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(54) Title: BALLISTIC PANEL ASSEMBLIES FOR USE IN BODY ARMOR AND METHOD OF FORMING BALLISTIC PANEL ASSEMBLIES

(57) Abstract: A ballistic panel assembly for use in body armor includes at least one subassembly including at least one layer including fibers that extend from at least one side thereof and at least one edge guard encompassing at least a portion of the extending fibers. The ballistic panel assembly further includes a waterproof cover encasing the at least one subassembly. The cover includes a front section and a rear section. A waterproof seal is formed between the front section and the rear section around at least a portion of perimeters thereof adjacent to the at least one edge guard after the subassembly is placed between the front section and the rear section. The edge guard can, for example, include an adhesive tape.

Title

**BALLISTIC PANEL ASSEMBLIES FOR USE IN BODY ARMOR AND METHOD OF FORMING BALLISTIC PANEL ASSEMBLIES**

This application claims the priority of Provisional Application No. 61/172,303 filed April 24, 2009, the entire disclosure of which is incorporated herein by reference.

Background of the Invention

[0001] The present invention relates generally to ballistic panel assemblies for use in body armor, body armor including such ballistic panel assemblies and methods of forming ballistic panel assemblies. These ballistic panel assemblies are also known as ballistic packages.

[0002] The following information is provided to assist the reader to understand the invention disclosed below and the environment in which it will typically be used.<sup>\*</sup> The terms used herein are not intended to be limited to any particular narrow interpretation unless clearly stated otherwise in this document. References set forth herein may facilitate understanding of the present invention or the background of the present invention. The disclosure of all references cited herein are incorporated by reference.

[0003] Concealable body armor for protection from, for example, edged weapons, sharp objects and ballistic threats, has been available for several decades. Since the introduction of concealable body armor, ballistic materials have been improved greatly, resulting in relatively flexible, soft or pliant body armor and increased comfort for the user. Modern, lightweight concealable body armor often includes ballistic (or ballistic resistant) panels or packages formed from a number of polymeric materials such as KEVLAR<sup>®</sup> ballistic grade fibers/fabrics (formed from para-aramid synthetic fibers) available from E. I. du Pont de Nemours and Company of Wilmington, Delaware USA.

[0004] Performance standards for ballistic panels are, for example, set forth in National Institute of Justice (NIJ) Standard-0101.06, "Ballistic Resistance of Body Armor". NIJ Standard-0101.06 is a technical document that specifies the minimum performance requirements that equipment must meet to satisfy the requirements of criminal justice agencies and the methods that shall be used to test this performance. This standard is used to determine which body armor models meet the minimum performance requirements for inclusion on the NIJ Compliant Products List.

[0005] Although significant developments have been made in ballistic resistant body armor, it remains desirable to develop improved ballistic panel assemblies for use in body armor to satisfy current and future performance requirements, including those set forth in NIJ Standard-0101.06.

#### Summary of the Invention

[0006] In one aspect, a ballistic panel assembly for use in body armor is provided, including at least one subassembly including at least one layer including fibers that extend from at least one side thereof and at least one edge guard encompassing at least a portion of the extending fibers. The ballistic panel assembly further includes a waterproof cover encasing the at least one subassembly. The cover includes a front section and a rear section. A waterproof seal is formed between the front section and the rear section around at least a portion of perimeters thereof adjacent to the at least one edge guard after the subassembly is placed between the front section and the rear section. The edge guard can, for example, include an adhesive tape. The waterproof seal can, for example, be formed between the front section and the rear section via a polymeric welding technique (for example, sonic or ultrasonic welding).

[0007] The at least one layer of the at least one subassembly can, for example, include a woven aramid fabric. In several embodiments, the at least one layer includes a woven para-aramid fabric.

[0008] The ballistic panel assembly can further include at least a first stitching around the entire perimeter of the subassembly through all layers of the subassembly. In several embodiments, the ballistic panel assembly also includes at least a second stitching around the entire perimeter of the

subassembly through all layers of the subassembly. The second stitching is spaced from the first stitching.

[0009] In another aspect, a method of forming a ballistic panel assembly for use in body armor is provided, including: forming at least one subassembly including at least one layer including fibers that extend from at least one side thereof and at least one edge guard encompassing at least a portion of the extending fibers; and encasing the subassembly and the at least one edge guard within a waterproof cover. The cover includes a front section and a rear section. A waterproof seal is formed between the front section and the rear section around at least a portion of perimeters thereof adjacent to the at least one edge guard after the subassembly is placed between the front section and the rear section.

[0010] In a further aspect, a ballistic panel assembly for use in body armor is provided, including at least one subassembly including at least one composite layer including a plurality of plies of a polymeric film and a plurality of plies formed from ultrahigh molecular weight polyethylene fibers. At least one ply of the polymeric film is alternated with a plurality of plies formed from ultrahigh molecular weight polyethylene fibers. In several embodiments, a single ply of the polymeric film is alternated with a plurality of plies formed from ultrahigh molecular weight polyethylene fibers. In a number of embodiments, the polymeric film is a polycarbonate film. The ballistic panel assembly can further include a waterproof cover encasing the at least one subassembly.

[0011] In still a further aspect, a ballistic panel assembly for use in body armor is provided, including at least one subassembly including a plurality of layers of material to form a strike face and a wear face and at least a first stitching around the entire perimeter of the subassembly through all layers of the subassembly. The ballistic panel assembly further includes a waterproof cover encasing the at least one subassembly. In several embodiments, the ballistic panel assembly further includes at least a second stitching around the entire perimeter of the subassembly through all layers of the subassembly. The second stitching is spaced from the first stitching.

[0012] The present invention, along with the attributes and attendant advantages thereof, will best be appreciated and understood in view of the following detailed description taken in conjunction with the accompanying drawings.

#### Brief Description of the Drawings

[0013] Figure 1 illustrates a top plan view of the front of an embodiment of an article of body armor of the present invention laid flat on a surface, wherein a front ballistic panel assembly interior to a vest carrier is shown in dashed lines.

[0014] Figure 2 illustrates a top plan view of the rear of the article of body armor of Figure 1 wherein the body armor is laid flat on a surface and the rear closure sections of the opposing closure mechanisms are folded back, wherein a rear ballistic panel assembly interior to the vest carrier is shown in dashed lines.

[0015] Figure 3A illustrates a top plan view of an embodiment of a subassembly for use in forming a front ballistic panel assembly of the article of body armor of Figure 1.

[0016] Figure 3B illustrates a top plan view of an embodiment of a subassembly for use in forming a rear ballistic panel assembly of the article of body armor of Figure 1.

[0017] Figure 3C illustrates a cross-sectional view of the subassembly of Figure 3A along line A-A thereof.

[0018] Figure 3D illustrates a top plan view of the front ballistic panel assembly.

[0019] Figure 3E illustrates a top plan view of the rear ballistic panel assembly.

[0020] Figure 3F illustrates a cross-sectional view of the ballistic panel assembly of Figure 3D along line B-B thereof.

[0021] Figure 4A illustrates a top plan view of another embodiment of a subassembly for use in forming the front ballistic panel assembly of the article of body armor of Figure 1.

[0022] Figure 4B illustrates a top plan view of another embodiment of a subassembly for use in forming the rear ballistic panel assembly of the article of body armor of Figure 1.

[0023] Figure 4C illustrates a cross-sectional view of the subassembly of Figure 4A along line A-A thereof.

[0024] Figure 4D illustrates a top plan view of the front ballistic panel assembly.

[0025] Figure 4E illustrates a top plan view of the rear ballistic panel assembly.

[0026] Figure 4F illustrates a cross-sectional view of the ballistic panel assembly of Figure 4D along line B-B thereof.

[0027] Figure 5A illustrates a top plan view of another embodiment of a subassembly for use in forming the front ballistic panel assembly of the article of body armor of Figure 1.

[0028] Figure 5B illustrates a top plan view of another embodiment of a subassembly for use in forming the rear ballistic panel assembly of the article of body armor of Figure 1.

[0029] Figure 5C illustrates a cross-sectional view of the subassembly of Figure 5A along line A-A thereof.

[0030] Figure 5D illustrates a top plan view of the front ballistic panel assembly.

[0031] Figure 5E illustrates a top plan view of the rear ballistic panel assembly.

[0032] Figure 5F illustrates a cross-sectional view of the ballistic panel assembly of Figure 5D along line B-B thereof.

#### Detailed Description of the Invention

[0033] In general, the present invention provides ballistic panel assemblies for use in body armor, body armor including such ballistic panel assemblies and methods of forming ballistic panel assemblies for use in body armor.

