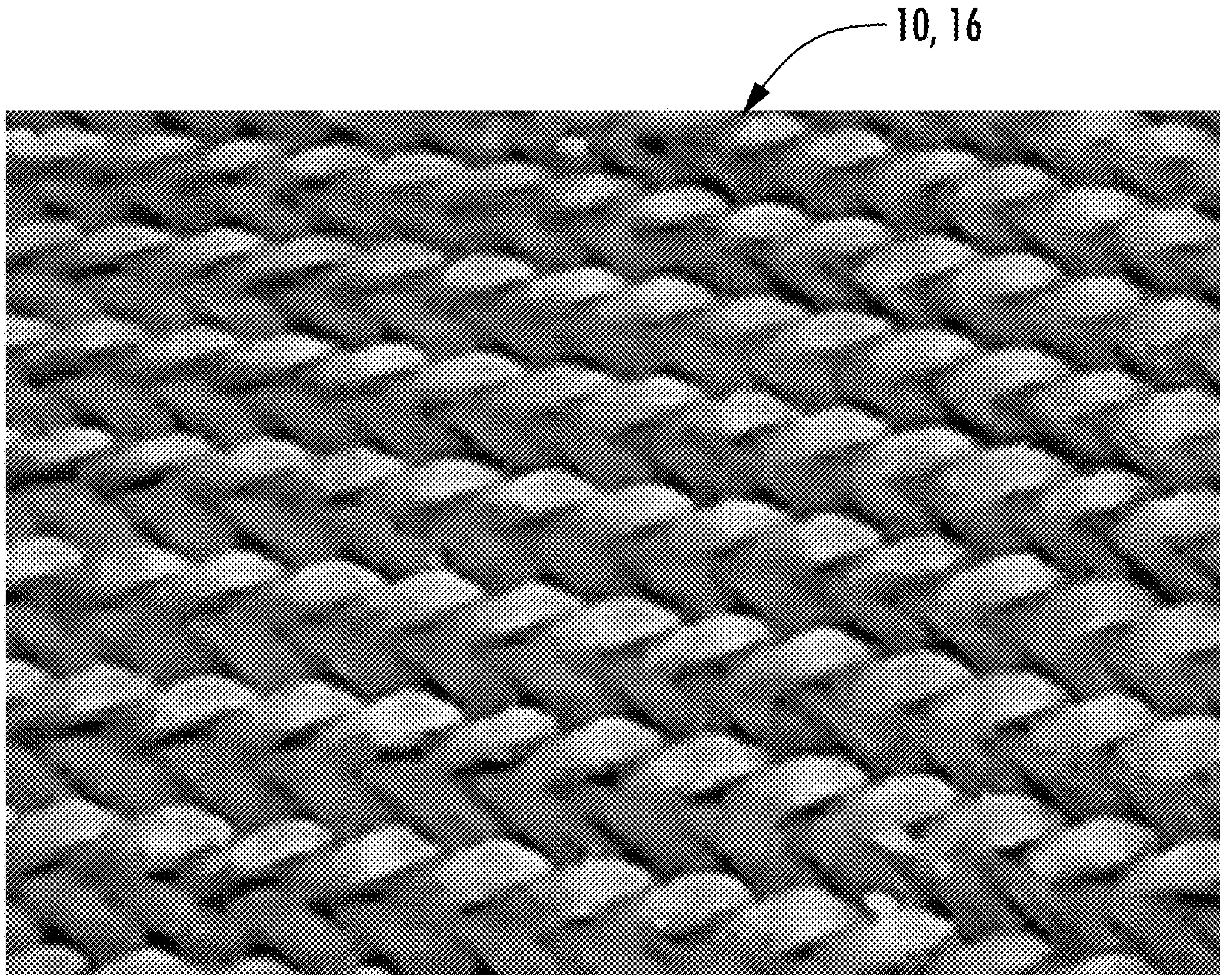



FIG. 2C

| SAMPLE CLOTH(S) | SAMPLE ID | AVERAGE SAMPLE THICKNESS (INCHES) | |
|---|---|---|---|
| | | GROUP 1 | GROUP 2 |
| FLAT TOW (FT) | 2-PLY | 0.016 | 0.016 |
| | 3-PLY | 0.022 | 0.023 |
| | 4-PLY | 0.030 | 0.030 |
| TWIL | 2-PLY | 0.018 | 0.018 |
| | 3-PLY | 0.025 | 0.025 |
| | 4-PLY | 0.031 | 0.032 |
| | 5-PLY | 0.040 | 0.041 |

FIG. 3A

| SAMPLE | NUMBER OF CONTACTS | FINAL ROUND CONTACT TIME |
|---|---|---|
| 5-PLY TWIL | 5 | NO FAILURE |
| 2-PLY TWIL | 2 | 3 |
| 2-PLY FLAT TOW | 4 | 3 |
| 3-PLY TWIL | 4 | 1 |
| 3-PLY FLAT TOW | 5 | 1 |

FIG. 3B

| SAMPLE TYPE | SAMPLE # | # OF CONTACTS ACHIEVED BEFORE FAILURE | FINAL ROUND CONTACT TIME (SECONDS) |
|---|---|---|---|
| 1 LAYER OF 3 PLY | 1 | 1 | < 1 |
| | 2 | 1 | < 1 |
| | 3 | 1 | < 1 |
| 1 LAYER OF 2 PLY | 1 | - | - |
| | 2 | - | - |
| | 3 | - | - |
| * 2 LAYERS OF 2 PLY | 1 | 1 | < 1 |
| | 2 | 1 | < 1 |
| | 3 | 1 | < 1 |
| | | | |
| * 3 LAYERS OF 2 PLY | 1 | 2 | 2 |
| | 2 | 4 | 2 |

