Abstract: A multilayer laminated structure particularly useful as soft body armor has layers of aramid fabric, thermoplastic sheet or polyolefinic fabric bonded together using a polyolefinic adhesive. The stack of layers is consolidated under heat and pressure to provide trauma packs having low weight and low trauma as required by Indian body armor standards.

Fig. 2
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1. **Field of the Invention**

This invention relates to trauma reducing laminates particularly suitable in ballistic resistant soft body armor and a method of their manufacture.

2. **Background of the Invention**

The primary objective of body armor research is to develop a low cost, light-weight, comfortable to wear system with ballistic-impact resistance. Body armor standards in India require that a projectile should be stopped under ballistic impact and that the penetration depth into a clay witness backing the armor during the testing should not exceed 25mm. If penetration depth exceeds this value, a wearer can incur serious blunt trauma. Aramid and ultra-high molecular weight polyethylene (UHMWPE) have been used as base materials for ballistic protection. These high performance fibers are characterized by low density, high strength, and high energy absorption.

However, to meet the protection requirements for typical ballistic threats, approximately 20-50 layers of fabric are required depending upon the type of fabric used. The resulting armor becomes heavy and may not meet the low trauma requirement, e.g. 25mm or below.

In tests such as NIJ 0101.06 of July 2007: "Ballistic Resistance of Personal Body Armor", the depth of the backface signature on a clay box upon impact of a projectile is used as a means to quantify the severity of the blow, or trauma, to which a hypothetical wearer would be subjected to.

There are several literature reports citing ways to manufacture ballistic armors that diminish the blow suffered by a person upon projectile impact.

GB2232063 by Lee describes a trauma reducing protective shield comprising two parallel layers of textile material, sandwiching a plurality of
polypropylene (PP) fibers extending perpendicular to the plane of the two parallel layers. Upon impact, the perpendicular fibers, this can be optionally impregnated with resin, become crushed and absorb and dissipate the kinetic energy of the projectile, which in turn lessens the intensity of trauma.

WO2006136323 by Boettger et al. discloses a trauma reducing pack comprising at least one panel of plastic material and at least one textile fabric layer affixed to the panel and consisting of yarns with fibers having a tensile strength of at least 900 MPa as measured according to ASTM D7269, wherein the plastic material is a self-reinforced thermoplastic material, such as for example PP tapes, these being in close contact to one another and bonded to one another at elevated temperature. These structures are able to provide a minor reduction in backface signature and additionally suffer from flammability issues.

WO2007021611 by Morin et al. discloses structures comprising high-modulus polyolefin fibers, in particular PP tape fibers, sandwiched between aramid fibers using an adhesive that are suitable in marine, automotive and electronic applications. However, these structures are stiff and hard, which can result in discomfort to the wearer.

US201204756 by Bader et al discloses trauma reducing laminates, comprising multiple layers of textile fabric of aramid or polyolefin bonded together by means of a polyolefinic adhesive.

The structures reported in the art do not address their applicability in meeting the environmental testing protocol as specified in NIJ 0101.06. Also the structures reported do not address the specific need for low back face signature (less than 25 mm) as desired in the Indian context. Also the structures reported in the art do not meet the cost and low weight requirements.

Thus, there is a strong felt need for a lighter, better performing trauma pack that provides higher protection from blunt trauma and that increases
survival rates when compared to the trauma packs known in the art, and are comfortable to wear.

**SUMMARY OF THE INVENTION**

5 An aspect of the present invention is a trauma reducing pack, comprising

(i) at least one first layer of aramid fabric comprising yarns having a tensile strength of at least 900 MPa and having a linear density of 444 - 1111 dtex, the fabric having an inner and outer surface.

10 (ii) at least one second layer of a thermoplastic sheet having a tensile strength of at least 60 MPa or a thermoplastic nonwoven fabric comprising yarns having a tensile strength of at least 900 MPa, the sheet or nonwoven fabric having an inner and outer surface, and

(ii) a polyolefinic adhesive having a melting point of from 70-150°C,

15 wherein the at least one first layer and the at least one second layer are bonded together by means of the polyolefinic adhesive.

Another aspect of the present invention is a body armor comprising the trauma pack.

20 **BRIEF DESCRIPTION OF DRAWINGS**

This invention is illustrated in the accompanying drawings, throughout which, like reference numerals indicate corresponding parts in the various figures.