[0034] As used herein and in the appended claims, the singular forms “a,” “an”, and “the” include plural references unless the content clearly dictates otherwise. Thus, for example, reference to “a panel assembly” includes a plurality of such panel assemblies and equivalents thereof known to those skilled in the art, and so forth, and reference to “the panel assembly” is a reference to one or more such panel assemblies and equivalents thereof known to those skilled in the art, and so forth.

[0035] Figure 1 illustrates an embodiment of an article of body armor 10 of the present invention in which a body armor carrier is in the form of a vest 20 as, for example, described in PCT International Patent Application Publication No. WO 2007/046863, the disclosure of which is incorporated herein by reference. As set forth in International Publication No. WO 2007/046863, vest 20 can be used alone or in operative connection with a connected garment such as shirt (not shown). For example, an exterior shell fabric of the body armor can be sewn to the shirt. A user of body armor 10 first dons body armor 10 and then adjusts the fit of body armor vest 20 using one or more side closure mechanisms as described in International Publication No. WO 2007/046863. Lightweight outer carriers in the form of vests similar to vest 20 are available from Mine Safety Appliances Company (MSA) of Pittsburgh, Pennsylvania under the mark MSA PARACLETE®. One skilled in the art appreciates that the ballistic panel assemblies of the present invention are suitable for use in many different configurations of body armor other than the configuration illustrated in Figure 1.

[0036] As described above, body armor 10 includes ballistic panel assemblies or ballistic resistant panel assemblies that provide resistance to, for example, edged weapons, sharp objects, and ballistic threats. As illustrated with dashed lines in, for example, Figure 1A, vest 20 includes a generally contiguous (in coverage), flexible front ballistic panel assembly 200. One skilled in the art appreciates that ballistic panel assembly 200 can be formed as one, integral section or assembly or as a plurality of separate sections or assemblies. However, the coverage provided by ballistic panel assembly 200 is preferably contiguous. Front ballistic panel assembly 200 includes side sections 210a and 210b adapted to extend around the side of a user. Ballistic panel assembly 200, including side sections 210a and 210b, is enclosed within an outer shell of fabric forming the front of carrier or vest 20. As illustrated with dashed lines in, for example, Figure 2, vest 20 also includes

a generally contiguous (in coverage), flexible rear ballistic panel assembly 300. Like front ballistic panel assembly 200, rear ballistic panel assembly 300 can be formed as one section or assembly or as a plurality of separate sections or assemblies. Rear ballistic panel assembly 300 includes side sections 310a and 310b adapted to extend around the side of a user. Like ballistic panel assembly 200, ballistic panel assembly 300, including side sections 310a and 310b, is enclosed within an outer shell of fabric forming the rear of carrier or vest 20.

**[0037]** Figures 3A through 3F illustrate one embodiment of a ballistic panel assembly or ballistic package of the present invention. Figure 3A illustrates a flexible subassembly 230 for use in forming front ballistic panel assembly 200, while Figure 3B illustrates a flexible subassembly 330 for use in forming rear ballistic panel assembly 300. Subassemblies 230 and 330 are designed for Type II level of ballistic performance as set forth in Section 2.2 of NIJ Standard-0101.06. In the embodiment of Figures 3A through 3F, each of front ballistic panel assembly 200 and rear ballistic panel assembly 300 is manufactured using generally the same materials and procedures and differ generally only in shape. Figure 3C illustrates a cross-sectional view of subassembly 230 along line A-A of Figure 3A. A cross-section of subassembly 330 along line A-A of Figure 3B (which is not shown) is identical to that of subassembly 230.

**[0038]** As illustrated in Figure 3C, subassembly 230 (as well as subassembly 330) includes, for example, a multi-ply (for example, a 2-ply) layer 232 of an aramid fabric on the front, outer or strike face thereof. The term "aramid" is short for aromatic polyamide. In one embodiment, layer 232 included two plies of GOLD FLEX® material available from Honeywell, which is a roll product including four plies of unidirectional aramid fiber. Adjacent plies are oriented differently at angles orthogonal to each other (that is, at 0°/90°/0°/90°) and sandwiched in a thermoplastic film. No adhesive was placed between the plies of GOLD FLEX material. Without limitation to any particular mechanism of operation, layer 232 is believed to operate, at least in part, to alter the shape, deform or flatten a projectile or bullet impacting layer 232 so that it has less potential to penetrate any adjacent layer(s).

**[0039]** Adjacent to layer 232 is a layer 234 including a plurality of plies of, for example, an aramid fabric. In one embodiment, layer 234 included, for example, 17 plies of TWARON® woven



fabric available from Teijin Aramid BV of Arnhem, The Netherlands. TWARON material is a very strong, light para-aramid (poly-paraphenylene terephthalamide), which has a high tensile strength and is thermally stable. TWARON fabrics also exhibit high impact and chemical resistance. No adhesive was used between the plies of TWARON fabric in layer 234. Without limitation to any particular mechanism of operation, it is believed that the projectile or bullet is stopped within layer 234 as a result, at least in part, of elongation and breakage of the high tensile strength fibers of the TWARON fabric.

**[0040]** Adjacent to layer 234 is a layer 236 of, for example, an aramid fabric that forms the back, inner or wear face of subassembly 230. In one embodiment, layer 236 was a multi-ply (for example, a 4-ply) layer of GOLD FLEX material with no adhesive between the plies thereof. layer 236 can operate, at least in part, to limit deformation of the wear face of subassembly 230 upon a ballistic strike thereto to limit the amount of blunt force trauma experienced by a user of vest 20. In that regard (and, once again, without limitation to any particular mechanism of operation,), layer 236 can, for example, operate to distribute rearward propagating force from the projectile or bullet over the surface area thereof and assists in limiting backface deformation or backface signature (BFS) as defined in Section 3.8 of NIJ Standard-0101.06. In that regard, the allowable BFS is the greatest extent of indentation in a backing material caused by a nonperforating impact on tested armor. As set forth in Section 3.9 of NIJ Standard-0101.06, the backing material is a homogeneous block of nonhardening, oil-based modeling clay placed in contact with the back of the armor panel during ballistic testing.

**[0041]** As illustrated in Figures 3A and 3B, each of subassemblies 230 and 330 includes stitching 240 and 340, respectively, around the perimeter thereof. Each of stitching 240 and stitching 340 assists in maintaining the integrity (particularly under the conditioning requirement of NIJ Standard-0101.06 and in subsequent use) of subassemblies 230 and 330, respectively, and improves the ballistic resistant performance thereof for strikes along the edge thereof. Unlike previously available ballistic panel subassemblies, the perimeter stitching of the present invention passes through all layers of subassemblies 230 and 330. The perimeter stitching of the present invention improves, for example, BFS performance in the case of edge strikes. In one embodiment,

the stitching was performed with Tex 90 nylon 6, 6 thread. The Tex size is 1/9 the denier size. In one embodiment, edge stitching 240 and 340 was positioned a distance "a" of approximately 1/2 inch from the edge of subassembly 230 and subassembly 330, respectively.

[0042] As also illustrated in Figures 3A and 3B, each of subassembly 230 and subassembly 330 also include generally orthogonal stitching therethrough in a quilt pattern 244 and 344, respectively. In one embodiment, spacing "b" between adjacent stitching lines in the quilt pattern was approximately 1 inch. An angle  $\alpha$  of the stitch lines was approximately 45°. The quilt stitching was done with Tex 90 nylon 6, 6 thread. Quilt pattern stitching, for example, improves backface deformation or BFS by stiffening subassembly 230. A closer quilt spacing b, can result in improved ballistic performance. However, a closer quilt spacing b is also associated with increased overall stiffness and thus less flexibility of the panel assembly.

[0043] In the illustrated embodiment, the lower edge of each of subassembly 230 and 330 was encompassed by an edge guard or trim 238 and 338, respectively. In one embodiment, a tape such as duct tape (a vinyl, fabric-reinforced, pressure sensitive tape) was used for edge guard 238 and edge guard 338. As illustrated in Figures 3D through 3F, subassemblies 230 and 330 were each placed within a waterproof cover 250 and 350, respectively, formed from a polymeric material which was sealed (for example, via sonic welding) around the perimeter thereof. In one embodiment, two sheets (cut to the appropriate size and shape) of a polymeric material such as polyurethane coated (on one side) nylon fabric were sonic welded around the perimeters thereof (to create a seal 252 and 352), leaving the bottom edge thereof unsealed. The polyurethane coated side faced inward on each of the front and rear. Subassemblies, 230 and 330 were then slid into the partially sealed covers 250 and 350, respectively, through the unsealed bottom edges thereof. Subsequently, the bottom edges of covers 250 and 350 were sealed via, for example, a polymer welding technique such as sonic welding.