FIG. 3C

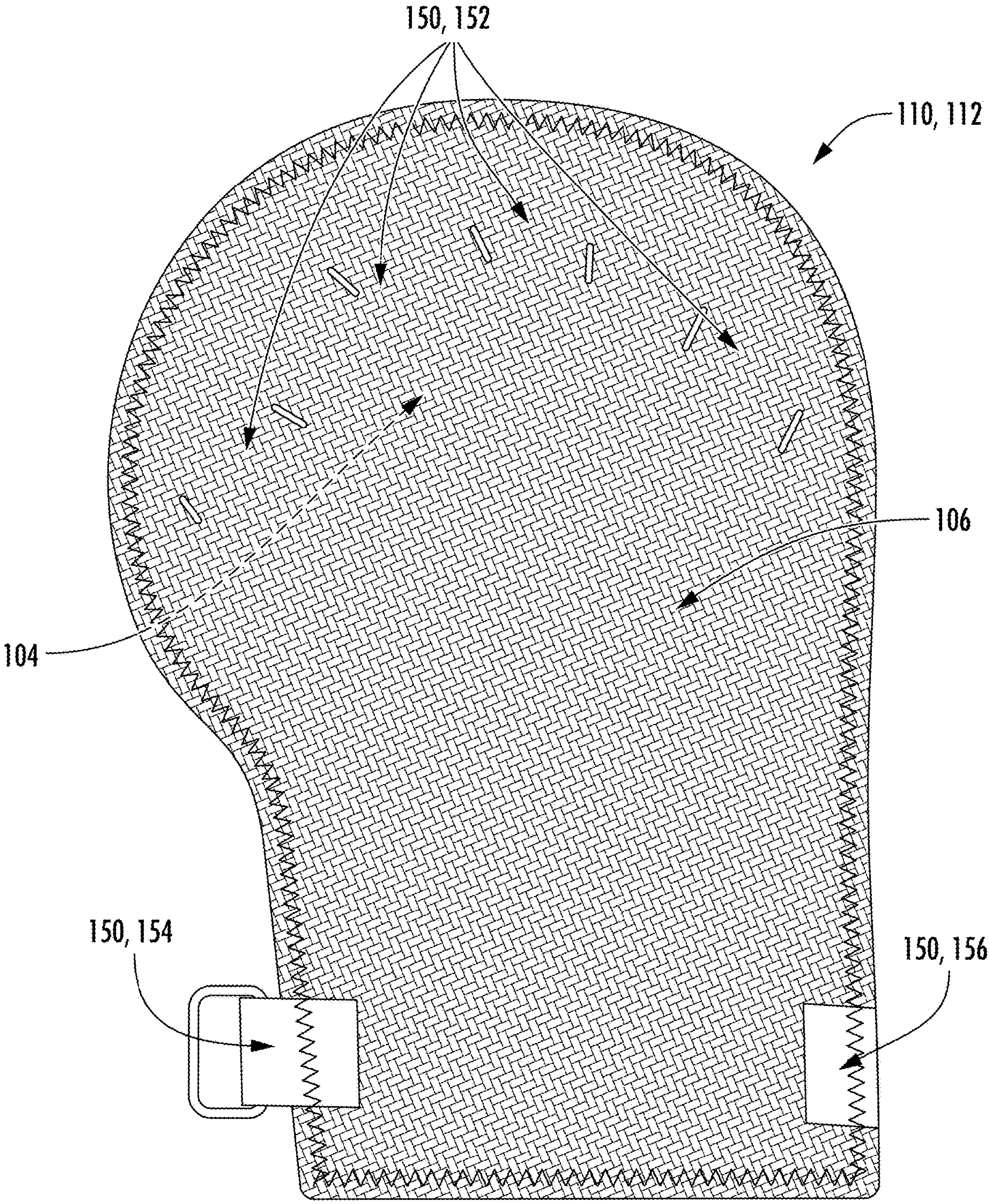



FIG. 4

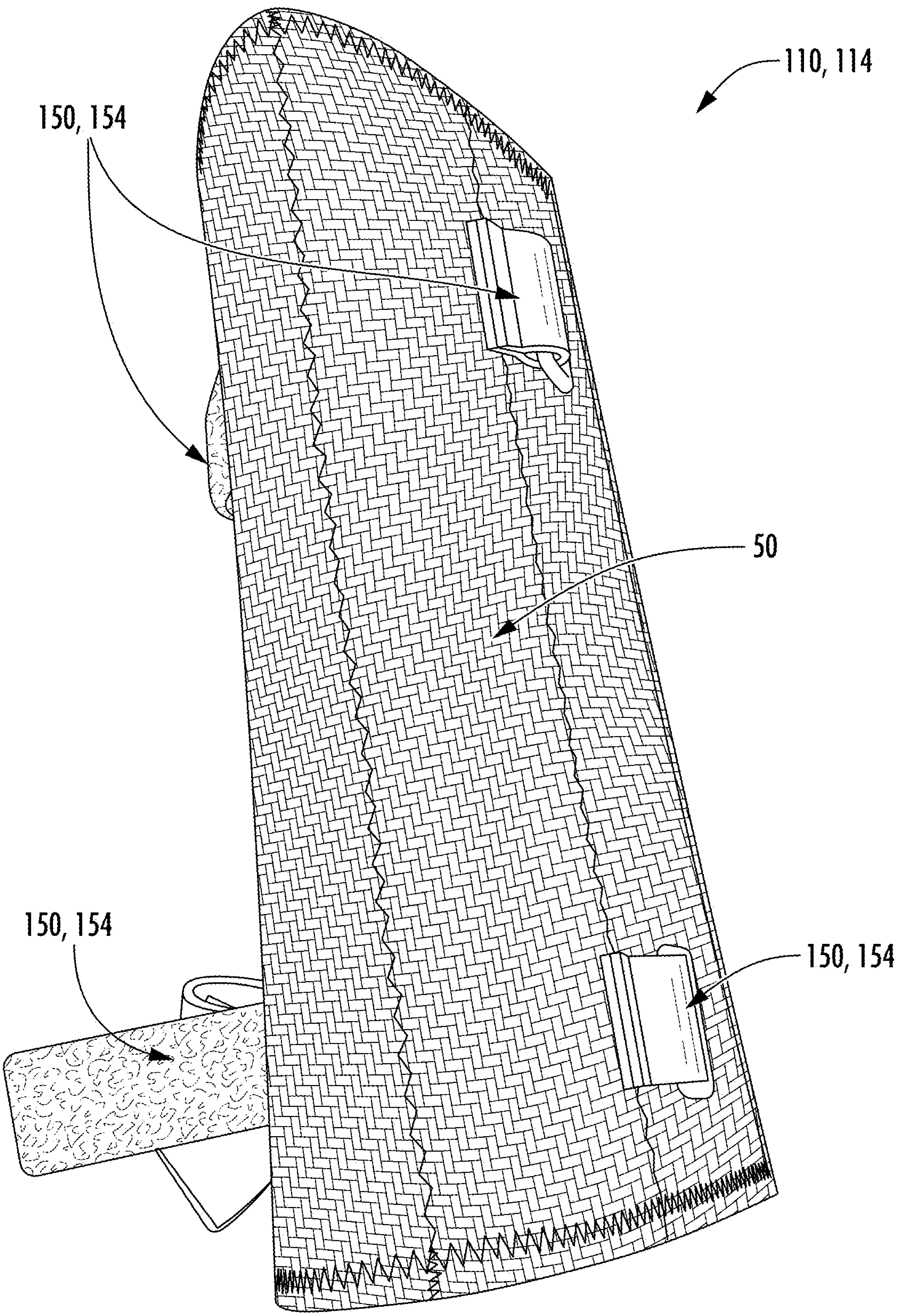



FIG. 5

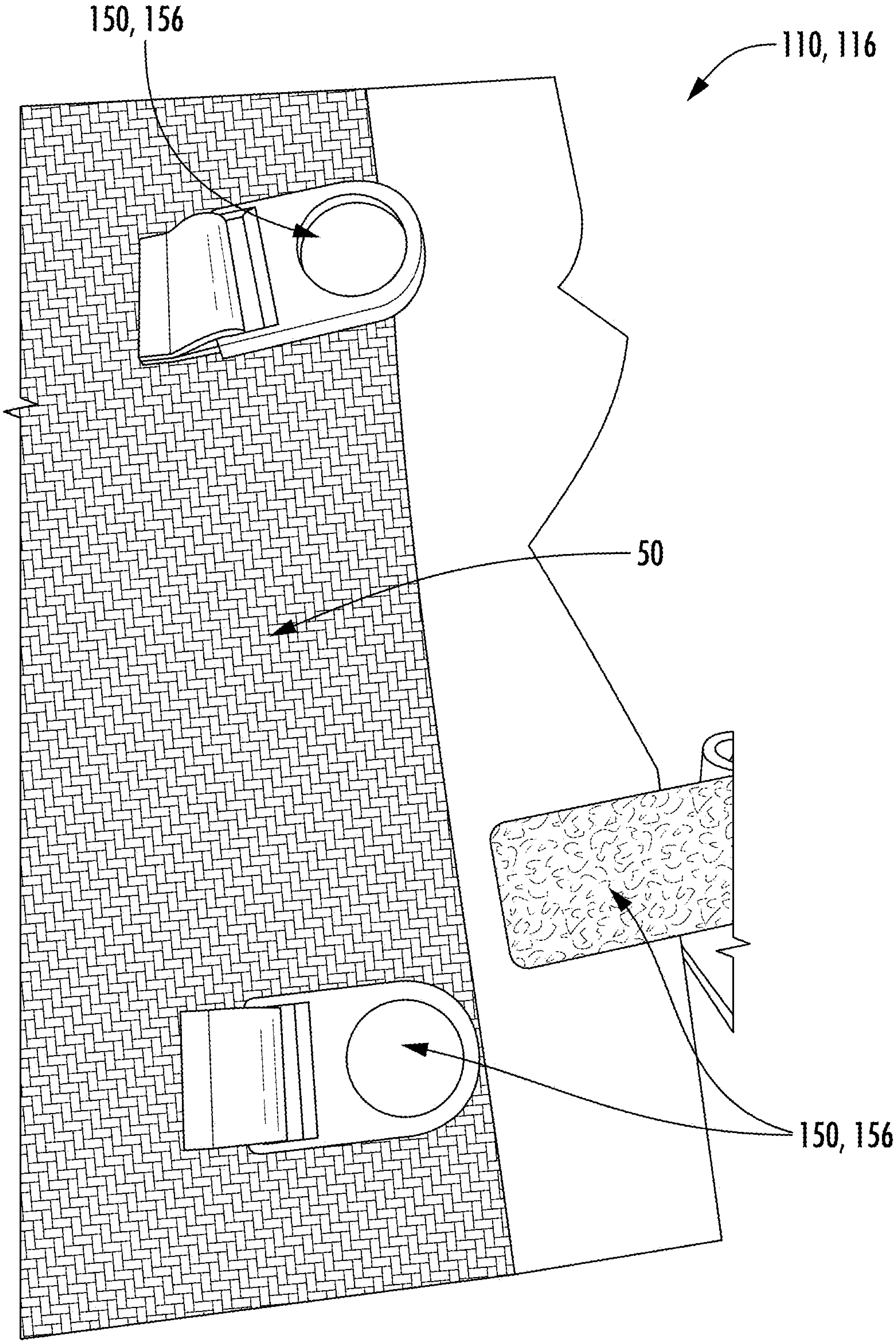



FIG. 6

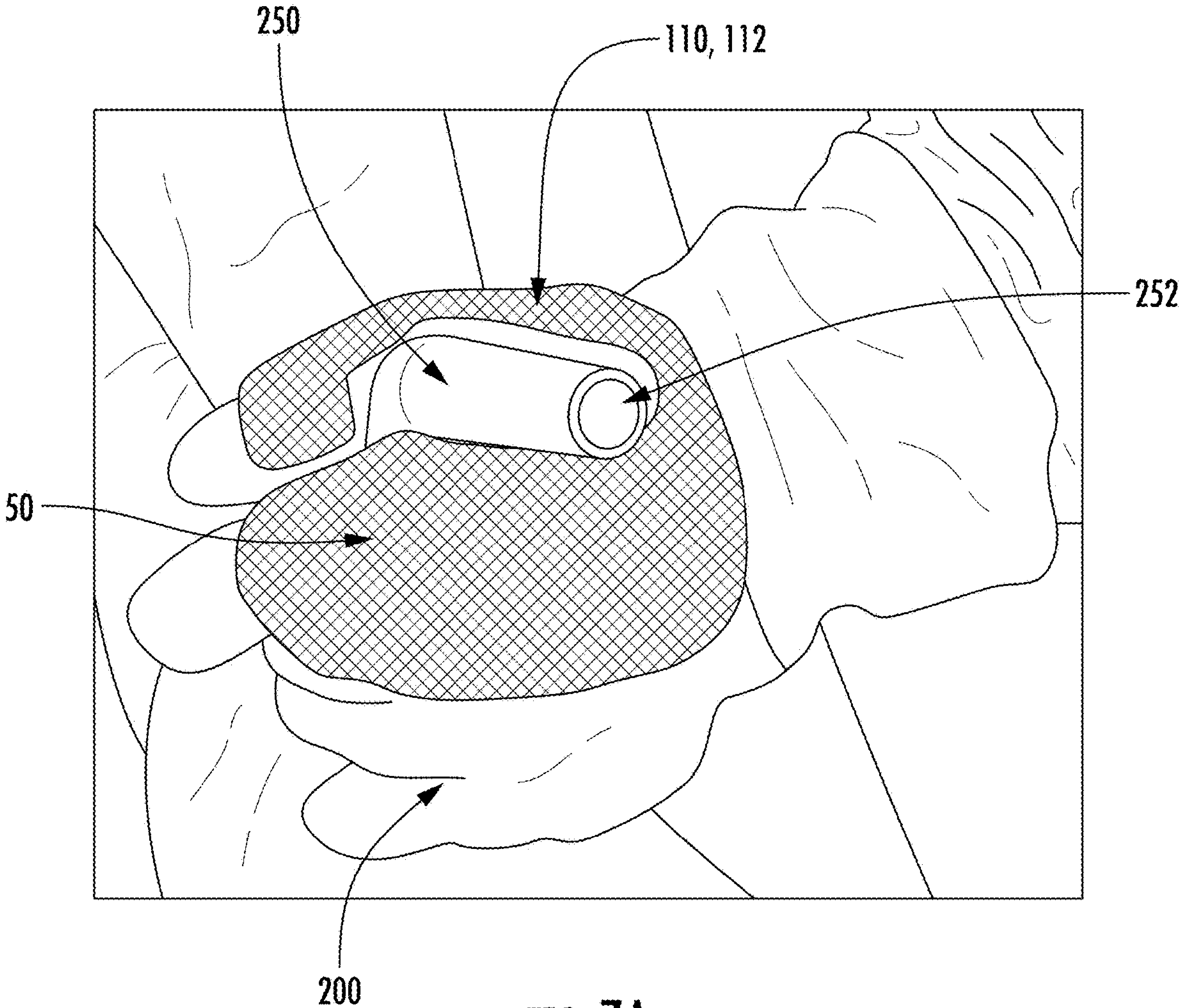



FIG. 7A

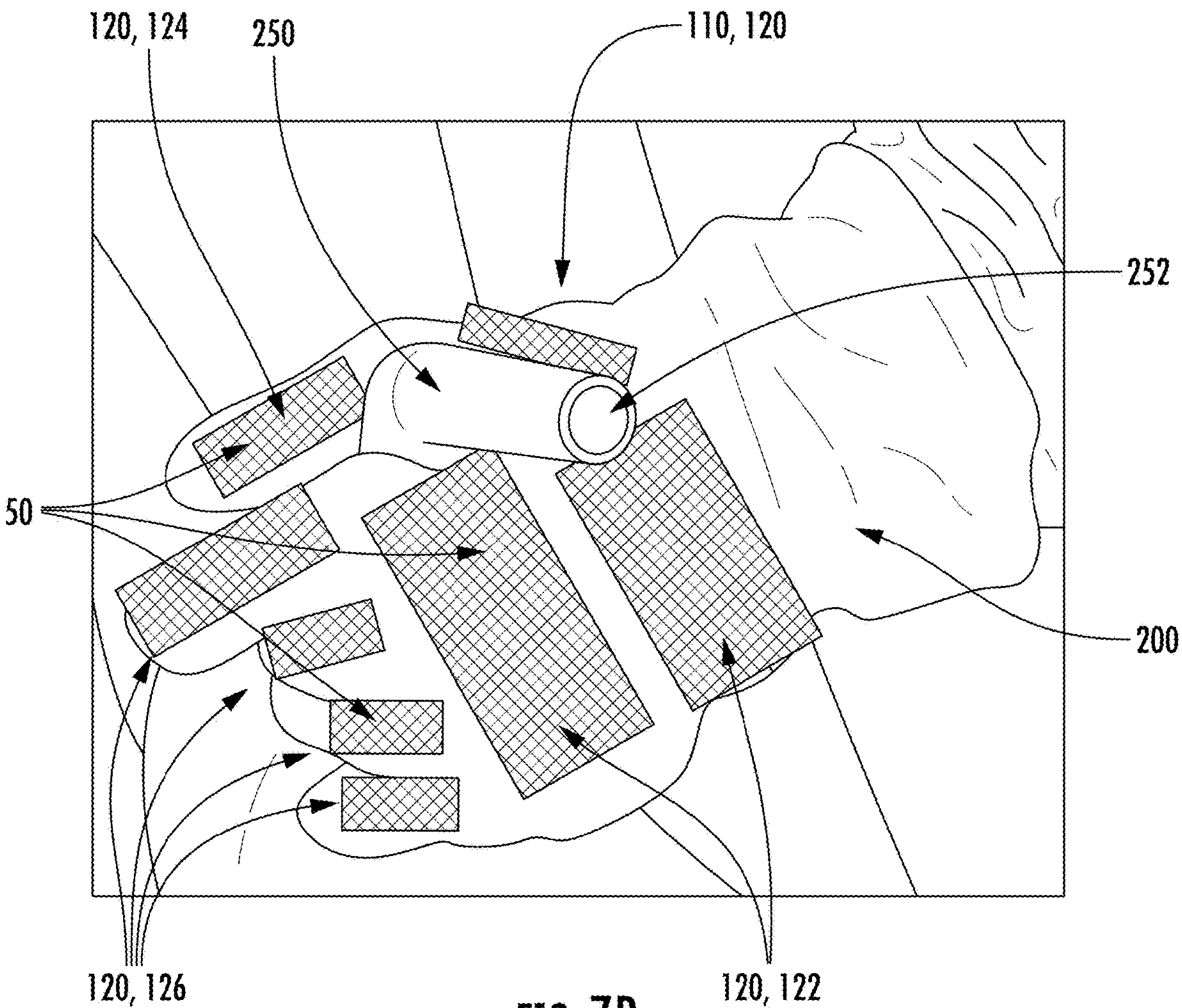



FIG. 7B

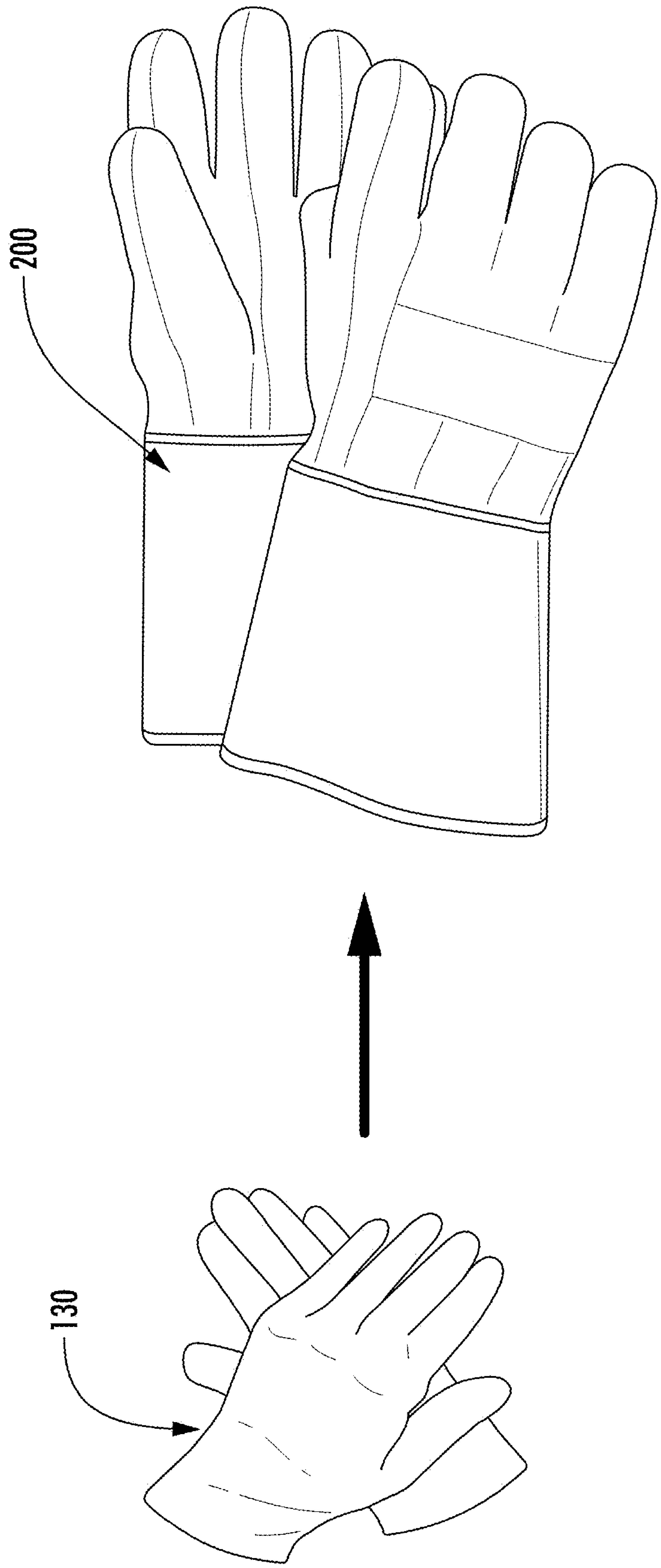



FIG. 8

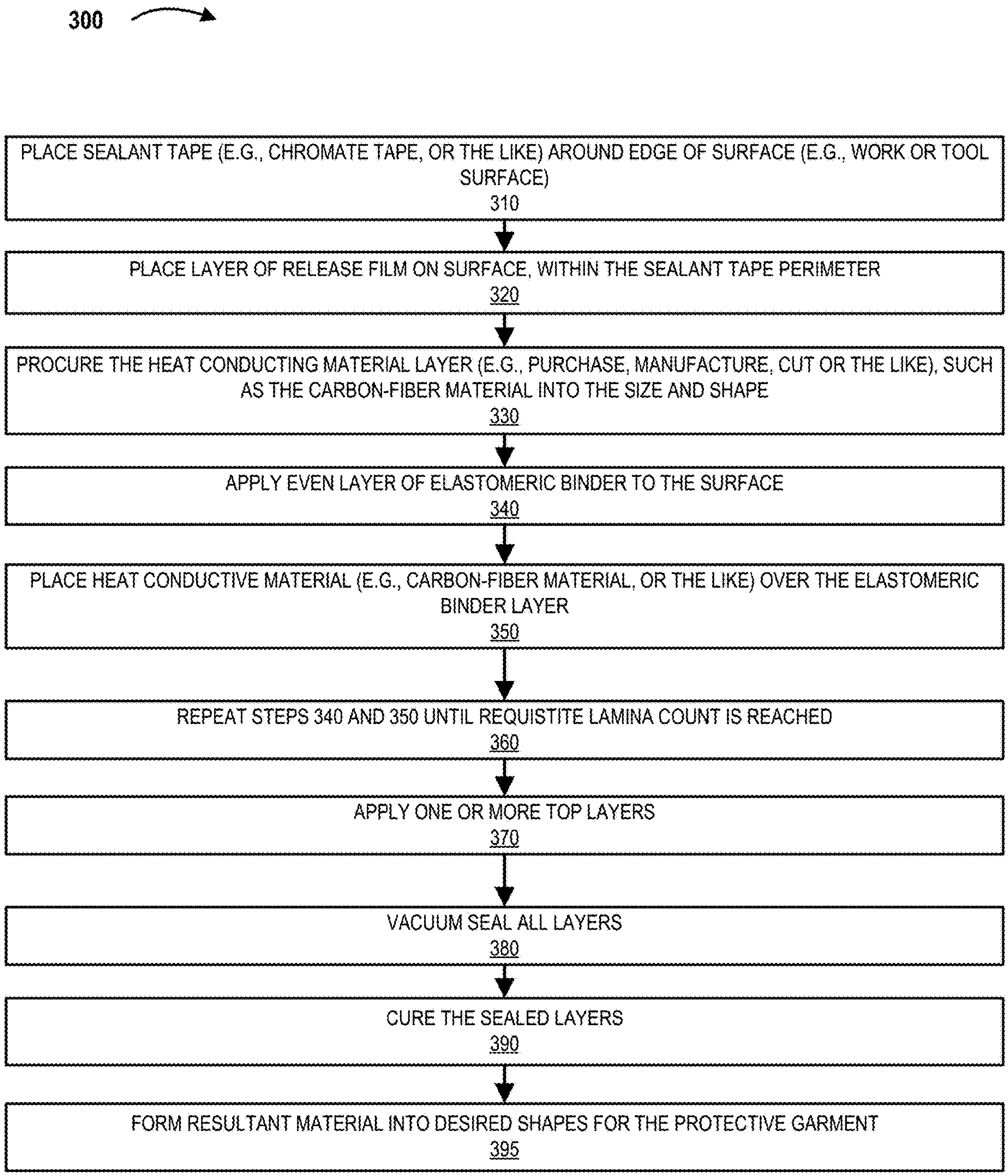

300
PLACE SEALANT TAPE (E.G., CHROMATE TAPE, OR THE LIKE) AROUND EDGE OF SURFACE (E.G., WORK OR TOOL SURFACE)
310
PLACE LAYER OF RELEASE FILM ON SURFACE, WITHIN THE SEALANT TAPE PERIMETER
320
PROCURE THE HEAT CONDUCTING MATERIAL LAYER (E.G., PURCHASE, MANUFACTURE, CUT OR THE LIKE), SUCH AS THE CARBON-FIBER MATERIAL INTO THE SIZE AND SHAPE
330
APPLY EVEN LAYER OF ELASTOMERIC BINDER TO THE SURFACE
340
PLACE HEAT CONDUCTIVE MATERIAL (E.G., CARBON-FIBER MATERIAL, OR THE LIKE) OVER THE ELASTOMERIC BINDER LAYER
350
REPEAT STEPS 340 AND 350 UNTIL REQUISTITE LAMINA COUNT IS REACHED
360
APPLY ONE OR MORE TOP LAYERS
370
VACUUM SEAL ALL LAYERS
380
CURE THE SEALED LAYERS
390
FORM RESULTANT MATERIAL INTO DESIRED SHAPES FOR THE PROTECTIVE GARMENT
395

*FIG. 9*

# PROTECTIVE GARMENT FOR IMPROVED WELDING PROTECTION

## PRIORITY CLAIM UNDER 35 U.S.C. § 119

**[0001]** The present application for a patent claims priority to U.S. Provisional Patent Application Ser. No. 63/528,595 entitled "Protective Garment for Improved Welding Protection", filed on Jul. 24, 2023, and U.S. Provisional Patent Application Ser. No. 63/604,504 entitled "Protective Garment for Improved Welding Protection", filed on Nov. 30, 2023, all of which are assigned to the assignee hereof and hereby expressly incorporated by reference herein.

## FIELD

**[0002]** This application relates generally to the field of personal protection equipment (PPE), and more particularly, to PPE with improved protection during welding, and in particular, for providing resistance to welding wire sticks.