25 Fig. 1 is a sectional view of a para-aramid - polycarbonate (PC) laminate.

Fig. 2 is a sectional view of another para-aramid - PC laminate.
Fig. 3 is a sectional view of a para-aramid - para-aramid laminate.
Fig. 4 is a sectional view of a para-aramid - polyolefin laminate.
Fig. 5 is a sectional view of another para-aramid - polyolefin laminate.
Fig. 6 is a sectional view of another para-aramid - para-aramid laminate.
DETAILED DESCRIPTION

The multilayer laminated structures for a trauma pack suitable for resisting a ballistic object contain a plurality of layers comprising at least one aramid fabric layer bonded together with another fabric or sheet layer with the help of an adhesive.

In some embodiments, the aramid fabric layer used in the ballistic resistant multilayer laminated structures according to the present invention is made of continuous filament yarns which are made of fibers. For purposes herein, the term "fiber" is defined as a relatively flexible, macroscopically homogeneous body having a high ratio of length to width across its cross-sectional area perpendicular to its length. The fiber cross section can be any shape, but is typically round. Herein, the term "filament" is used interchangeably with the term "fiber".

By "aramid", it is meant a polyamide wherein at least 85% of the amide (-CONH-) linkages are attached directly to two aromatic rings. Suitable aramid fibers are described in Man-Made Fibers - Science and Technology, Volume 2, Section titled Fiber-Forming Aromatic Polyamides, page 297, W. Black et al., Interscience Publishers, 1968. Aramid fibers and their production are, also, disclosed in U.S. Patents 4,172,938; 3,869,429; 3,819,587; 3,673,143; 3,354,127; and 3,094,511. The preferred aramid is a para-aramid. The preferred para-aramid is poly (p-phenylene terephthalamide) which is called PPD-T.

The fabric may be woven, unidirectional, multidirectional, including bidirectional, or nonwoven.

By "unidirectional (UD) fabric" is meant a fabric layer (ply) in which the component yarns or fibers are aligned in a parallel direction within the plane of the fabric.

By "multidirectional fabric" is meant a fabric comprising a plurality of unidirectional fabric layers in which the orientation of the yarns or fibers in one UD fabric layer is offset with respect to the orientation of yarns or fibers in the next layer. In one embodiment, the "multidirectional aramid" fabric of the invention comprises two layers of unidirectional fabric of para-aramid yarns with the yarns aligned in a +45/-45° orientation with respect to the machine
direction of the fabric. The multidirectional fabric further comprises a polyester yarn binding thread stitched through the UD fabric layers in a direction orthogonal to the plane of the UD fabric layers. The machine direction is the long direction within the plane of the fabric, i.e. the direction in which the fabric is being produced by the machine. A multidirectional fabric comprising two layers of unidirectional fabric is also known as a bidirectional fabric.

The term "nonwoven" means here a web including a multitude of randomly oriented fibers. By "randomly oriented" is meant that the fibers have no long range repeating structure discernable to the naked eye. The fibers can be bonded to each other, or can be unbonded and entangled to impart strength and integrity to the web. The fibers can be staple fibers or continuous fibers, and can comprise a single material or a multitude of materials, either as a combination of different fibers or as a combination of similar fibers each comprised of different materials.

Nonwoven fabrics or webs have been formed from many processes such as for example, melt blowing processes, spun bonding processes, and bonded carded web processes. The basis weight of nonwoven fabrics is usually expressed in ounces of material per square yard (osy) or grams per square meter (gsm) and the fiber diameters useful are usually expressed in microns.

As used herein the term "spunbond fibers" refers to small diameter fibers which are formed by extruding molten thermoplastic material as filaments from a plurality of fine, usually circular capillaries of a spinneret with the diameter of the extruded filaments then being rapidly reduced as by, for example, in U.S. Pat. No. 4,340,563 to Appel et al., and U.S. Pat. No. 3,692,618 to Dorschner et al., U.S. Pat. No. 3,802,817 to Matsuki et al., U.S. Pat. Nos. 3,338,992 and 3,341,394 to Kinney, U.S. Pat. Nos. 3,502,763, and U.S. Pat. No. 3,542,615 to Dobo et al. Spunbond fibers are generally continuous and larger than 7 microns, more particularly, they are usually between about 15 and 50 microns.

By tape is meant a highly oriented non filamentary polyolefin sheet. Preferably the tape comprises two cross plied sheets arranged orthogonally to each other and bonded by an adhesive film or scrim, such an arrangement sometimes being referred to as bidirectional tape.
As used in this application, the term "high modulus" refers to materials having a modulus greater than 1,000 grams per denier (gpd).