[0044] The inventors have discovered that extending fibers or filaments of, for example, woven fabrics used to form subassemblies 230 and 330 interfere with forming edge seals 252 and 352. Application of edge guards or trims 238 and 338 to bottom edge (or other edge corresponding to the last edge of covers 250 and 350 to be sealed) of subassemblies 230 and 330, respectively,

prevents such interference and enables a waterproof seal. A waterproof seal of subassemblies 230 and 330 is important to maintaining the ballistic performance thereof.

**[0045]** Figures 4A through 4F illustrate another embodiment of a ballistic panel assembly suitable for use in the present invention. Figure 4A illustrates a flexible subassembly 430 for use in forming front ballistic panel assembly 400 (which can be used in vest 20 as an alternative to ballistic panel assembly 200), while Figure 4B illustrates a flexible subassembly 530 for use in forming rear ballistic panel assembly 500 (which can be used in vest 20 as an alternative to ballistic panel assembly 300). In the embodiment of Figures 4A through 4F, each of ballistic panel assembly 400 and rear ballistic panel assembly 500 is manufactured using the same materials/procedures and differ generally only in shape. Figure 4C illustrates a cross-sectional view of subassembly 430 along line A-A of Figure 4A. A cross-section of subassembly 530 along line A-A of Figure 4B (which is not shown) is identical to that of subassembly 430.

**[0046]** As illustrated in Figure 4C, subassembly 430 (as well as subassembly 530), for example, includes a multi-ply (for example, a 2-ply) layer 432 of an aramid fabric on the front, outer or strike face thereof. Subassemblies 430 and 530 are designed for a Type IIIA level of ballistic performance as set forth in Section 2.3 NIJ Standard-0101.06. In one embodiment, layer 432 included two plies of GOLD FLEX material. No adhesive was placed between the plies of GOLD FLEX material. Similar to layer 232, layer 432 is believed to operate, at least in part, to alter the shape, deform or flatten a projectile or bullet impacting layer 432 so that it has less potential to penetrate any adjacent layer(s).

**[0047]** Adjacent to layer 432 is a layer 434 including, for example, a plurality of plies of an aramid fabric. In one embodiment, layer 434 included, for example, 14 plies of TWARON® fabric. No adhesive was used between the plies of TWARON fabric in layer 434. The projectile or bullet is believed to be stopped within layer 434 as a result, at least in part, of elongation and breakage of the high tensile strength fibers of the TWARON fabric.

**[0048]** Adjacent to layer 434 is another layer 436 of, for example, an aramid fabric. In one embodiment, layer 436 was a multi-ply (for example, a 2-ply) layer of GOLD FLEX material with

no adhesive between the plies thereof. Layer 436 can, for example, operate, at least in part, to limit deformation of the wear face (or “back deformation”) of subassembly 430 to limit the amount of blunt force trauma experienced by a user of vest 20. Layer 436 is, for example, believed to assist in distributing rearward propagating force from the projectile or bullet over the surface area thereof.

[0049] Adjacent to layer 436 is another layer 437 of, for example, an aramid fabric forming the back, inner or wear surface of subassembly 430. In one embodiment, layer 437 was a multi-ply layer (for example, a 10-ply layer) of GOLD FLEX material with no adhesive between the plies thereof. Layer 437 is, for example, believed to operate to further distribute rearward propagating force from the projectile or bullet over the surface area thereof to limiting backface deformation or BFS.

[0050] As illustrated in Figures 4A and 4B, each of subassemblies 430 and 530 includes a first or outer perimeter stitching 440 and 540, respectively, and a second or inner perimeter stitching 442 and 542, respectively, around the perimeter and through all layers thereof. As described above, such perimeter stitching assists in maintaining the integrity of subassemblies 430 and 530, respectively, and improves the ballistic resistant (for example, backface deformation or BFS) performance thereof for ballistic strikes along the edge thereof. A double row of stitching results, for example, in better BFS performance along the edge than a single row of stitching, but increases the stiffness along the edge or perimeter. In one embodiment, the stitching was performed with Tex 90 nylon 6, 6 thread. In one embodiment, each of edge stitching 440 and 540 was positioned a distance “a” of approximately 1/2 inch from the edge of subassembly 430 and subassembly 530, respectively, and the spacing a’ between first edge stitching 440 and second edge stitching 442 (as well as between first edge stitching 540 and second edge stitching 542) was approximately 1 inch.

[0051] As also illustrated in Figures 4A through 4C, a portion q (see Figure 4C) of each of subassembly 430 and subassembly 530 also includes generally orthogonal stitching therethrough in a quilt pattern 444 and 544, respectively. As illustrated in Figure 4C, portion q included layers 432, 434 and 436. Layer 437 was not quilted. In one embodiment, spacing “b” between adjacent stitching lines in the quilt patterns was approximately 1 inch. An angle  $\alpha$  of the stitch lines was

approximately 45°. The quilt stitching was also done with Tex 90 nylon 6, 6 thread. As described above, a closer quilt spacing  $b$ , results in improved ballistic/BFS performance, but is associated with increased stiffness. Quilting portion  $q$ , but not layer 437 resulted in suitable BFS performance while maintaining sufficient flexibility.

**[0052]** As described in connection with subassemblies 230 and 330, the lower edge of each of subassembly 430 and 530 was encompassed by an edge guard or trim 438 and 538, respectively. In one embodiment, a tape such as duct tape was used as edge guards 438 and 538. As illustrated in Figures 4D through 4F, subassemblies 430 and 530 were each placed within a waterproof cover 450 and 550, respectively, formed from a polymeric material which was sealed (for example, via sonic welding) around the perimeter thereof. In one embodiment, two sheets (cut to the appropriate shape) of a polyurethane coated (on one side) nylon fabric were sonic welded around the perimeters thereof (to create perimeter seals 452 and 552), leaving the bottom edge thereof unsealed. The polyurethane coated side faced inward on each of the front and rear. Subassemblies, 430 and 530 were then slid into covers 450 and 550, respectively, through the unsealed bottom edge. Subsequently, the bottom edges of covers 450 and 550 were sealed via, for example, sonic welding. As described above, application of tape 438 and 538 to bottom edge (or other edge corresponding to the last edge of covers 450 and 550 to be sealed) of subassemblies 430 and 530, respectively, prevents interference of fabric filaments in forming a waterproof seal.

**[0053]** Figures 5A through 5F illustrate another embodiment of a ballistic panel assembly suitable for use in the present invention. Figure 5A illustrates a flexible subassembly 630 for use in forming front ballistic panel assembly 600 (which can be used in vest 20 as an alternative to ballistic panel assembly 200), while Figure 5B illustrates a flexible subassembly 730 for use in forming rear ballistic panel assembly 700 (which can be used in vest 20 as an alternative to ballistic panel assembly 300). Subassemblies 630 and 730 are designed for a Type IIIA level of ballistic performance as set forth in Section 2.3 NIJ Standard-0101.06. In the embodiment of Figures 5A through 5F, front ballistic panel assembly 600 and rear ballistic panel assembly 700 are manufactured using generally the same materials/procedures and differ generally only in shape. Figure 5C illustrates a cross-sectional view of subassembly 630 along line A-A of Figure 5A. A

cross-section of subassembly 730 along line A-A of Figure 5B (which is not shown) is identical to that of subassembly 630.

**[0054]** As illustrated in Figure 5C, subassembly 630 (as well as subassembly 730) includes a layer 632 of a plurality of plies of a high-strength fabric on the outer or strike face thereof. In one embodiment, layer 632 included, for example, 20 plies of DYNEEMA® UD-SB31 composite material available from DSM Dyneema of Geleen, The Netherlands. The DYNEEMA UD-SB31 material is a “unidirectional” material in which the fibers (ultrahigh molecular weight polyethylene fibers) are laid parallel, in the same plane, rather than being woven together. Dyneema UD (unidirectional) materials are made of several layers of DYNEEMA fibers, with the direction of fibers in each layer at 90° to the direction of the fibers in the adjacent layers. Without limitation to any particular mechanism, the unidirectional configuration of the fibers in DYNEEMA UD materials is believed to allow the energy transferred from an impact of a bullet or other threat to be distributed along the fibers faster and more efficiently than in conventional woven fabrics. No adhesive was placed between the plies of DYNEEMA material. Layer 632 is believed to operate to both deform the projectile or bullet and to stop the projectile or bullet within layer 632.