## BACKGROUND

**[0003]** In the welding industry, one common injury results from personal contact with high temperature welding leads, typically referred to as a "wire-stick." A wire-stick injury is prone to infection and may result in lost production time. Although standard welding PPE includes insulated gloves and other burn-resistant clothing, there is a need for PPE with improved protection.

## BRIEF SUMMARY

**[0004]** Embodiments of the present disclosure relate to a protective garment. The protective garment provides improved safety and customization of personal protective equipment (PPE), in particular for welding protection, specifically for protection from wire-sticks from exposed welding wires during a welding process. Due to the small diameter of a welding lead, a wire-stick can penetrate traditional PPE, resulting in both a puncture wound and a burn. To protect against wire-stick injuries, the present invention is a heat conducting composite material (e.g., a polymer matrix composite, carbon fiber reinforced polymer, or the like) made of one or more layers of a heat conducting material and a matrix.

**[0005]** In particular embodiments, the one or more heat conducting material layers include a material that provides active conduction of heat, such as a carbon fiber layer, such as a woven or non-woven carbon-fiber layer. In other embodiments, the heat conducting material layer may be made of any material that is a good conductor of heat, such as graphene, aluminum sulfide, or the like. The matrix may be a binder or other type of matrix, which may be an elastomeric binder, such as a polymer, or the like. The polymer may be a plastic (e.g., polyurethane, or the like), a rubber, a resin, silicone, or other like polymer. It should be understood that the one or more layers of heat conducting material and the matrix may be formed as separate layers, may be interstitial with each other (e.g., the matrix may extend