The multilayer structure used in the method according to the present invention is a pre-assembled structure of at least one aramid layer and at least one other layer comprising either a thermoplastic sheet or a nonwoven fabric. The layers are laminated together using an adhesive and a thermopressing process. Preferably, the thermoplastic sheet has a tensile strength of at least 60 MPa when measured according to ASTM D885/D885M-10a (2014). The thermoplastic sheet can be chosen among polycarbonate (PC), acrylonitrile butadiene styrene (ABS), ethylene-methacrylic acid copolymers (sold under the trade name of Surlyn®), bidirectional polyolefinic tape and mixtures thereof. Preferably, the thermoplastic sheet is made of polycarbonate of thickness ranging from 0.2 to 2.0 mm. More preferably, the thermoplastic sheet is made of multidirectional polyolefinic tape. The thermoplastic nonwoven layer can be chosen among a wide variety of nonwoven materials chosen among polyethylene, polyesters, polypropylene etc. Preferably, the thermoplastic nonwoven fabric comprises yarns having a tensile strength of at least 900 MPa when measured according to ASTM D885/D885M-10a (2014).

A suitable polyolefinic adhesive according to the present invention may be chosen from polyolefin, such as for example polyethylene's, ethylene copolymers, polypropylenes, propylene copolymers, and/or combinations thereof, having a melting point of from 70°C to 150°C. when measured according to ASTM D1238-13, and having melt flow viscosity of from 0.2 g/10 min to 10 g/10 min when measured according to ASTM1 238 at 190°C using a weight of 2.16 kg.

The polyolefinic adhesive may be grafted. Suitable grafting agents may be chosen among ethylenically unsaturated organic acids and their esters, half-esters and anhydrides such as for example maleic anhydride, alkyl hydrogen maleate, maleic acid, fumaric acid, alkyl hydrogen fumarate, and/or combinations thereof.

In the case where the polyolefins are grafted, the grafting agent is present of from 0.1 weight percent to 3.5 weight percent, based on the total
weight of the polyolefin. Suitable polyethylenes may be chosen among very low density polyethylenes (VLDPE), linear low density polyethylenes (LLDPE), low density polyethylenes (LDPE), metallocene polyethylenes (mPE), high density polyethylenes (HDPE), ultra-high molecular weight polyethylenes (UHMWPE) and/or combinations thereof. Preferably, the polyethylene is a linear low density polyethylene (LLDPE).

Suitable ethylene copolymers may be chosen among ethylene vinyl acetate, ethylene (meth) acrylate copolymers, ethylene (meth) acrylic acid copolymers and their corresponding ionomers, ethylene vinyl alcohol, and/or combinations thereof. The polyolefinic adhesive may be suitably applied to the assembly of polyolefinic textile fabric in various ways, such as for example by placing the adhesive in between the layers of polyolefinic fabric and/or on both sides of the assembly.

Suitable adhesives according to the present invention may be chosen from are ethenolic copolymers of polyolefins or grafted polyolefins having functional groups such as vinyl acetate (VA) or methacrylic acid (MAA). The acid groups are neutralized fully or partially with neutralizing agents such as sodium, potassium, zinc, magnesium, lithium and combinations thereof. Suitable adhesives for use in the present invention are commercially available under the trademark Surlyn® from E. I. du Pont de Nemours and Company, Wilmington, Delaware, USA.

A trauma pack is made of at least one aramid fabric layer and at least one thermoplastic sheet or a thermoplastic nonwoven fabric layer, said layers being bonded to each other using a polyolefinic adhesive. The different layers of the trauma pack are simultaneously heated in a press during a time and at a pressure and temperature sufficient to ensure that the adhesive softens, flows and coats the fibers of the fabric layers without substantially altering the chemical and physical properties of the individual layers.

Typically, the trauma pack is pressed at a pressure between 2 and 100 bars and more preferably between 10 and 70 bars. The temperature is typically at least about 30°C beyond the melting point of the thermoplastic sheet or nonwoven fabric to enable proper flow of the adhesive. The thermopressing time is preferably between 10 and 60 minutes and depends on the number of different layers of the pile. The impregnated composite
structure is cooled, typically to 50°C, while keeping constant the pressure and then is cooled to room temperature under ambient conditions.

An aspect of the present invention is a trauma reducing pack, comprising

a. At least one first layer of aramid fabric comprising yarns having a tensile strength of at least 900 MPa and having a linear density of 444-1 111 dtex (400-1 000 denier) having an inner and outer surface.

b. At least one second layer of a thermoplastic sheet having a tensile strength of at least 60 MPa or a thermoplastic nonwoven fabric comprising yarns having a tensile strength of at least 900 MPa, the sheet or nonwoven fabric having an inner and outer surface, and
c. a polyolefinic adhesive having a melting point of from 70-1 50°C, wherein at least one first layer and at least one second layer are bonded together by means of the polyolefinic adhesive.

In one embodiment of the present invention, the polyolefinic adhesive in the trauma reducing pack is an ethylene copolymer.

In another embodiment of the present invention, the polyolefinic adhesive in the trauma reducing pack is a grafted polyolefin.