**[0055]** Adjacent to layer 632 is a composite layer 634 including, alternating layers of a high-strength material (for example, an ultrahigh molecular weight polyethylene material such as DYNEEMA) and a high-strength polymeric film. In one embodiment, layers 634a of polycarbonate were alternated with a multi-ply (for example, a 2-ply) layers 634b of DYNEEMA UD-SB31 material. In one such embodiment, there were eight layers 634a of singly-ply polycarbonate alternated with eight layers 634b of 2-ply DYNEEMA material, for a total of 24 plies in layer 634. The surface of layer 634 opposite the surface in contact with layer 632, forms the inner or wear surface of subassembly 630. Without limitation to any particular mechanism of operation, layer 634 is, for example, believed to distribute rearward propagating force from the projectile or bullet over the surface area thereof and assists in limiting backface deformation or BFS.

**[0056]** The inventors have discovered that alternate layers of polycarbonate and ultrahigh molecular weight polyethylene material (for example, DYNEEMA material), wherein a single ply of polycarbonate is alternated with a plurality of plies of DYNEEMA material, operate more

effectively to limit backface deformation or BFS than alternate layers of polycarbonate and a single ply of DYNEEMA material. Alternating a single ply of polycarbonate with a plurality of plies of DYNEEMA material (for example, two plies) can also result in equivalent or better ballistic performance while using less material (and thus resulting in a thinner and lighter subassembly) than the case in which polycarbonate is alternated with a single ply of DYNEEMA material. Use of a polymeric material such as polycarbonate rather than only DYNEEMA material can, for example, save on fabrication costs as materials such as polycarbonate are less expensive than DYNEEMA material.

**[0057]** As illustrated in Figures 5A and 5B, similar to subassemblies 430 and 530, each of subassemblies 630 and 730 includes a first or outer perimeter stitching 640 and 740, respectively, and as second or inner perimeter stitching 642 and 742, respectively, around the perimeter thereof. As described above, such perimeter stitching assist in maintaining the integrity of subassemblies 630 and 730, respectively, and improves the ballistic resistant performance thereof for strikes along the edge thereof. Once again, a double row of stitching results in improved ballistic performance along the edge, but increases the stiffness along the edge or perimeter. In one embodiment, the stitching was performed with Tex 90 nylon 6, 6 thread. In one embodiment, each of edge stitching 640 and 740 was positioned a distance "a" of approximately 1/2 inch from the edge of subassembly 630 and subassembly 730, respectively, and the spacing a' between first edge stitching 640 and second edge stitching 642 (as well as between first edge stitching 740 and second edge stitching 742) was approximately 1 inch. In the embodiment of Figures 4A through 4F, no portion of subassemblies 630 or 730 was quilted. Subassemblies 630 and 730 were suitable to satisfy the backface deformation of BFS requirements of NIJ Standard-0101.06 without introducing the stiffness associated with quilt stitching.

**[0058]** As illustrated in Figures 5D through 5F, subassemblies 630 and 730 were each placed within a waterproof cover 650 and 750, respectively, formed from a polymeric material which was sealed (for example, via sonic welding) around the perimeter thereof. As described above, two sheets (cut to the appropriate shape) of a polyurethane coated (on one side) nylon fabric was sonic welded around the perimeters thereof (to create a seal 652 and 752), leaving the bottom edge thereof

unsealed. The polyurethane coated side faced inward on each of the front and rear sides. Subassemblies, 630 and 730 were then slid into covers 650 and 750, respectively, through the unsealed bottom edge. Subsequently, the bottom edges of covers 650 and 650 were sealed via, for example, sonic welding.

**[0059]** As described above, extending fibers or filaments from various layers of the subassemblies used in the present invention can interfere with the formation of a waterproof seal. Such extending fibers or filaments can, for example, be present in the case of woven fabrics. As there were no extending fibers or filaments from any layer of subassemblies 630 or 730, no tape or other edge guard or trim was required in connection with subassemblies 630 or 730.

**[0060]** Although the present invention has been described in detail in connection with the above embodiments and/or examples, it should be understood that such detail is illustrative and not restrictive, and that those skilled in the art can make variations without departing from the invention. The scope of the invention is indicated by the following claims rather than by the foregoing description. All changes and variations that come within the meaning and range of equivalency of the claims are to be embraced within their scope.



**What Is Claimed Is:**

1. A ballistic panel assembly for use in body armor, comprising:  
  
at least one subassembly comprising at least one layer comprising fibers that extend from at least one side thereof and at least one edge guard encompassing at least a portion of the extending fibers; and
- 5 a waterproof cover encasing the at least one subassembly, the cover comprising a front section and a rear section, a waterproof seal being formed between the front section and the rear section around at least a portion of perimeters thereof adjacent to the at least one edge guard after the subassembly is placed between the front section and the rear section.
2. The ballistic panel assembly of claim 1 wherein the at least one layer comprises a  
10 woven aramid fabric.
3. The ballistic panel assembly of claim 1 wherein the at least one layer comprises a woven para-aramid fabric.
4. The ballistic panel assembly of claim 1 further comprising at least a first stitching around the entire perimeter of the subassembly through all layers of the subassembly.
- 15 5. The ballistic panel assembly of claim 4 further comprising at least a second stitching around the entire perimeter of the subassembly through all layers of the subassembly, the second stitching being spaced from the first stitching.
6. The ballistic panel assembly of claim 1 wherein the edge guard comprises an adhesive tape.
- 20 7. The ballistic panel assembly of claim 1 wherein the waterproof seal is formed between the front section and the rear section via a polymeric welding technique.
8. A method of forming a ballistic panel assembly for use in body armor, comprising:  
  
forming at least one subassembly comprising at least one layer comprising fibers that extend  
25 from at least one side thereof and at least one edge guard encompassing at least a portion of the extending fibers; and

encasing the subassembly and the at least one edge guard within a waterproof cover, the cover comprising a front section and a rear section, a waterproof seal being formed between the front section and the rear section around at least a portion of perimeters thereof adjacent to the at least one edge guard after the subassembly is placed between the front section and the rear section..

5           9.     A ballistic panel assembly for use in body armor, comprising:

at least one subassembly comprising at least one composite layer comprising a plurality of plies of a polymeric film and a plurality of plies formed from ultrahigh molecular weight polyethylene fibers, wherein at least one ply of the polymeric film is alternated with a plurality of plies formed from ultrahigh molecular weight polyethylene fibers.

10           10.    The ballistic panel assembly of claim 8 wherein a single ply of the polymeric film is alternated with a plurality of plies formed from ultrahigh molecular weight polyethylene fibers.

11.    The ballistic panel assembly of claim 9 wherein the polymeric film is a polycarbonate film.

15           12.    The ballistic panel assembly of claim 9 further comprising a waterproof cover encasing the at least one subassembly.

13.    A ballistic panel assembly for use in body armor, comprising:

at least one subassembly comprising a plurality of layers of material to form a strike face and a wear face and at least a first stitching around the entire perimeter of the subassembly through all layers of the subassembly; and

20    a waterproof cover encasing the at least one subassembly.

14.    The ballistic panel assembly of claim 12 further comprising at least a second stitching around the entire perimeter of the subassembly through all layers of the subassembly, the second stitching being spaced from the first stitching.