around, between, or be located on a portion of a surface of the heat conducting material. As such, the matrix may hold one or more layers of the heat conducting material together and/or the fibers of the heat conduction material together within a layer. In some embodiments, a primer may be used to aid the bonding between the heat conducting material and the matrix. In particular embodiments, the heat conducting composite is a carbon fiber reinforced polymer (CFRP) made from woven carbon fibers and a polymer that holds the woven fibers together and/or the layers of woven fibers together. Additionally, or alternatively, a softener may be utilized to make the matrix, and thus, the protective layer, more flexible.

**[0006]** As will be described in further detail herein, the heat conducting composite material may be cut, formed, stitched, molded, or otherwise shaped into various protective garments that may be worn over appendages (e.g., hands, arms, legs, or the like) or other parts of a user's body (e.g., chest, back, head, neck, or the like). The protective garments may be worn as PPE directly or as guards over other forms of PPE or portions of the user's body. As such, in particular embodiments the protective garments may be welding guards that are worn over welding gloves, arms, legs, or the like. In other embodiments, the protective garments may be aprons, capes, chest shields, back shields, neck protection, head protection (e.g., masks with welding glass, or the like), shirts, jackets, pants, or other like protection over any portion of the user's body.

**[0007]** As will also be described in further detail herein, the protective garments may be worn as inserts under other forms of PPE. The inserts may be worn under gloves or other outerwear (e.g., shirts, pants, shielding, or the like). In particular embodiments, when worn under gloves the inserts may be a full glove insert, partial glove insert, or the like.