In still another embodiment of the present invention, the fibers in the aramid fabric are woven, nonwoven, unidirectional or multidirectional.

In yet another embodiment of the present invention, the thermoplastic sheet is selected from polycarbonates, acrylonitrile butadiene styrene, ethylene-methacrylic acid copolymers, bidirectional polyolefinic tape or combinations thereof.

In another embodiment of the present invention, the thermoplastic nonwoven fabric is a spunbond nonwoven of polyolefin.

In another embodiment of the present invention, the polyolefin is a polyethylene, polypropylene, polybutene, or a blend or copolymer thereof.

In another embodiment of the present invention, the multidirectional polyolefinic tape is a cross-plied non-fibrous ultra-high molecular weight polyethylene (UHMWPE) tape.
In still another embodiment of the present invention, the trauma pack has an areal density of less than 1000 g/m2.

In yet another embodiment of the present invention, the trauma pack comprises from 1 to 4 layers of para-aramid fabric, from 1 to 5 layers of thermoplastic sheet, from 1 to 3 layers of nonwoven fabric and from 1 to 4 layers of polyolefinic adhesive.

Another aspect of the present invention is a body armor comprising at least one trauma pack.

DETAILED DESCRIPTION OF FIGURES

Figure 1 is a sectional view of a para-aramid - polycarbonate laminate comprising:

1. Para-aramid fabric
2. Polyolefinic adhesive
3. Polycarbonate sheet

Figure 2 is a sectional view of another para-aramid - polycarbonate laminate comprising:

1A. First layer of para-aramid fabric
2A. First layer of polyolefinic adhesive film
3. Polycarbonate sheet
2B. Second layer of polyolefinic adhesive film
1B. Second layer of para-aramid fabric

Figure 3 is a sectional view of a para-aramid - para-aramid laminate comprising:

1A. First layer of 1000 denier para-aramid fabric
2A. First layer of polyolefinic adhesive film
3A. First layer of 600 denier para-aramid fabric
2B. Second layer of polyolefinic adhesive film
3B. Second layer of 600 denier para-aramid fabric
2C. Third layer of polyolefinic adhesive film
1B. Second layer of 1000 denier para-aramid fabric
Figure 4 is a sectional view of another para-aramid - para-aramid laminate comprising:

1. Para-aramid fabric
2. Polyolefinic adhesive
3. A plurality of polyolefin sheet layers

Figure 5 is a sectional view of another para-aramid - polyolefin laminate:

1A. First layer of 1000 denier para-aramid fabric
2A. First layer of polyolefinic adhesive film
3A. First layer of spun bonded polyethylene nonwoven fabrics
2B. Second layer of polyolefinic adhesive film
3B. Second layer of spun bonded polyethylene nonwoven fabrics
2C. Third layer of polyolefinic adhesive film
3C. Third layer of spun bonded polyethylene nonwoven fabrics
2D. Fourth layer of polyolefinic adhesive film
1B. Second layer of 1000 denier para-aramid fabric

Figure 6 is a sectional view of a para-aramid - polyolefin laminate comprising:

1A. First layer of 3300 denier para-aramid fabric
2. A layer of polyolefinic adhesive film
1B. Second layer of 3300 denier para-aramid fabric

**TEST METHODS**

Temperature: All temperatures were measured in degrees Celsius (°C).

Linear Density: The linear density of a yarn or fiber was determined by weighing a known length of the yarn or fiber based on the procedures described in ASTM D1907/D1 907M-12 and D885/D885M-10a (2014).
Decitex or "dtex" is defined as the weight, in grams, of 10,000 meters of the yarn or fiber. Denier (d) is 9/10 times the decitex (dtex).

**Tensile Properties:** The fibers to be tested were conditioned and then tensile tested based on the procedures described in ASTM D885/D885M-10a (2014). Tenacity (breaking tenacity), modulus of elasticity, force to break and elongation to break are determined by breaking test fibers on an Instron universal test machine.

**Areal Density:** The areal density of the fabric layer was determined by measuring the weight of one square meter of fabric i.e., 1m x 1m. The areal density of a composite structure was determined by the sum of the areal densities of the individual layers.

Melt flow index was measured as per ASTM D 1238-13.

The environmental conditioning protocol consisted of exposing body armor to environmental conditioning inside a chamber wherein the temperature and relative humidity are maintained at 65±2°C and 80±5% respectively for 10 days. Conditioned soft body armor was tested in a ballistic test for backface signature. The value of backface signature of soft body armor should be less than 25mm before and after conditioning.