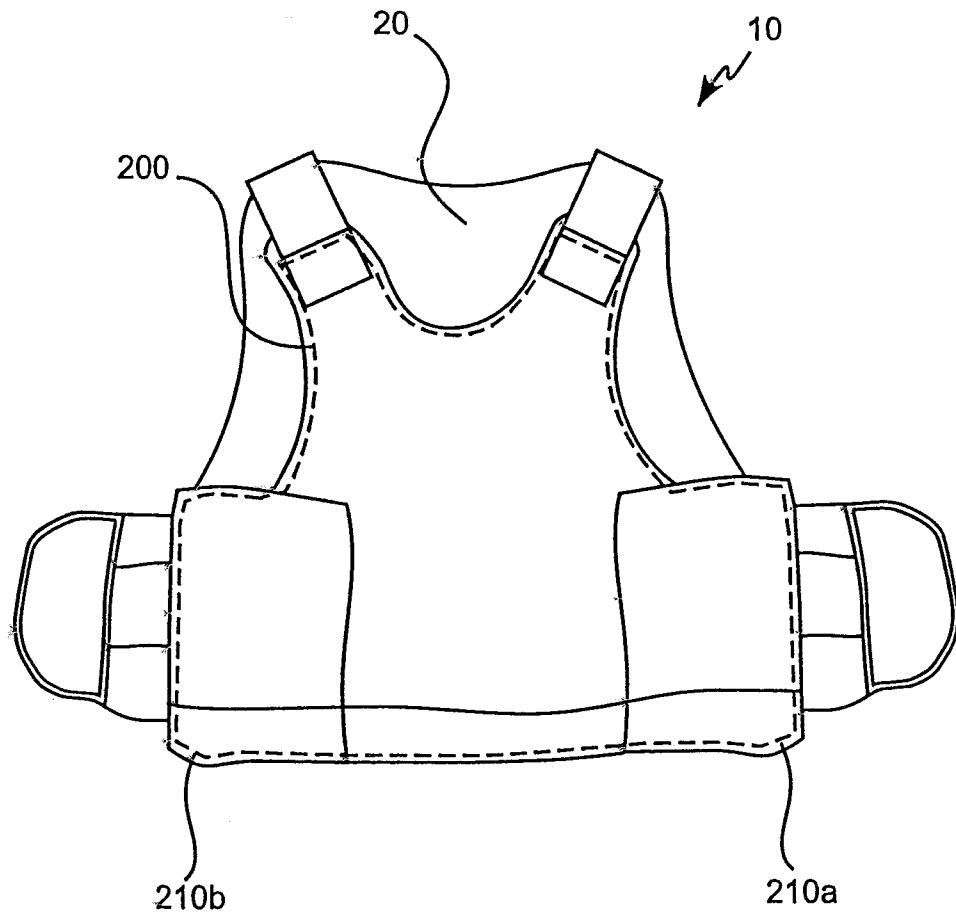


FIG. 1

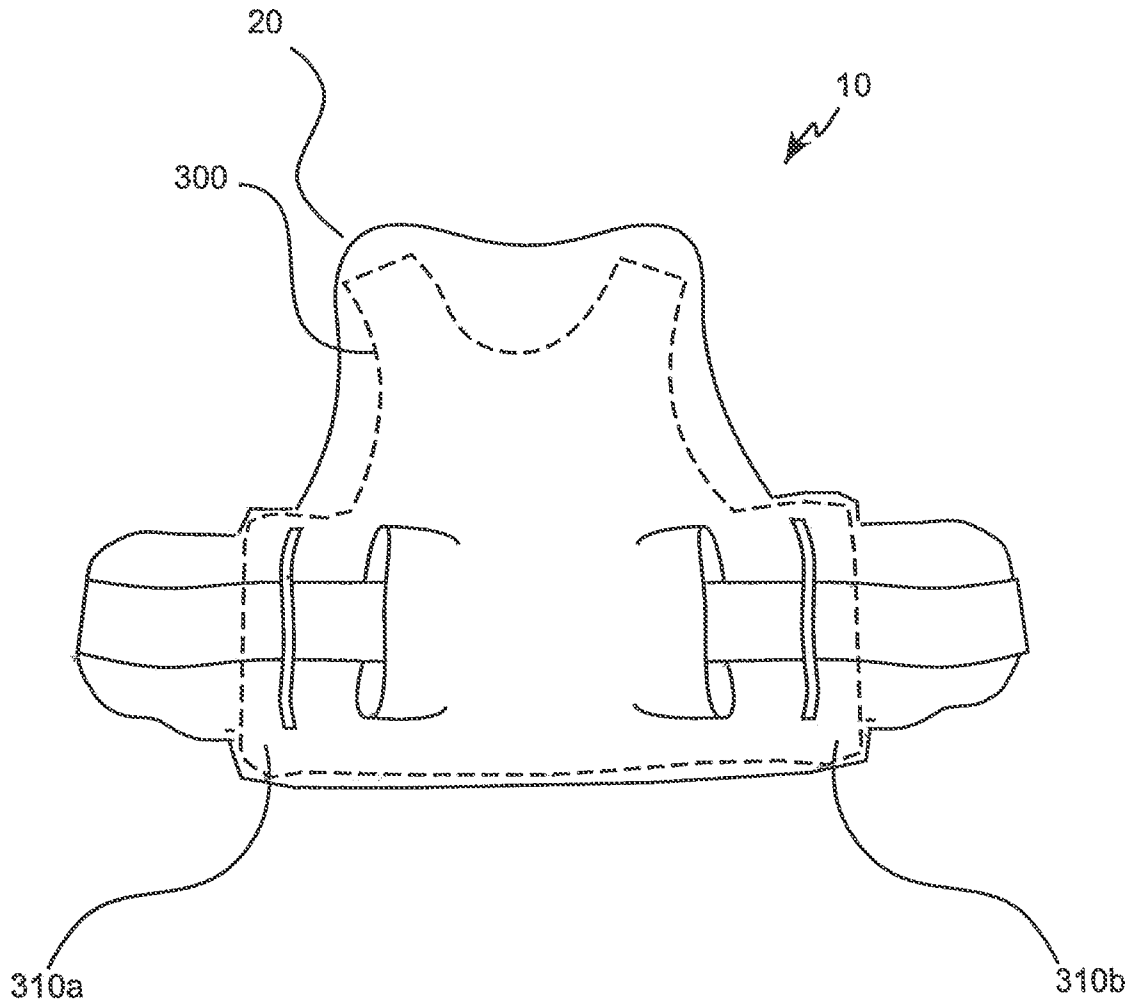


FIG. 2

FIG. 3A

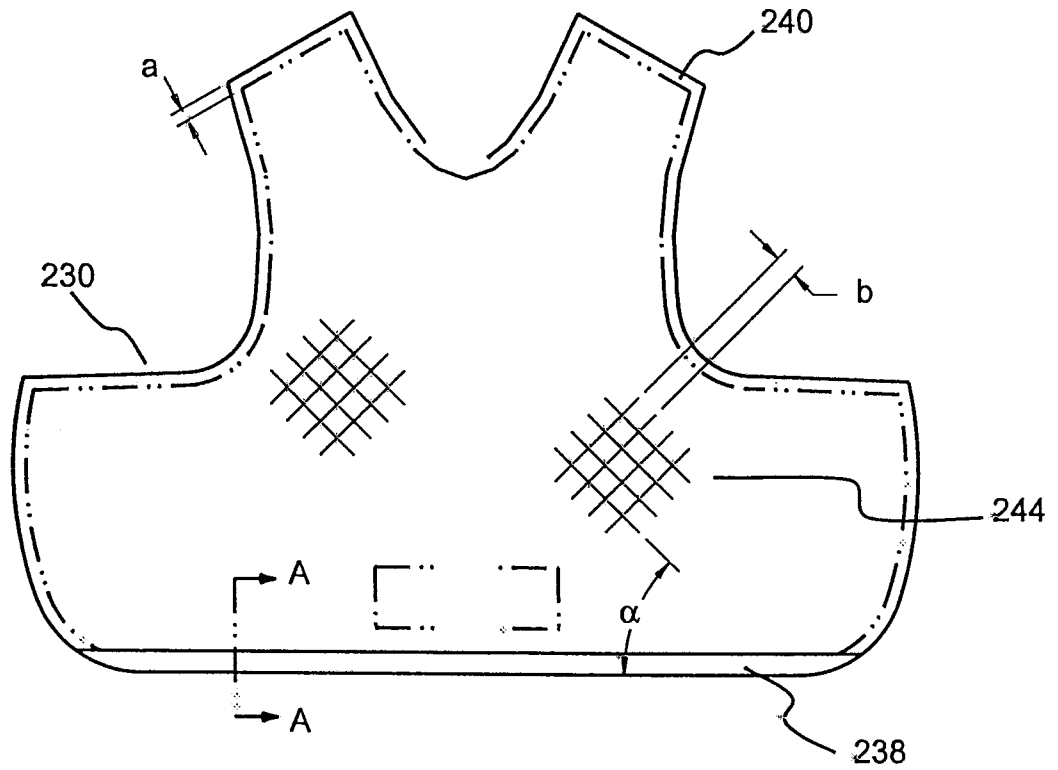
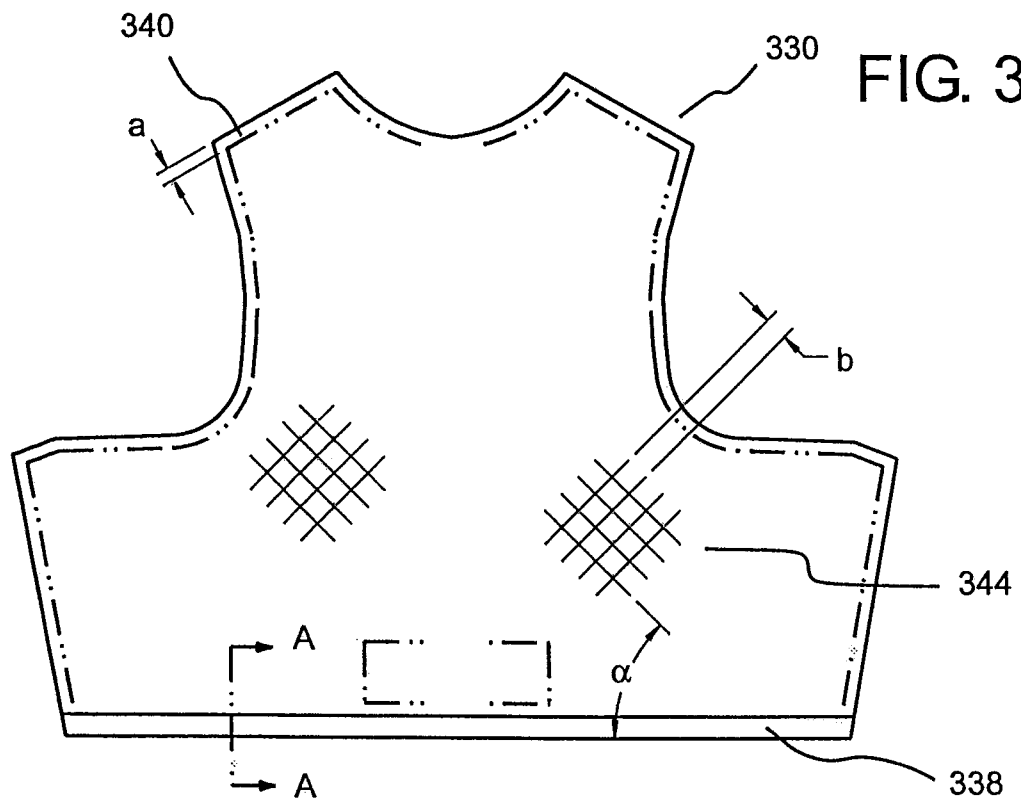