**[0008]** As such, regardless of whether the protective garments may be guards that are worn over PPE or inserts worn under PPE, when the PPE wears out (e.g., in hours, days, weeks, or the like) the PPE may be replaced, while the protective garments made from the CFRP material may be used with new PPE. For example, in particular embodiments, when worn with respect to welding gloves, when the gloves wear out (e.g., which may occur within a single day), the gloves may be replaced while the guards and/or inserts made of the CFRP material may continue to be used with new gloves.

**[0009]** One embodiment of the invention is a protective garment having a heat conducting composite material. The heat conducting composite material comprising one or more heat conducting layers and a matrix operatively coupled to the one or more heat conducting layers. The heat conducting composite provides protection from wire sticks during welding.

**[0010]** In further accord with embodiments of the invention, the one or more heat conducting layers comprise at least a woven fiber layer.

**[0011]** In other embodiments of the invention, the one or more heat conducting layers comprise at least a carbon fiber layer.

**[0012]** In still other embodiments, the one or more heat conducting layers comprise at least a graphene layer.

**[0013]** In yet other embodiments, the woven fiber layer comprises a twill weave carbon fiber cloth, a flat-tow weave carbon fiber cloth, or a triaxial twill weave carbon fiber cloth.

**[0014]** In other embodiments, the matrix comprises a polymer that holds the woven fiber layer together.

**[0015]** In further accord with embodiments, the polymer comprises a plastic, a rubber, a resin, or a silicone-based polymer matrix.

**[0016]** In other embodiments, the matrix comprises a softener.

[0017] In still other embodiments, the heat conducting composite material comprises a plurality of fiber layers and the matrix operatively couples the plurality of fiber layers together to form a fiber reinforced polymer material.

[0018] In yet other embodiments, the protective garment is an appendage guard.

[0019] In other embodiments, the appendage guard is worn over a glove or over an arm or leg.

[0020] In further accord with embodiments, the protective garment is a protective insert garment that is worn under an outer glove.

[0021] In other embodiments, the protective garment comprises a garment connector that is configured to be removably operatively coupled with an appendage or a garment located on the appendage.

[0022] In still other embodiments, the garment connector comprises at least one of a fastener, a hook or loop connector, a strap and ring, or a strap and clip.

[0023] In yet other embodiments, the heat conducting composite material is integrally operatively coupled with a garment for use on an appendage.

[0024] In other embodiments, the protective garment is a glove having a fabric material and the heat conducting composite material is operatively coupled to at least a portion of the fabric material.

[0025] Another embodiment of the invention is a method of forming a protective garment for improved welding protection. The method comprises positioning one or more heat conducting material layers for receipt of a matrix. The method further comprises applying the matrix over at least a portion of the one or more heat conducting material layers.

[0026] In further accord with embodiments, the one or more heat conducting material layers comprise at least two heat conducting material layers with the matrix located between the at least two heat conducing material layers.

[0027] In other embodiments, the one or more heat conducting layers comprise a woven carbon fiber layer and wherein the matrix is a polymer.

[0028] In still other embodiments, the polymer comprises a plastic, a rubber, a resin, or a silicone based polymer matrix.

[0029] To the accomplishment the foregoing and the related ends, the one or more embodiments comprise the features hereinafter described and particularly pointed out in the claims. The following description and the annexed drawings set forth certain illustrative features of the one or more embodiments. These features are indicative, however, of but a few of the various ways in which the principles of various embodiments may be employed, and this description is intended to include all such embodiments and their equivalents.

## BRIEF DESCRIPTION OF DRAWINGS

[0030] The accompanying drawings illustrate some of the embodiments of the invention and are not necessarily drawn to scale, wherein:

[0031] FIG. **1** illustrates a welding environment in which a welder utilizes PPE for protection;

[0032] FIG. **2**A illustrates an example of a carbon fiber material in a woven twill pattern for use as the heat conducting material of the protective garment, in accordance with embodiments of the present invention;

[0033] FIG. **2**B illustrates an example of a carbon fiber material in a flat tow (plain weave) pattern for use as the heat conducting material of the protective garment, in accordance with embodiments of the present disclosure;

[0034] FIG. **2**C illustrates an example of a carbon fiber material in a triaxial twill weave pattern for use as a heat conducting material of the protective garment, in accordance with embodiments of the present invention;

[0035] FIG. **3**A illustrates a chart of various carbon-fiber samples created for testing of the heat conductive material, in accordance with embodiments of the present disclosure;

[0036] FIG. **3**B illustrates heat conducting composite material fail testing results for the samples illustrated in FIG. **3**A, in accordance with embodiments of the present disclosure;

[0037] FIG. **3**C illustrates heat conducting composite material fail testing results for additional samples of single and multiple layers of various 2 or 3 ply samples, in accordance with embodiments of the present disclosure;

[0038] FIG. **4** illustrates a protective garment in the form of an appendage guard for a glove, in accordance with embodiments of the present disclosure;

[0039] FIG. **5** illustrates a protective garment in the form of an appendage guard for an arm, in accordance with embodiments of the present disclosure;

[0040] FIG. **6** illustrates a protective garment in the form of a removable guard, in accordance with embodiments of the present disclosure;

[0041] FIG. **7**A illustrates a protective garment in the form of a removable glove guard, in accordance with embodiments of the present disclosure;

[0042] FIG. **7**B illustrates a protective garment in the form of a plurality of removable glove guards, in accordance with embodiments of the present disclosure;

[0043] FIG. **8** illustrates a protective garment in the form of an insert having a carbon-fiber layer that is worn under gloves, in accordance with embodiments of the present disclosure;

[0044] FIG. **9** illustrates a method of forming a protective garment for improved wire stick resistance, in accordance with embodiments of the present invention.

## DETAILED DESCRIPTION

[0045] Embodiments of the present invention now may be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all, embodiments of the invention are shown. Indeed, the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure may satisfy applicable legal requirements. Like numbers refer to like elements throughout.

[0046] The present invention provides improved safety and customization of personal protective equipment (PPE), in particular for welding protection, specifically for protection from wire-sticks from exposed welding wires during welding operations, such as after the welding arc is no longer present and hot metal remains on the welding wire. Although the present invention may be used specifically in the welding industry, the invention is not limited to this setting. Rather, the present invention may be used to provide enhanced protection against any form of high-temperature punctures. Traditional welding PPE, especially hand protection, utilizes heat-resistant gloves, such as the gloves illustrated in the welding operation of FIG. **1**. Traditional gloves are often made of a combination of leather and a heat-resistant material such as aramid fiber or aluminum foil. Although this PPE offers heat protection and cut protection, it may offer insufficient protection from a "wire-stick" injury, characterized by a puncture from a high-temperature welding lead wire. Due to the small diameter of a welding lead, a wire-stick can penetrate traditional PPE, resulting in both a puncture wound and a burn.

**[0047]** To protect against wire-stick injuries, the present invention is a heat conducting composite made of one or more layers of a heat conducting material and a matrix. In particular embodiments, the one or more heat conducting material layers include a carbon fiber layer, such as a woven carbon-fiber layer, and the matrix comprises binder or other matrix, such as a polymer. The polymer may be a plastic (e.g., polyurethane, or the like), rubber, resin, silicone (e.g., with or without a primer to improve chemical adhesion between the carbon fibers in a layer and/or between layers), or the like polymer. In particular embodiments, the heat conducting composite is a carbon fiber reinforced polymer (CFRP) in which the matrix is a polymer (e.g., polyurethane, or the like) that is used to hold the woven fibers of the CFRP together and/or adjacent layers of CFRP together. In some embodiments, the matrix may further include a softener in order to provide a more flexible polymer to allow for improved flexibility in the CFRP. As such, in some embodiments the matrix is a 74-30 or 74-20 polyurethane (e.g., two part mixture) with or without the softener (e.g., a 74/75 poly softener, or the like). It should be understood that the softener may be used within the matrix in any ratio, such as in a 1:1:1, 2:2:1, or the like (between the two part polymer and the softener). In some embodiments the ratio of the softener may be 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.75, 0.8, 0.9, or the like with respect to the two part polyurethane. Generally, the use of the softener improves the flexibility of the composite layer, but may reduce the resistance, at least partially, to welding wire-sticks. In other embodiments, additionally or alternatively, the one or more heat conducting material layers may include other types of material such as graphene and/or the matrix may be made of another material.

**[0048]** As will be described in further detail herein, the heat conducting composite material may be cut, formed, stitched, glued, molded, or otherwise shaped into various protective garments that may be worn over appendages (e.g., hands, arms, legs, or the like) or other parts of a user's body (e.g., chest, or the like). The protective garments may be worn as PPE directly, as guards over other forms of PPE or portions of the user's body, or as inserts (e.g., full glove insert, partial glove insert, or the like) under other forms of PPE. As such, in particular embodiments the protective garments may be welding guards that are worn over welding gloves or other welding PPE. Alternatively, or additionally, in particular embodiments the protective garments may be inserts (e.g., full glove insert, partial glove insert with one or more finger holes, or the like) that are worn under welding gloves or other welding PPE. As such, as welding gloves or other PPE wears out, the gloves or other PPE may be replaced while the welding guards and/or inserts may continue to be used with new gloves or other new PPE.

