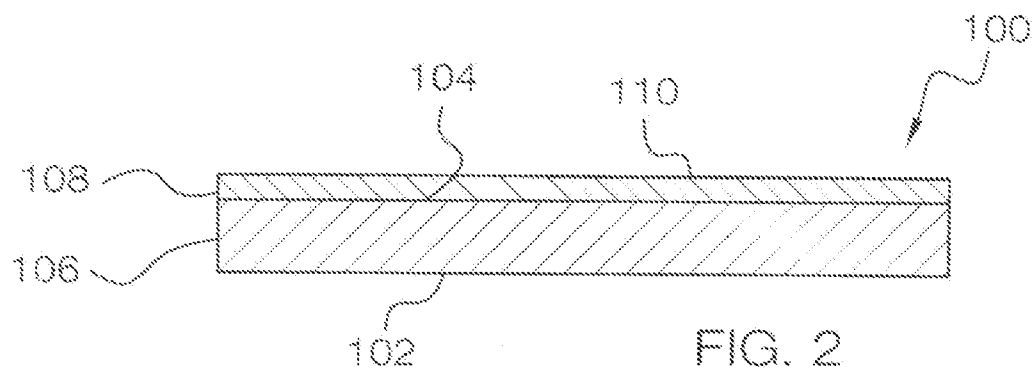
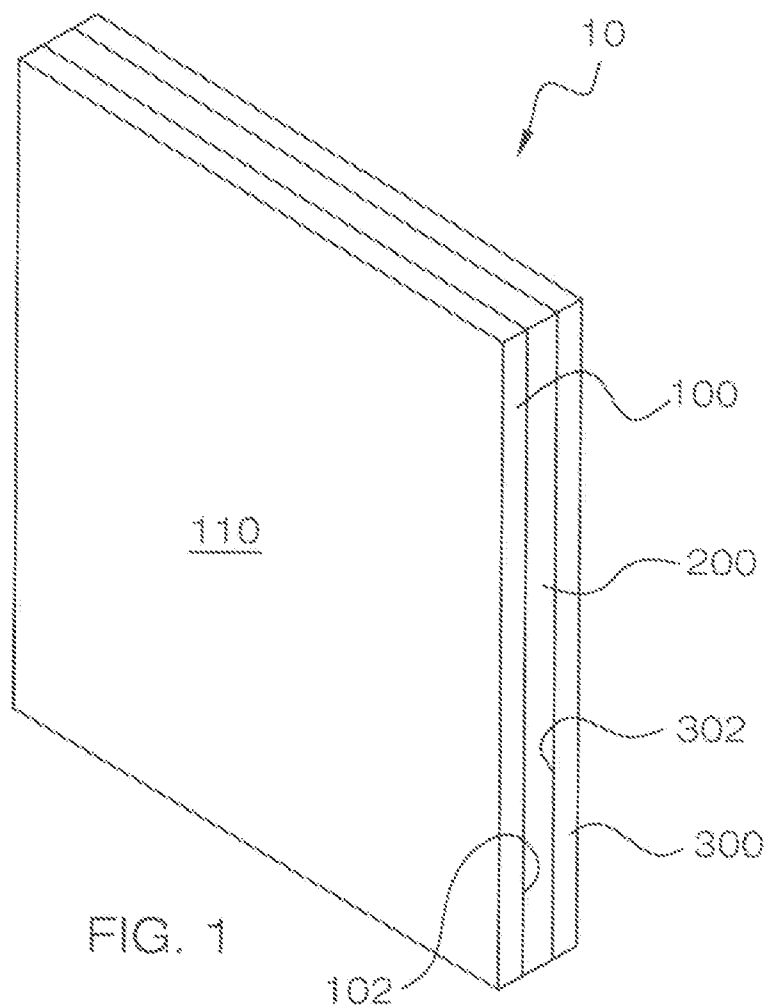