FIG. 3B



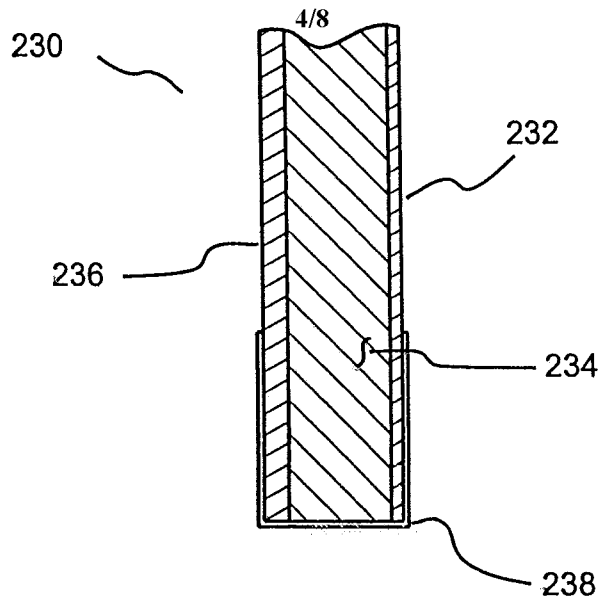


FIG. 3C

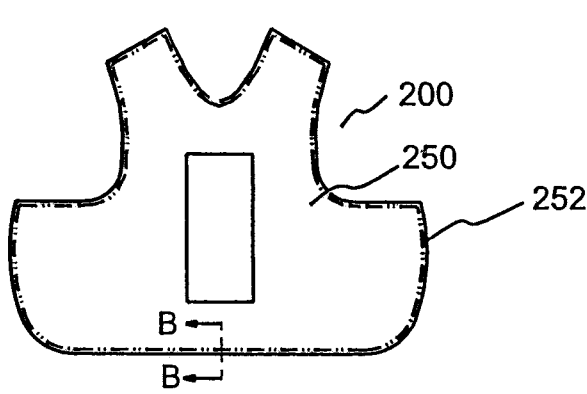


FIG. 3D

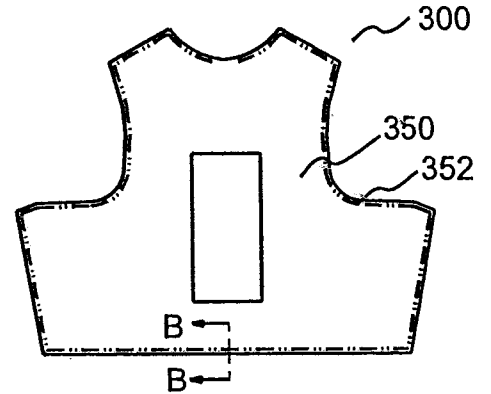


FIG. 3E

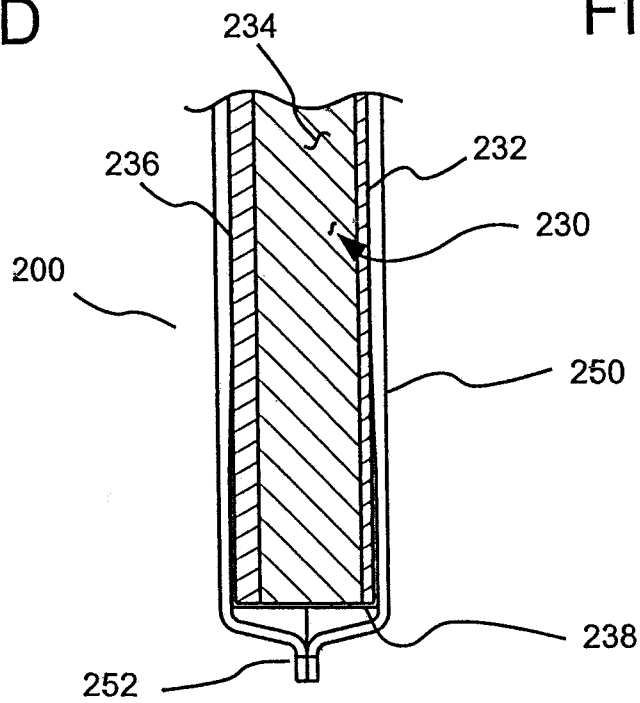


FIG. 3F

FIG. 4A

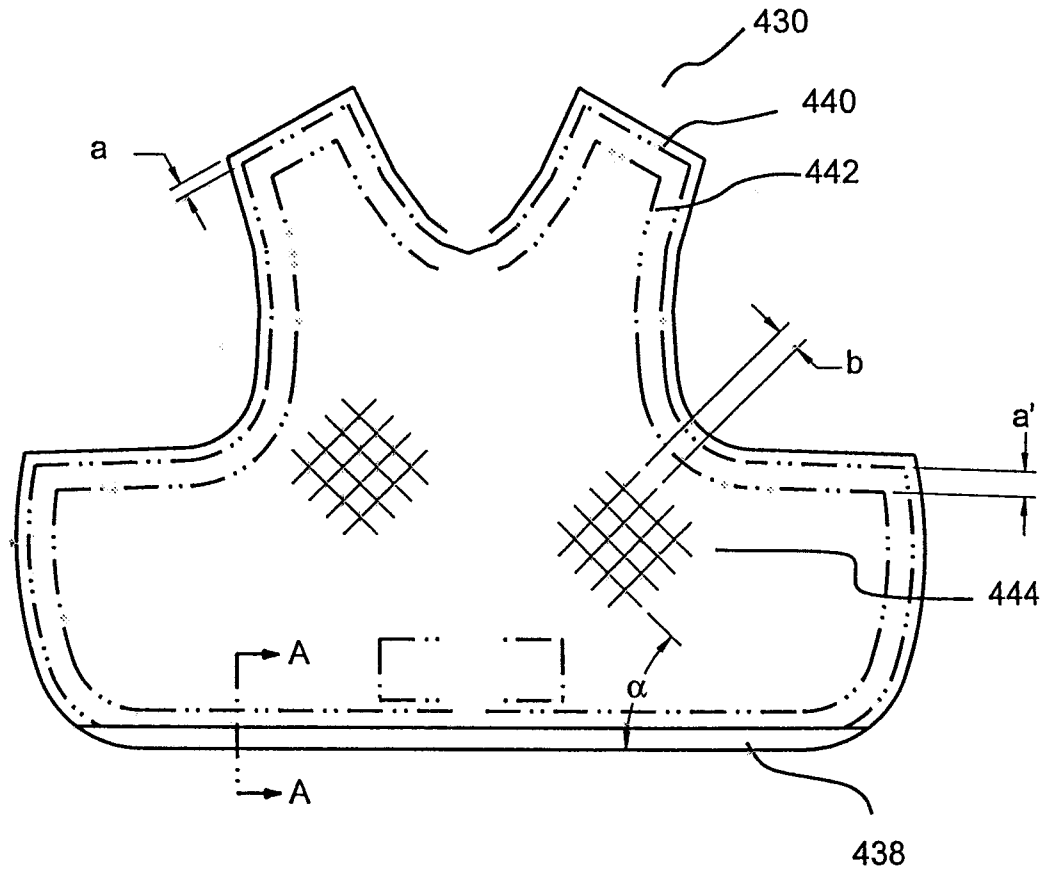
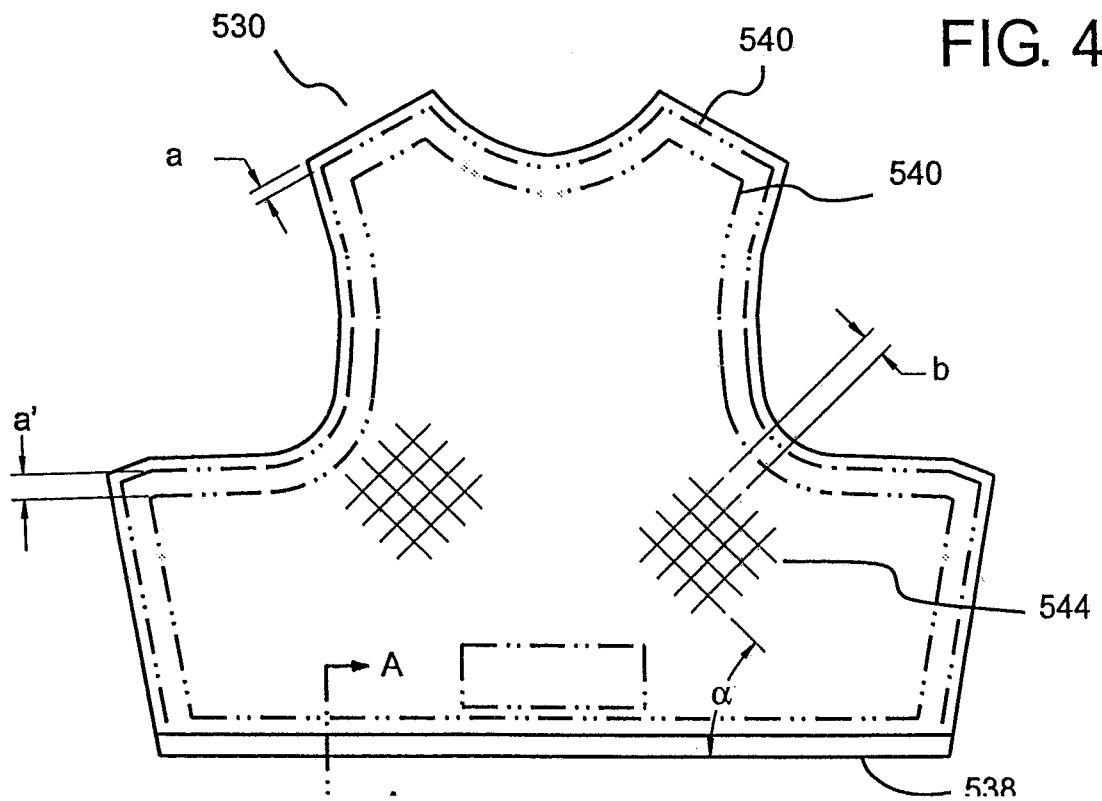