**[0049]** FIGS. **2**A through **2**C illustrate examples of woven carbon-fiber material **10**, in accordance with embodiments of the present invention. In some embodiments the woven carbon-fiber material may be a twill woven carbon-fiber material **12**, as illustrated in FIG. **2**A. In other embodiments the woven carbon-fiber material **10** may be a tow woven carbon fiber material **14** (otherwise described as a plain weave), as illustrated in FIG. **2**B. In still other embodiments, the woven carbon-fiber material **10** may be a triaxial twill weave carbon-fiber material **16**, as illustrated in FIG. **2**C. As such, the carbon-fiber material **10** may comprise a plurality of longitudinal tows **18** (i.e., a warp) and a plurality of transverse tows **19** (i.e., a weft). Each tow of the material **10** may comprise a flat tow, or a fiber bundle which has been flattened prior to being woven into the material **10**. In some embodiments, the weave of the material **10** may comprise a plain weave, characterized by a pattern of "one-over, one-under" in the weave, as illustrated in FIG. **2**B. In other embodiments, as illustrated in FIG. **2**A, the weave may comprise a twill weave, characterized by a pattern of "two-over, two-under" in the weave. In other embodiments, as illustrated in FIG. **2**C, the weave may comprise a triaxial twill weave, characterized by a pattern of three sets of parallel weaves interacting at angles of approximately sixty degrees. The woven carbon-fiber material **10** may be characterized by a "K count," or the average number of fiber filaments contained within each tow. For example, the material **10** illustrated in FIG. **2**A comprises 3,000 carbon fiber filaments in each tow, resulting in a K count of 3K. However, it should be understood that each tow may have the same or different K counts, of 0.5, 1, 2, 3, 4, 5, 6, 8, 10, 12 or the like K (or range between, overlap, or fall outside of any of these values). Furthermore, while the material is discussed as being a woven carbon-fiber material **10**, it should be understood that the material may be a different type of fiber material that may or may not be woven and/or may or may not be made of a different material that provides heat conductive properties (e.g., graphene, or the like). Regardless of the specific type of material and/or pattern, the material may allow the heat conducting composite material to be a flexible material and/or conform to complex three-dimensional shapes.

**[0050]** The carbon fiber material may have a melting point of approximately 3657 degrees Celsius, a thermal conductivity of 100 W/mK, and a heat capacity of 800 J/g K. The rubber (e.g., with or without a softener) may have a melting point of 177 degrees Celsius, a thermal conductivity of 0.5 W/mK, and a heat capacity of 1550 J/g K. While specific values are provided herein, it should be understood that any of these values may range from +/−1, 2, 3, 4, 5, 7, 10, 15, 20, 25, 30, 40, 50, or other like percentages, or any values falling within, outside, or overlapping these values. As such, it should be understood that these values may have ranges and still fall within the scope of the disclosure of this invention.

**[0051]** It should be understood that the heat conducting composite material may be formed from multiple layers operatively coupled by a matrix forming a heat conducting composite material having different numbers of plies (e.g., 1-ply, 2-ply, 3-ply, 4-ply, 5-ply, 10-ply, or the like, or range between, overlap, or fall outside of these number of plies). While in some embodiments the matrix may be used to operatively couple the heat conducting layers together, it should be understood that additionally, or alternatively, mechanical connectors (e.g., fasteners, clamps, clips, staples, bands, or the like) may be used to aid in holding the one or more heat conducting layers together. It should be understood that regardless of the specific number of layers and/or the materials being used, the heat conducting composite material provides protection from wire-sticks. However, as will be described in further detail herein, some composite materials provide improved protection from wire-sticks over other materials, including other composite materials. For example, during testing it was found that the woven carbon-fiber material **10** was able to withstand high temperatures and effectively conduct heat, thereby moving the heat throughout the material **10**. Moreover, the combination of the matrix (e.g., polymer, with or without a softener) with the woven carbon-fiber material aided in restricting the movement of the fibers with respect to each other, thus aiding in resisting penetration of the hot welding wire between the woven fibers. Additionally, the matrix provides an effective insulator (e.g., ablates the heat from the wire-stick, vaporizes after repeated contact from the wire-stick, or the like) absorbing the heat as the heats moves through the woven carbon-fiber material.

**[0052]** Furthermore, it should be understood that depending on the number layers of the heat conducting material and/or the type and thickness of the matrix applied to the one or more layers of the heat conducting material, the resulting heat conducting composite material may be flexible to shape (e.g., mold, or the like), stitch (e.g., sew together, with other materials, with connectors, or the like), or to conform as needed in order to create a protective garment, such as at least the protective garments described herein. As such, the number of layers and/or the matrix applied may create protective garments that have the thicknesses described in the chart illustrated in FIG. **3**A. It should be understood that the one or more heat conducing materials may be layered in the same orientation or may have different orientations (e.g., +/−5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, or the like degrees from an adjacent layer).

**[0053]** Different types of heat conducting composite materials having different plies were formed and tested. In particular, samples of 12K plain weave flat tow (FT) and 3K twill weave were produced having different numbers of plies, such as 2-ply, 3-ply, and 4-ply FT samples, and 2-ply, 3-ply, 4-ply, and 5-ply twill samples. The samples had the thicknesses illustrated in the table in FIG. **3**A. The Group 1 samples were tested measuring time and force of a weld wire stick, while the Group 2 samples were tested measuring the heat transfer through the composite material. The group 1 samples were tested using a 25-pound compressive load cell to contact the samples with 5 pounds of force for 5 seconds. Additional testing included fail testing in which the Group 1 samples were subjected to repeated contact with the welding lead in the same location with 5 pounds of force for 5 seconds until material failure (i.e., allowing the lead wire to pass through the heat conductive composite), without allowing the material to cool between contacts. During the initial single contact testing none of the Group 1 samples failed. During the failure testing, the table in FIG. **3**B illustrates the number of contacts that that the samples survived, as well as the time during the final contact when the material failed. As illustrated in FIG. **3**B, the materials provided more protection as the number of plies increased. While the flat tow samples generally allowed for more contacts than the twill samples, the protection was similar, and the twill samples provided more flexibility and ability to be formed into complex shapes.

**[0054]** The samples were also compared to alternate materials that included aramid fiber, as well as control samples of carbon fibers that did not include the matrix between the layers. The single ply aramid fiber sample failed on the first contact at 4 seconds and a 5-ply aramid fiber was able to survive a single contact but failed on a second contact. With respect to the carbon-fiber control samples, 5 layers of carbon fiber were stacked with no binder, which failed immediately during the first contact.

**[0055]** With respect to the Group 2 samples illustrated in FIG. **3**A, the Group 2 samples were tested by holding the wire in contact with the samples for 5 seconds and the samples were viewed using a thermal camera on the opposite side of the samples being contacted by the weld wire. As expected, the thicker samples allowed less heat to be transmitted to the opposite side of the samples, and the heat quickly dissipated when the weld wire was removed from the samples. As such, should the protective garment utilize less plies, an additional insulative layer may be used on the inner layer in order to aid in reducing the amount of heat that may potentially reach a user.

**[0056]** Furthermore, samples of single layers having 2 or 3 plies, double layers of 2 ply material, and triple layers of 2 ply material were also tested and compared to each other, as illustrated in FIG. **3**C. This testing utilized an average of 5 lbs. of force for up to 5 seconds. As illustrated by the chart in FIG. **3**C, the single layer of 2 ply material performed the worst, while the single layer of the 3 ply material and the double layer of the 2 ply material had similar performance (the double layer performed slightly better as the puncture holes were smaller). As further illustrated in FIG. **3**C, the triple layer of 2 ply material performed better than the other samples with respect to the puncture testing, however, it has reduced flexibility with respect to the double layer of 2 ply material.

**[0057]** While the samples of the heat conductive composite material generally utilized one or more layers of heat conductive materials and a matrix between the layers, it should be understood that other layers of material may also be included in the protective garment to provide additional functionality, such as one or more insulation layers (e.g., to provide additional layers of insulation for the user), one or more layers of cotton material (e.g., to provide comfort for the user), one or more layers of aramid fiber cloth (e.g., to provide strength and/or durability to the protective garment), one or more layers of moisture wicking material (e.g., synthetic, natural, or the like fibers, or other like materials), wear resistant materials (e.g., leather, neoprene, nitrile, or the like), and/or other types of materials to provide other benefits for the protective garment.

**[0058]** FIGS. **4** through **6** illustrate different protective garments **100** that may utilize the heat conductive composite material **102** discussed herein. As illustrated in FIG. **4**, in some embodiments the protective garment **100** may comprise an appendage guard **110**, and in particular, a glove guard **112**. As illustrated in FIG. **4**, the glove guard **112** may be worn over at least a portion of a glove **200**, such as standard welding gloves **200**, as illustrated in some embodiments in FIG. **1**. In some embodiments, the glove guard **112** may be worn over a holding hand glove **202** (e.g., non-dominant hand, hand used to hold, move, or the like) the welder is using to hold the components the welder is welding and not the welding hand glove **204** (e.g., dominate hand, hand used to hold the welding gun **250**, or the like) since a welder is more likely to receive a wire-stick from a wire **252** on the holding hand glove **202** and not the welding hand glove **204**. As illustrated in FIG. **4**, the glove guard **200** may have a shape that generally conforms to an outer surface **210** of a glove **200**.