**Trauma Test Method (Back Face Deformation or BFD)**

The body armor containing a ballistic pack and trauma pack was fastened to a clay box of Roma No 1 clay, with the ballistic pack facing away from the clay and then subjected to a ballistic impact by a 9 x 19 mm bullet (OFB, India) traveling at a speed of 400±15 m/s, shot from a distance of 5 meters. Back face deformation is also known as Back Face Signature. After the bullet hit the pack, the depth of crater created on the clay was measured and recorded as the back face signature (or trauma); For each test sample, the test was average of 3 panels with 4 shots each.

**DESCRIPTION OF LAYERS**

Fabric layers and adhesive films of the following description were used for preparing the multilayer laminated composite trauma pack;
KL-1 was a textile fabric having a plain weave and having areal density of 190 g/m², consisting of poly (p-phenylene terephthalamide) yarns having a linear density of 1000 denier and 8.5 x 8.5 ends per centimeter available from E. I. du Pont de Nemours and Company, Wilmington, Delaware, USA (hereinafter DuPont) under the trade name of Kevlar® para-aramid and was cut into 400 x 400 mm sheets.

KL-2 was a multidirectional textile fabric having areal density of 300 g/m², consisting of poly (p-phenylene terephthalamide) having a linear density of 400 denier available from DuPont under the trade name of Kevlar® XPS300 and was cut into 400 x 400 mm sheet.

KL-3 was a multidirectional textile fabric having areal density of 510 g/m², consisting of poly(p-phenylene terephthalamide) having a linear density of 1000 denier available from DuPont under the trade name of Kevlar® XPS102 and was cut into 400 x 400 mm sheet.

KL-4 was a textile fabric having a plain weave and having areal density of 165 g/m², consisting of poly (p-phenylene terephthalamide) yarns having a linear density of 600 denier and 8.5 x 8.5 ends per centimeter available from DuPont under the trade name of Kevlar® para-aramid and was cut into 400 x 400 mm sheet.

KL-5 was a textile fabric having a plain weave and having areal density of 440 g/m², consisting of poly (p-phenylene terephthalamide) yarns having a linear density of 3300 denier and 6.5 x 6.5 ends per centimeter available from E. I. du Pont de Nemours and Company, Wilmington, Delaware, USA (hereinafter DuPont) under the trade name of Kevlar® para-aramid and was cut into 400 x 400 mm sheets.

IC 600D was a commercially available Kevlar® composite fabric having an areal density of 900 g/m² available from DuPont.
PE-1 was a bidirectional tape made of ultra-high molecular weight polyethylene having areal density of 111 g/m$^2$ available from DuPont Company under the trade name of Tensylon$^\text{TM}$ HSBD 30A.

PE-2 was a spun bonded polyethylene nonwoven fabrics having areal density of 73 g/m$^2$ available from DuPont under the trade name of Tyvek®.

PE-3 was a spun bonded polyethylene nonwoven fabric having areal density of 105 g/m$^2$ available from DuPont under the trade name of Tyvek®.

PC-1 was a Polycarbonate sheet of 0.8mm thicknesses having aerial density of 1000g/m$^2$ available from SABIC Innovative Plastics under the trade name of Lexan®.

PC-2 was a Polycarbonate sheet of 0.3mm thicknesses having aerial density of 475 g/m$^2$ available from SABIC Innovative Plastics under the trade name of Lexan®.

Adhesive Film 1 was a maleic anhydride modified linear low density polyethylene having maleic anhydride content in the range of 0.05 to 1.5%; having melting points in the range of 85 to 120°C; melt flow index in the range of 2 to 9 g/10min and having aerial density of 50 g/m$^2$ available from DuPont under the trade name of Bynel®.

Adhesive Film 2 was an ethylene copolymer having functional groups such as vinyl acetate; having melting points in the range of 115 to 130°C; melt flow index in the range of 3 to 8 g/10min and having aerial density of 50 g/m$^2$ available from Nolax® AG under the trade name of Nolax®.

Adhesive Film 3 was a ethylene copolymer having functional groups such as methacrylic acid with partial neutralization with zinc or sodium metal ions; having melting points in the range of 80 to 100°C; melt flow index in the range of 3 to 8 g/10min and having aerial density of 50 g/m$^2$ available from DuPont under the trade name of Surlyn®.
EXAMPLES

Examples prepared according to the process or processes of the current invention are indicated by numerical values. Control or Comparative Examples are indicated by letters. With the exception of Control A, all Examples and Comparative Examples were tested in a final assembly comprising a ballistic pack and a trauma pack. The assembly configurations are described in the following text and tables. Data and test results relating to the Comparative and Inventive Examples are shown in Tables 1-3.

EXAMPLE A

A commercially available Kevlar® composite fabric having an areal density of 900 g/m² available from E. I. du Pont de Nemours and Company under the trade name of IC 600D was used as the trauma pack. The ballistic pack comprised 11 layers of KL2.