FIG. 4B



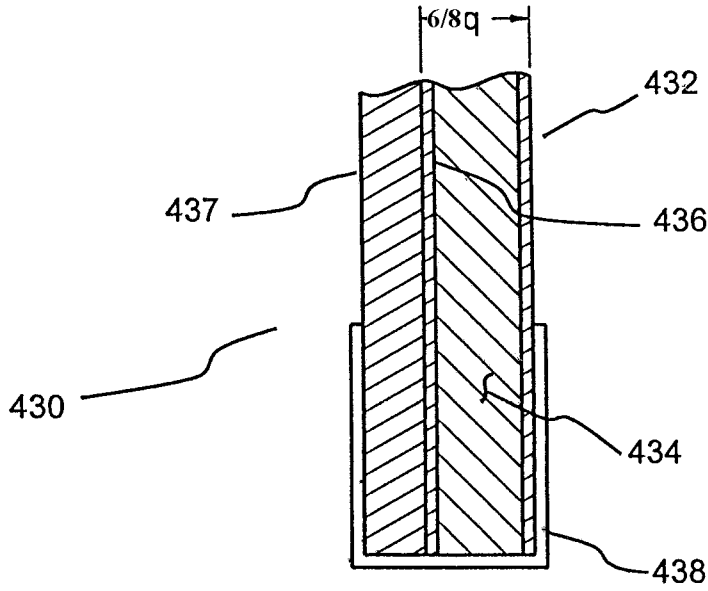


FIG. 4C

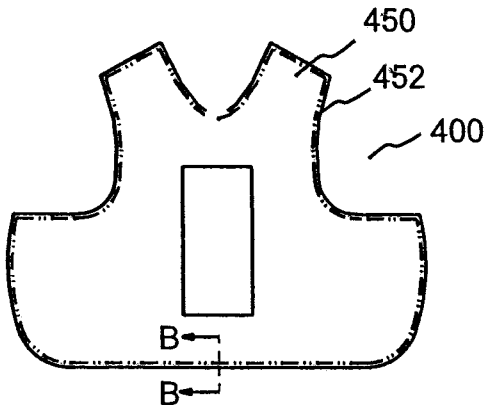


FIG. 4D

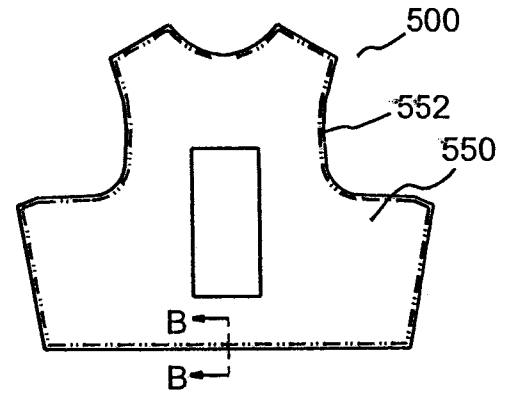


FIG. 4E

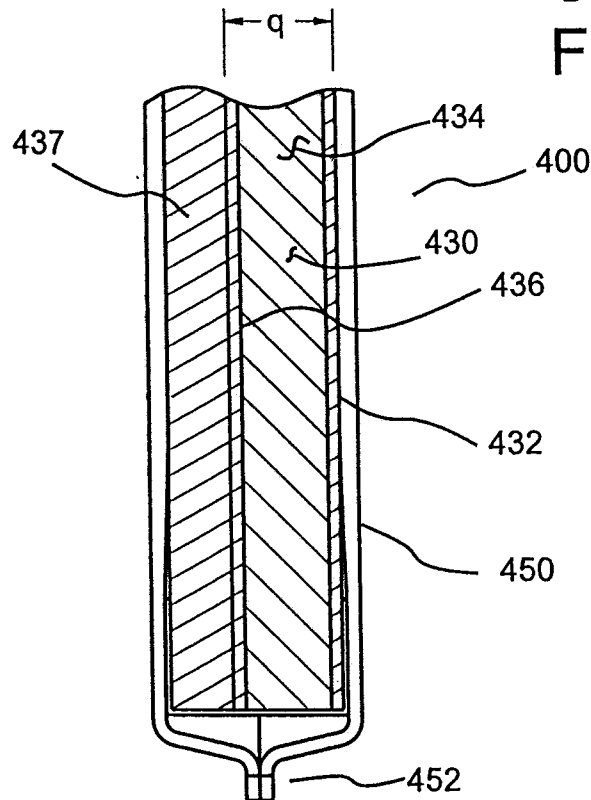


FIG. 4F



FIG. 5A

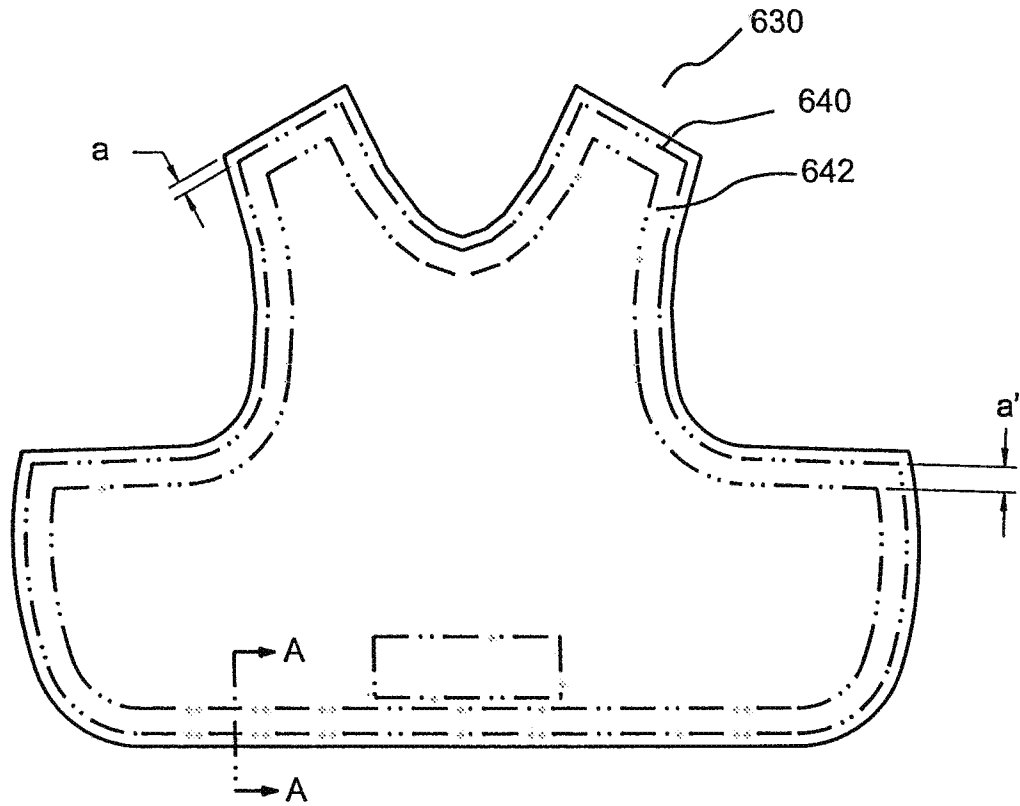