**[0059]** It should be understood that regardless of the type of protective garment **100** being used, the protective garment **100** may utilize one or more garment connectors **150** that are used to operatively couple the protective garment **100** to a user, to other PPE, to itself around a user, or the like. For example, the protective garment connector **150** may comprise one or more bands **152** (e.g., elastic bands, or the like) made of high temperature resistant material through which a user may insert one or more fingers of a glove **200**. The stitching for the plurality of the bands **152** are illustrated in FIG. **4** (e.g., bands **152** would extend from the inner side **104** of the protective garment **100**) on the outer side of the protective garment **106**. Moreover, as further illustrated in FIG. **5**, the protective garment connector **150** may comprise a strap and ring **154**. As such, in some embodiments, the strap and ring **150** may be used to strap the protective garment **100** around at least a portion of an appendage.

**[0060]** FIG. **5** illustrates another embodiment of the appendage guards **110**, such as an arm guard **114** (or a leg guard). As illustrated in FIG. **5**, the arm guard **114** may be wrapped around an arm (or a leg) of a user in order to protect a user's arm or leg. In particular, a welder may wrap the arm guard **114** around the holding arm **206** during welding. As discussed with respect to FIG. **4**, the arm guard **114** may include a protective garment connector **150**, such as a strap and ring **154** that may be used to operatively couple the arm guard **114** around an arm of the user. However, in other embodiments, the arm guard **114** may utilize other types of garment connectors **150**, such as hook and loop connectors on the edges of the of the arm guard **114**. In other embodiments, as will be described with respect to FIG. **6**, a strap and clip **156** connection may be used to wear the protective garment **100**.

**[0061]** FIG. **6** illustrates another embodiment of the protective garment **100**, such as a flap **116** that may be operatively coupled to different locations of a user (e.g., chest, arm, leg, shoulder, or the like). As previously discussed, the garment connector **150** may comprise a strap and clip **156** connection, such as a button push clip, or other types of clips not specifically illustrated in the figures.

**[0062]** FIG. **7**A illustrates other embodiments of the glove guard **112** previously described with respect to FIG. **4**. As illustrated in FIG. **7**A, the glove guard **112** may be formed, at least partially to the shape of a glove **200**, such as around the shape of the inner and/or outer surfaces of the thumb, the back of the hand, the pointer finger, and/or the index finger of the glove **200** in order to allow the welder more range of movement with respect to the glove guard **112** (e.g., versus the glove guard **112** illustrated in FIG. **4**). The area covered by the glove guard **112** illustrated in FIG. **7**A may cover the areas in which most welding wire-sticks occur. As previously discussed with respect to FIG. **4**, the protective garment connector **150** may include bands **152**, straps, hook and loop connectors, fasteners (e.g., button snaps, buttons, other types of fasteners), or other connectors.

**[0063]** FIG. **7**B illustrates another embodiment of the glove guard **112**, which may comprise of a plurality of glove guard sections **120**, such as individual back of hand guards **122**, thumb guards **124**, finger guards **126**, or the like that may be collectively and/or individually operatively coupled to a glove **200** through the use of garment connectors **150**, such as hook and loop connectors, or the like. In this embodiment, the individual glove guard sections **120** may be used and replaced in the event that one of the glove guards **120** becomes damaged due to one or more welding wire-sticks. As such, an entire glove guard **112** does not need to be replaced should it become exposed to a heated hot weld wire that damages the protective garment **100**.

**[0064]** In other embodiments, other types of garment connectors **150** may be utilized in order to operatively couple the protective garment **100** to the user and/or to other PPE of the user. For example, fasteners (e.g., snap, buttons, zippers, or the like) may be used to operatively couple the garment connectors **150** to the user, to other PPE, or to itself to allow the user to wear the protective garment **100**.

**[0065]** FIG. **8** illustrates another embodiment of the invention in which the protective garment **100** is a protective insert garment **130** made from one or more layers of materials. The protective insert garment **130** may be worn within a glove **200**, such as within traditional welding gloves, such that should a welding wire penetrate a traditional welding glove **200** the protective insert garment **130** may aid in preventing weld stick injuries. It should be understood that the protective insert garment **130** may be more expensive than the glove **200** under which it is worn, and as such, the protective insert garments **130** may be required to last longer than the gloves **200**. That is, the outer gloves **200** may be used and disposed of on a day-by-day, week-by-week, month-by-month basis, while the protective insert garment **130** may last days, weeks, months, or the like longer than the outer gloves **200**.

**[0066]** The protective insert garment **130** may have one or more layers of the CFRP material formed from the carbon fiber material and the matrix (e.g., polymer, such as a polyurethane with or without a binder and/or softener layer, or other like material) that is used to hold the woven carbon fibers and/or adjacent layers of carbon fibers together. It should be understood that while the matrix layer may cover the fibers of the carbon fiber layer, the matrix may wear out over time. For example, the friction between the CFRP and the skin of a user's hand and/or the interior of the glove **200** in which the protective insert garment **130** is located may rub against the CFRP, which may result in the matrix layer being worn away. For example, the matrix layer (e.g., the polymer) may wear away during use. When the matrix is worn away, the carbon fibers of the carbon fiber layer may be at least partially exposed. The partially exposed carbon fibers may irritate the skin of user and/or may damage the glove **200** located over the protective insert garment **130**. As such, the CFRP layer may include one or more inner layers and/or one or more outer layers that provide additional protection to the CFRP layer of the protective insert garment **130** in order to reduce the wear of the CFRP layer (e.g., the matrix layer thereof) and/or reduce the chance for exposing the carbon fiber, which may irritate the skin and/or damage the glove **200**.

**[0067]** Moreover, the one or more inner layers and/or outer layers may provide additional functionality, such as one or more insulation layers (e.g., to provide additional layers of insulation for the user), one or more layers of cotton material (e.g., to provide comfort for the user), one or more layers of aramid fiber cloth (e.g., to provide strength and/or durability to the protective garment), one or more layer of moisture wicking material (e.g., synthetic, natural, or the fibers, or other like materials), wear resistant materials (e.g., leather, neoprene, nitrile, or the like), and/or other types of materials to provide other benefits for the protective garment. For example, the moisture wicking material may include materials (e.g., formed from synthetic, natural, or the like fibers, or other materials), such as nylon, wool, polyester, polypropylene, micromodal, bamboo, or the like materials. The moisture wicking material may be located on the inner side of the protective insert garment **130**. Additionally, or alternatively, the outer layer of the protective insert garment **130** may have a wear resistant material (e.g., leather-goatskin or the like, neoprene, nitrile, canvas, or the like). It should be understood that the one or more layers of the protective insert garment **130** may be formed as previously discussed herein, such as formed through adhesives, stitching, molding, or the like processes. The protective insert garments **130** may be used as an insert within gloves **200**. As such, the protective insert garments **130** may be full gloves. However, in some embodiments the protective insert garments **130** may have one or more portions missing, such as one or more of the fingers removed (e.g., missing pinky, ring, middle, index, and/or thumb). In other embodiments a portion of the fingers may be missing (e.g., underside of the fingers missing and replaced with finger straps, or the like), the palm of the insert may be missing, the outside of the hand adjacent the pinky may be missing, or other portions of the protective inset garments **130** may be missing. The missing portions of the protective insert garments **130**, like the glove guards **120** previously discussed herein, may provide improved movement of the user's hand and/or fingers without sacrificing safety since some areas of the hand are less likely to receive a weld stick then other areas.

**[0068]** The gloves **200** used with the protective insert garment **130** may be specific types of gloves **200** for the protective insert garment **130**. However, in some embodiments the protective insert garment **130** may be used with any type of glove **200** (e.g., a universal insert for use with any or most gloves **200**). In other embodiments the protective insert garment **130** may be configured and/or specified for use with a particular outer glove **200** (e.g., having particular single or multiple layers). As such, the protective insert garment **130** may be provided as an individual insert for use with an outer glove **200** and/or with one or more outer gloves **200** (e.g., multiple gloves **300**) that may be disposed of over-time as they become worn before the protective insert garment **130** requires replacement.

**[0069]** In some embodiments, instead of the protective garment **100** being a guard that is used over other PPE and/or an insert **130** used under other PPE, the protective garment **100** itself may be used as PPE or within PPE. For example, in some embodiments the protective garments **100**, such as gloves **200**, protective suits, or other protective clothing, or portions thereof, may be made from (e.g., have a layer formed of) the heat conducting composite material **102**. For example, the heat conducting composite material **102** may be stitched and/or molded into a glove **200** or may comprise of a layer of a glove **200** that comprises one or more other layers of material.

**[0070]** Moreover, in some embodiments, not specifically illustrated in the figures, the protective garments may be aprons, capes, chest shields, back shields, neck protection, head protection (e.g., masks with welding glass, or the like), shirts, jackets, pants, or other like protection. These garments may be used as a guard or outerwear over any portion of the user's body or other garments worn by the user, and/or as an insert or innerwear under other garments worn by the user. For example, the aprons, capes, chest shields, back shields, neck protection, head protection, or the like may be worn as PPE, under outerwear (e.g., shirts, pants, jackets, shielding, or the like), and/or over innerwear (e.g., shirts, pants, shielding, or the like).