CONTROL A

A stack of 15 layers of multidirectional woven fabric KL2 made of 400 denier Kevlar® yarn and having areal density of 300 g/m² was used as the ballistic pack without any trauma pack.

EXAMPLE B

A trauma pack was formed by stacking one layer of textile fabric KL1, a layer of PC1 and another layer of KL1 (KL1-PC1-KL1). The stack was used without any consolidation and this stack has areal density of 1380 g/m². The ballistic pack comprised 9 layers of KL2.

EXAMPLE C

A trauma pack was formed by superimposing in order in a stack, a first layer of textile fabric KL1, a first layer of adhesive Film 1, a first layer of textile fabric KL4, a second layer of adhesive Film 1, second layer of textile fabric KL4, a third layer of adhesive Film 1 and a second layer of textile fabric of KL1 (KL1-Film1-KL4-Film1-KL4-Film1-KL1). The stack was consolidated in an industrial hydraulic press having heating and cooling capability as described
in example 1, except that the preheating temperature was 115°C. The stack
was heated to 125°C for 10 minutes and 60 ton which was then cooled to room
temperature to yield a laminate/trauma reducing pack having an aerial density
of 860 g/m². The ballistic pack comprised 11 layers of KL2.

EXAMPLE D

A trauma pack was formed by superimposing in order in a stack, a first
layer of textile fabric KL5, a first layer of adhesive Film 1 and a second layer
of textile fabric KL5. The stack was consolidated in an industrial hydraulic
press having heating and cooling capability as described in example 1, except
that the preheating temperature was 115°C. The stack was heated to 125°C
for 10 minutes and 60 ton which was then cooled to room temperature to yield
a laminate/trauma reducing pack having an aerial density of 930 g/m². The
ballistic pack comprised 11 layers of KL2.

EXAMPLE 1

A trauma pack was formed by superimposing in order in a stack, a
first textile fabric of KL1, a layer of adhesive Film 2 and a layer of
polycarbonate sheet PC1 (KL1-Film2-PC1). The stack was consolidated in an
industrial hydraulic press (mold preheated to 125°C) having heating and
cooling capability for 10 minutes at 140°C and 60 ton and then cooled to room
temperature to yield a laminate/trauma reducing pack having an aerial density
of 1240 g/m². The ballistic pack comprised 10 layers of KL2.

EXAMPLE 2

A trauma pack was formed as described in example 1, except that
lamination with KL1 and Film2 was done on both sides of PC sheet. The
construction of the laminate was KL1-Film2-PC1-Film2-KL1 and the aerial
density of resultant pack was 1480 g/m². The ballistic pack comprised 9 layers
of KL2.
EXAMPLE 3
A trauma pack was formed as described in example 1, except that PC2 was used in place of PC1. The construction of the laminate was KL1-Film2-PC2 and the aerial density of resultant pack was 715 g/m². The ballistic pack comprised 11 layers of KL2.

EXAMPLE 4
A trauma pack was formed as described in example 2, except that PC2 was used in place of PC1. The construction of the laminate was KL1-Film2-PC2-Film2-KL1 and the aerial density of resultant pack was 955 g/m². The ballistic pack comprised 8 layers of KL2.

EXAMPLE 5
A trauma pack was formed by superimposing, in a stack, a first layer of textile fabric KL1, a first layer of adhesive Film 1, a first layer of spunbonded polyethylene PE2, a second layer of adhesive Film 1, second layer of spunbonded polyethylene PE2, a third layer of adhesive Film 1 and a second layer of textile fabric of KL1 (KL1-Film1-PE2-Film1-PE2-Film1-PE2-Film1-KL1). The stack was consolidated in an industrial hydraulic press as described in example 1, except that the preheating temperature and molding temperatures were 115°C and 125°C respectively to yield a laminate/trauma reducing pack having an aerial density of 800 g/m². The ballistic pack comprised 11 layers of KL2.

EXAMPLE 6
A trauma pack was formed as described in example 5, except that Film 2 was used instead of film 1 (KL1-Film2-PE2-Film2-PE2-Film2-Film2-KL1) to yield a laminate/trauma reducing pack having an aerial density of 800 g/m². The ballistic pack comprised 11 layers of KL2.

EXAMPLE 7
A trauma pack was formed as described in example 5, except that Film 3 was used instead of film 1 (KL1-Film3-PE2-Film3-PE2-Film3-PE2-
Film3-KL1) to yield a laminate/trauma reducing pack having an areal density of 800 g/m². The ballistic pack comprised 11 layers of KL2.