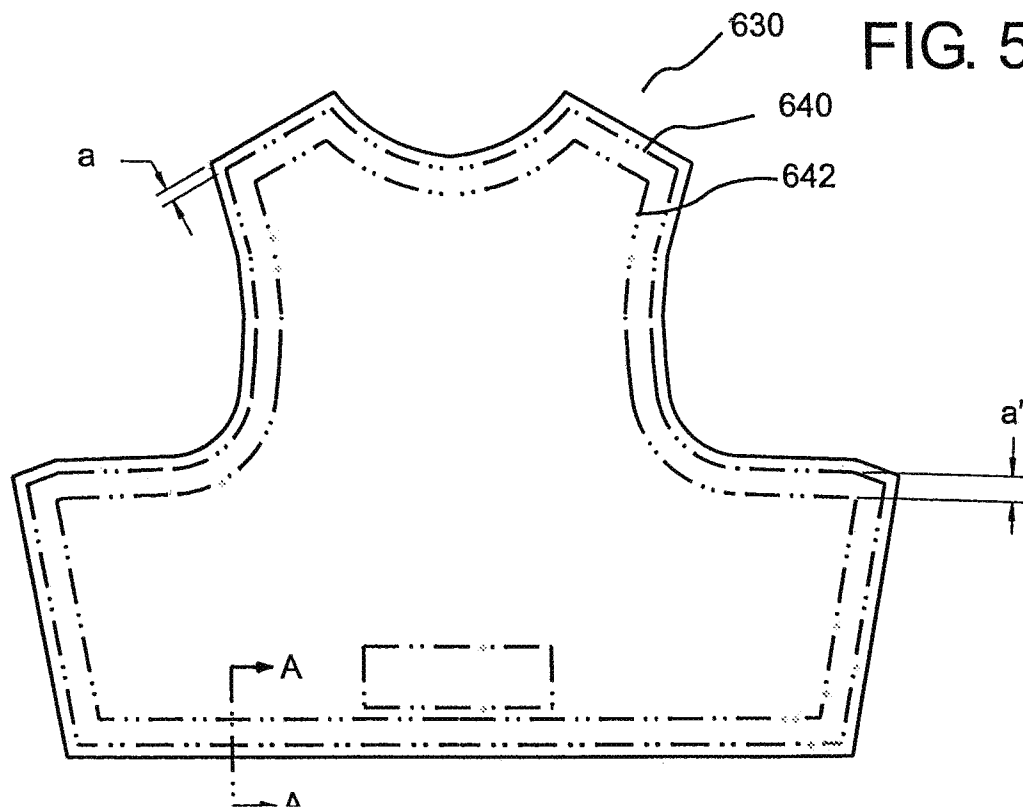


FIG. 5B



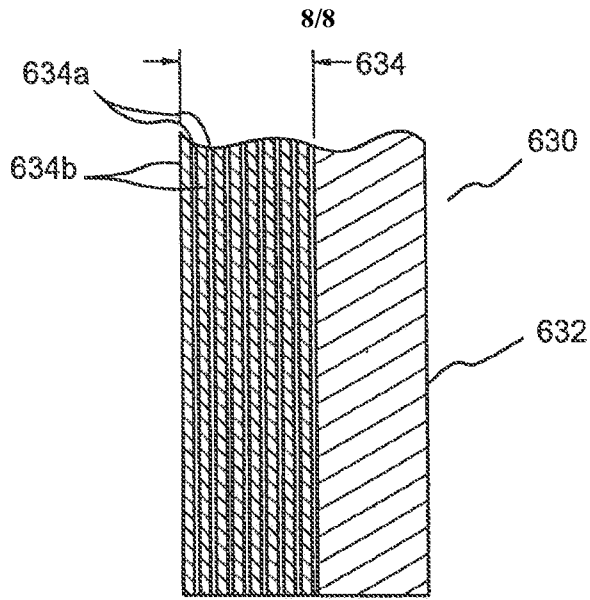


FIG. 5C

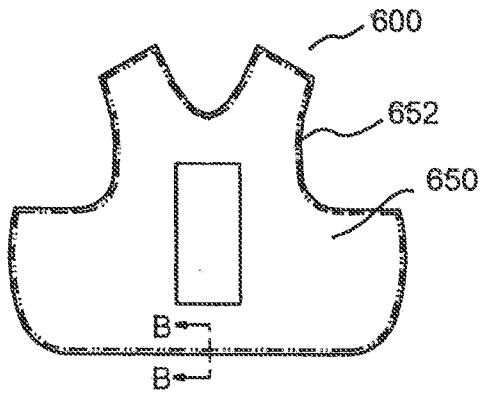


FIG. 5D

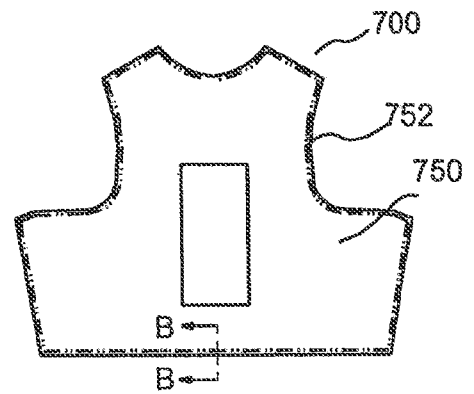


FIG. 5E

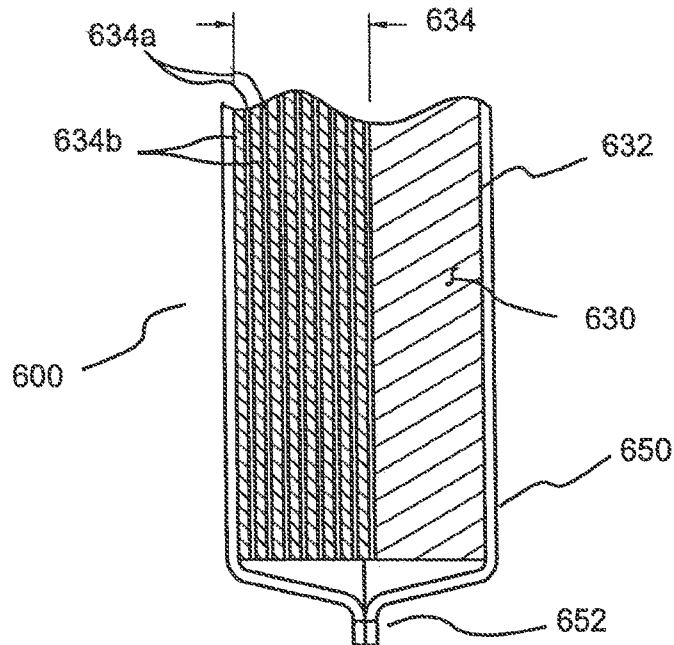


FIG. 5F