**[0071]** Consequently, as discussed herein, the protective garments may be worn as PPE, guards, and/or inserts, on a user's body, over other PPE or traditional garments, and/or under other PPE or traditional garments.

**[0072]** FIG. **9** illustrates a method of forming the heat conductive composite materials described herein. The method may begin at block **310**, where a perimeter of sealant tape (e.g., chromate tape, or the like) is placed around a surface (e.g., work surface, tooling surface, manufacturing surface, or the like). The perimeter of sealant tape (e.g., chromate tape, or the like) may be used to form the desired size and shape of the heat conductive composite material.

**[0073]** The method may then continue to block **320**, where a layer of release film, such as peel-ply, is placed on the surface within the sealant tape perimeter. The release film may allow easy removal of the composite material from the surface and/or provide a barrier between the composite and a breeder/breather cloth.

**[0074]** Then, in block **330**, the one or more heat conducting material layers, such as the carbon-fiber layers **10** are procured (e.g., cut, or the like) into the desired shapes, depending on the desired properties of the protective garment **100**. For example, a protective garment **100** with fewer layers may result in lower thermal protection but higher conformability for complex shapes. Alternatively, a protective garment **100** with more layers may result in higher thermal protection but lower conformability for complex shapes.

**[0075]** The method may then continue to block **340**, where a layer of the matrix is applied to the surface (e.g., work, tool, manufacturing, or the like surface). In some embodiments, the matrix may comprise a liquid polymer, which may be applied to the surface by evenly spreading the liquid over the layer of release film. As described herein, the matrix polymer may provide the protective garment **100** with additional protective properties (such as, for example, scaling any air gaps between the woven fibers, providing additional insulation, or the like).

**[0076]** Thereafter, a layer of heat conductive material may be placed on top of the matrix layer, as illustrated in block **350**. Moreover, as illustrated in block **360** one or more additional layers of the matrix and heat conductive material are layered according to steps **340** and **350**, in order to achieve the predetermined number of layers corresponding to the desired properties of the protective garment **100**, such as the amount of thermal resistance, puncture resistance, and moldability. The alternating layers of the matrix and the heat conductive material may be added, one at a time, to the work surface.

**[0077]** If only a single matrix and heat conductive material is used, or after the desired number of plies are added, the method may proceed to block **370**, where a top layer is applied to the work surface. In some embodiments, the top layer may comprise the same release film (e.g., peel ply) used in block **320**. Additionally, or alternatively, an additional bleeder/breather cloth layer may be added at this step of the process.

**[0078]** The method may then continue to block **380**, where all layers on the surface may be vacuum sealed. In some embodiments, this may be achieved by placing a nylon bag or like over the surface and securing the bag to the perimeter of the sealant tape. A vacuum pump may then be applied to remove the air within the bag. In some embodiments, the layers may be vacuum sealed to a vacuum gauge reading of approximately 25 in/Hg to 35 in/Hg (e.g., approximately 28.5 in/Hg, or the like).

**[0079]** Next, as shown in block **390**, the sealed layers may be left to cure into a single compound layer of laminated material. The sealed layers may be left to cure to a predetermined period of time depending on the properties of the matrix, such as 12, 16, or 24 hours. As such, the heat conductive composite material is formed.

**[0080]** The method may then continue to block **395**, where the heat conductive composite material may be cut into one or more predetermined shapes, depending on the desired shape of the protective garment **100**. In some embodiments, block **395** may further comprise stitching and/or molding the heat conductive composite material into the desired garment and/or securing the one or more garment connectors **150** to the protective garment **100**. As such, the final protective garment may be formed into a glove, other clothing, a glove guard, an arm guard, a leg guard, a foot guard, a chest guard, and/or any other wearable protective garment.

**[0081]** Additionally, and/or alternatively, instead of using sealant tape (e.g., chromate tape, or the like) described with respect to block **310** and/or a vacuum described with respect to blocks **380** and **390** to create the CFRP, compression molding may be used to create the CFRP. For example, the same or similar materials described with respect to FIG. **9** may be used, except that the stack of layers may be heated and then compressed between compression members (e.g., plates, molds, or the like and/or clamps or the like), and thereafter and allowed to cure. This process may be more commercially viable (e.g., more cost effective, or the like) than the vacuum sealing and curing described with respect to blocks **380** and **390**.

**[0082]** It should be understood that while a general process for forming the protective garment **100**, has been described herein with respect to FIG. **9**, any type of process may be used to create the conductive composite material **102** and/or the protective garments **100** thereof. It should be understood that the process used to form the conductive composite material **102** and/or the protective garments **100** may be manual, automated, partially manual and/or automated, or the like. For example, the heat conductive composite material **102** may be automatically formed using partially continuous sheets of material that are layered, heated, pressed, vacuum sealed, cured, or the like separately, partially together in individual layers, together, or the like. As such, the heat conductive composite material **102** may be manufactured in bulk for use in creating the protective garment **100**.

**[0083]** It should be understood that "operatively coupled," when used herein, means that the components may be formed integrally with each other, or may be formed separately and coupled together. Furthermore, "operatively coupled" means that the components may be formed directly to each other, or to each other with one or more components located between the components that are operatively coupled together. Furthermore, "operatively coupled" may mean that the components are detachable from each other, or that they are permanently coupled together.

**[0084]** Also, it will be understood that, where possible, any of the advantages, features, functions, devices, and/or operational aspects of any of the embodiments of the present invention described and/or contemplated herein may be included in any of the other embodiments of the present invention described and/or contemplated herein, and/or vice versa. In addition, where possible, any terms expressed in the singular form herein are meant to also include the plural form and/or vice versa, unless explicitly stated otherwise. Accordingly, the terms "a" and/or "an" shall mean "one or more."

**[0085]** Certain terminology is used herein for convenience only and is not to be taken as a limiting, unless such terminology is specifically described herein for specific embodiments. For example, words such as "top", "bottom", "upper", "lower", "first", "second", or the like may merely describe the configurations shown in the figures and described herein for some embodiments of the invention. Indeed, the components may be oriented in any direction and the terminology, therefore, should be understood as encompassing such variations unless specified otherwise. The terminology includes the words specifically mentioned above, derivatives thereof and words of similar import.

**[0086]** While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other changes, combinations, omissions, modifications and substitutions, in addition to those set forth in the above paragraphs, are possible. Those skilled in the art will appreciate that various adaptations, modifications, and combinations of the just described embodiments can be configured without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.

What is claimed is:

**1**. A protective garment, the protective garment comprising:
- a heat conducting composite material comprising:
  - one or more heat conducting layers; and
  - a matrix operatively coupled to the one or more heat conducting layers;
- wherein the heat conducting composite provides protection from wire sticks during welding.

**2**. The protective garment of claim **1**, wherein the one or more heat conducting layers comprise at least a woven fiber layer.

**3**. The protective garment of claim **1**, wherein the one or more heat conducting layers comprise at least a carbon fiber layer.

**4**. The protective garment of claim **1**, wherein the one or more heat conducting layers comprise at least a graphene layer.

**5**. The protective garment of claim **2**, wherein the woven fiber layer comprises a twill weave carbon fiber cloth, a flat-tow weave carbon fiber cloth, or a triaxial twill weave carbon fiber cloth.

**6**. The protective garment of claim **2**, wherein the matrix comprises a polymer that holds the woven fiber layer together.

**7**. The protective garment of claim **6**, wherein the polymer comprises a plastic, a rubber, a resin, or a silicone-based polymer matrix.

**8**. The protective garment of claim **6**, wherein the matrix comprises a softener.

**9**. The protective garment of claim **1**, wherein the heat conducting composite material comprises a plurality of fiber layers and the matrix operatively couples the plurality of fiber layers together to form a fiber reinforced polymer material.

**10**. The protective garment of claim **1**, wherein the protective garment is an appendage guard.

**11**. The protective garment of claim **10**, wherein the appendage guard is worn over a glove or over an arm or leg.

**12**. The protective garment of claim **1**, wherein the protective garment is a protective insert garment that is worn under an outer glove.

**13**. The protective garment of claim **1**, wherein the protective garment comprises:

a garment connector, wherein the garment connector is configured to be removably operatively coupled with an appendage or a garment located on the appendage.

**14**. The protective garment of claim **13**, wherein the garment connector comprises at least one of a fastener, a hook or loop connector, a strap and ring, or a strap and clip.

**15**. The protective garment of claim **1**, wherein the heat conducting composite material is integrally operatively coupled with a garment for use on an appendage.

**16**. The protective garment of claim **1**, wherein the protective garment is a glove, and the glove comprises:

a fabric material, wherein the heat conducting composite material is operatively coupled to at least a portion of the fabric material.

**17**. A method of forming a protective garment for improved welding protection, the method comprising:

positioning one or more heat conducting material layers for receipt of a matrix; and

applying the matrix over at least a portion of the one or more heat conducting material layers.

**18**. The method of claim **17**, wherein the one or more heat conducting material layers comprise at least two heat conducting material layers with the matrix located between the at least two heat conducing material layers.

**19**. The method of claim **17**, wherein the one or more heat conducting layers comprise a woven carbon fiber layer, and wherein the matrix is a polymer.

**20**. The method of claim **19**, wherein the polymer comprises a plastic, a rubber, a resin, or a silicone based polymer matrix.

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