EXAMPLE 8

A trauma pack was formed as described in example 5, except that PE3 was used instead of PE2 (KL1-Film1-PE3-Film1-PE3-Film1-PE3-Film1-KL1) to yield a laminate/trauma reducing pack having an areal density of 895 g/m². The ballistic pack comprised 11 layers of KL2.

EXAMPLE 9

A trauma pack was formed by superimposing, in order in a stack, a first layer of textile fabric KL2, a layer of adhesive Film 1, and five layers of bidirectional UHMWPE tape PE1 (KL2-Film1-PE1-PE1-PE1-PE1). The stack was consolidated in an industrial hydraulic press as described in example 1, except that the preheating temperature and molding temperatures were 115°C and 125°C respectively to yield a laminate/trauma reducing pack having an areal density of 900 g/m². The ballistic pack comprised 11 layers of KL2.

Ballistic Trauma Test

For examples 1, 2, 5-9, only one layer of test samples was placed behind a ballistic pack consisting of multiple layers of KL2, and two layers of non-ballistic foam XLPE based on cross-linked polyethylene having an areal density of 100 g/m² and a thickness of 4 millimeters each in order to form a stack.

For examples 3 and 4, two layers of test samples were placed behind a ballistic pack consisting of multiple layers of KL2, and two layers of non-ballistic foam XLPE based on cross-linked polyethylene having an areal density of 100 g/m² and a thickness of 4 millimeters each in order to form a stack.

The inventive test sample consisted of a trauma reducing pack according to Examples 1-9.
The comparative test sample consisted of trauma reducing packs according to Control A and Examples A-C, in order to achieve a comparable areal density to the inventive sample of Examples 1-9.

Each stack was fastened to a clay box of Roma No 1 clay, with the ballistic pack facing away from the clay and then subjected to a ballistic impact by a 9 x 19 mm bullet (OFB, India) traveling at a speed of 400±15 m/s, shot from a distance of 5 meters.

After the bullet hit the stack, the depth of crater created on the clay was measured and recorded as the back face signature (or trauma); the results are shown in Table 1 to Table 3. For each test sample, the test was average of 3 panels with 4 shots each.

<table>
<thead>
<tr>
<th>Ballistic Pack</th>
<th>Trauma Pack</th>
<th>Aerial Density (g/m²)</th>
<th>Backface Signature mean (mm)</th>
<th>Std Dev</th>
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</thead>
<tbody>
<tr>
<td>15 L KL2</td>
<td>Control A</td>
<td>NA</td>
<td>18.4</td>
<td>2.8</td>
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<tr>
<td>9 L KL2</td>
<td>Example B</td>
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<td>29.2</td>
<td>4.3</td>
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<td>1240</td>
<td>10.6</td>
<td>0.9</td>
</tr>
<tr>
<td>9 L KL2</td>
<td>Example 2</td>
<td>1480</td>
<td>13.4</td>
<td>1.3</td>
</tr>
<tr>
<td>11 L KL2</td>
<td>Example 3</td>
<td>715</td>
<td>14.1</td>
<td>0.6</td>
</tr>
<tr>
<td>8 L KL2</td>
<td>Example 4</td>
<td>955</td>
<td>14.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Among the aramid-PC laminates using aramid-PC laminates containing aramid layer on both sides did not help much. But such aramid-PC structures were better in performance compared to aramid only structures (example B).
Among the aramid-polyolefin laminates, a change in adhesive film from a grafted to a straight chain ethylene copolymer (examples 5- example 7) significantly improved the backface signature, also change of polyethylene (example 7 and example 8) from a lower to higher areal density did not improve the backface signature.

On the other hand, a stack of multiple layers of bidirectional UHMWPE tape (Tensylon™) joined with KL2 layer with adhesive film showed further reduced backface signature. Also separate adhesive layer was not required between layers for this structure as Tensylon™ had adhesive layer on one side.

### Environmental Conditioning Test Results

Each trauma pack was subjected to the temperature of 65±2°C and relative humidity of 80±5% for 10 days. The environmentally conditioned pack was then placed behind a ballistic pack of multiple layers of KL2 and before two layers of non-ballistic foam XLPE based on cross linked polyethylene.

<table>
<thead>
<tr>
<th>Ballistic Pack</th>
<th>Trauma Pack</th>
<th>Aerial Density (g/m²)</th>
<th>Backface Signature mean (mm)</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 L KL2</td>
<td>Example A</td>
<td>900</td>
<td>15.5</td>
<td>2.1</td>
</tr>
<tr>
<td>11 L KL2</td>
<td>Example C</td>
<td>860</td>
<td>19.9</td>
<td>1.5</td>
</tr>
<tr>
<td>11 L KL2</td>
<td>Example D</td>
<td>930</td>
<td>20.2</td>
<td>1.4</td>
</tr>
<tr>
<td>11 L KL2</td>
<td>Example 5</td>
<td>800</td>
<td>18.5</td>
<td>2.0</td>
</tr>
<tr>
<td>11 L KL2</td>
<td>Example 6</td>
<td>800</td>
<td>17.9</td>
<td>2.3</td>
</tr>
<tr>
<td>11 L KL2</td>
<td>Example 7</td>
<td>800</td>
<td>14.9</td>
<td>2.9</td>
</tr>
<tr>
<td>11 L KL2</td>
<td>Example 8</td>
<td>895</td>
<td>18.7</td>
<td>1.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ballistic Pack</th>
<th>Trauma Pack</th>
<th>Aerial Density (g/m²)</th>
<th>Backface Signature mean (mm)</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 L KL2</td>
<td>Example A</td>
<td>900</td>
<td>15.5</td>
<td>2.1</td>
</tr>
<tr>
<td>15 L KL2</td>
<td>Control A</td>
<td>NA</td>
<td>18.4</td>
<td>2.8</td>
</tr>
<tr>
<td>11 L KL2</td>
<td>Example 9</td>
<td>900</td>
<td>12.4</td>
<td>1.1</td>
</tr>
</tbody>
</table>
having an area density of 100 g/m² and a thickness of 4 millimeters for testing backface signature according to the following method.

The stack was fastened to a clay box of Roma No 1 clay, with the ballistic pack facing away from the clay box and then subjected to a ballistic impact of a 9 x 19 mm bullet (OFB, India) traveling at a speed of 400±15 m/s, shot from a distance of 5 meters. After the bullet hit the stack, the depth of the back face signature was measured and recorded; the results are shown in Table 4. For each pack, the test was average of 3 panels with 4 shots each.

Soft body armor containing trauma pack as described above showed backface signature before and after environmental conditioning as shown in Table 4 below:

<table>
<thead>
<tr>
<th>Trauma Pack</th>
<th>Backface Signature (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Conditioning</td>
</tr>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Example A</td>
<td>15.5</td>
</tr>
<tr>
<td>Example D</td>
<td>20.2</td>
</tr>
<tr>
<td>Example 1</td>
<td>10.6</td>
</tr>
<tr>
<td>Example 2</td>
<td>13.4</td>
</tr>
<tr>
<td>Example 5</td>
<td>18.5</td>
</tr>
<tr>
<td>Example 8</td>
<td>18.7</td>
</tr>
<tr>
<td>Example 9</td>
<td>12.4</td>
</tr>
</tbody>
</table>

All trauma packs even after environmental conditioning showed backface signature less than 25mm.
CLAIMS

We claim:

1. A trauma reducing pack, comprising
   (i) at least one first layer of aramid fabric comprising yarns having a tensile strength of at least 900 MPa and having a linear density of 444 - 1111 dtex, the fabric having an inner and outer surface.
   (ii) at least one second layer of a thermoplastic sheet having a tensile strength of at least 60 MPa or a thermoplastic nonwoven fabric comprising yarns having a tensile strength of at least 900 MPa, the sheet or nonwoven fabric having an inner and outer surface, and
   (ii) a polyolefinic adhesive having a melting point of from 70-150°C, wherein the at least one first layer and the at least one second layer are bonded together by means of the polyolefinic adhesive.

2. The trauma reducing pack of claim 1, wherein the polyolefinic adhesive is an ethylene copolymer or a grafted polyolefin.

3. The trauma reducing pack of claim 1, wherein the fabric is woven, nonwoven, unidirectional or multidirectional.

4. The trauma reducing pack of claim 1, wherein the thermoplastic sheet is polycarbonate, acrylonitrile butadiene styrene copolymer, ethylene-methacrylic acid copolymer, bidirectional polyolefinic tape or combinations thereof.

5. The trauma pack of claim 1, wherein the thermoplastic nonwoven fabric is a spunbond nonwoven of polyolefin.

6. The trauma pack of claim 5, wherein the polyolefin is a polyethylene, polypropylene, polybutene, or a blend or copolymer thereof.

7. The trauma pack of claim 4, wherein the multidirectional polyolefinic tape is a cross-plied non-fibrous ultra-high molecular weight polyethylene (UHMWPE) tape.
8. The trauma pack of claim 1 having an aerial density of less than 1000 g/m².

9. The trauma pack of claim 1 comprising:
   (i) from 1 to 4 layers of aramid fabric,
   (ii) from 1 to 5 layers of thermoplastic sheet,
   (iii) from 1 to 3 layers of nonwoven fabric, and
   (iv) from 1 to 4 layers of polyolefinic adhesive.

10. A body armor comprising at least one trauma pack according to claim 1.