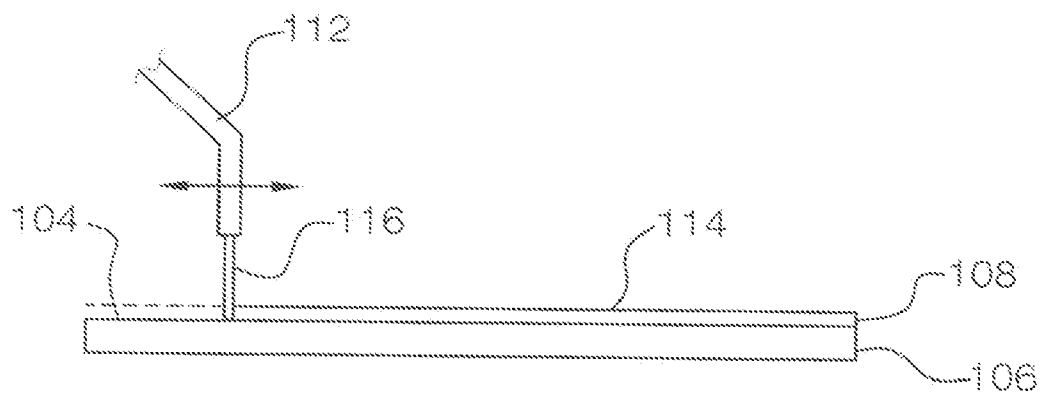


FIG. 3

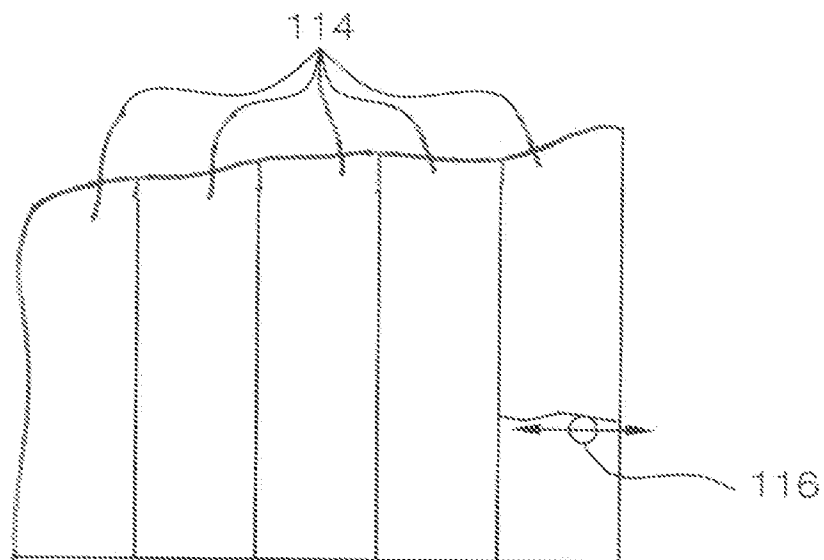


FIG. 4

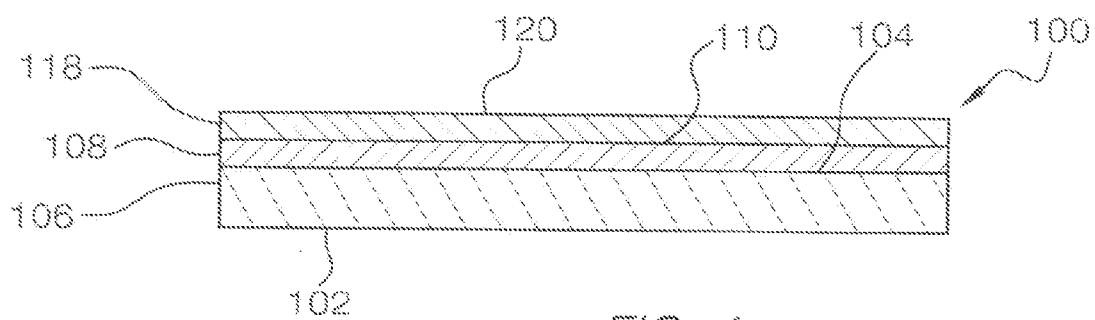


FIG. 4a

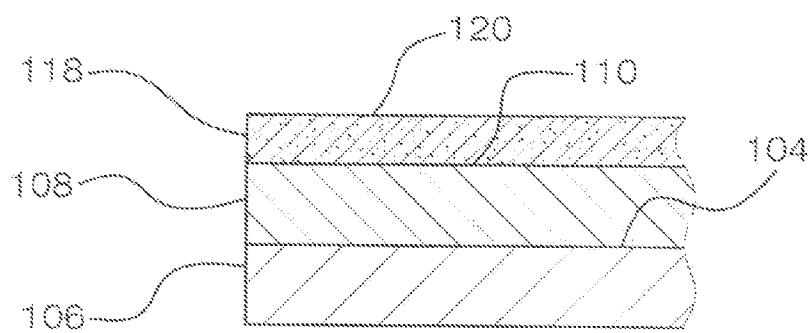


FIG. 4b

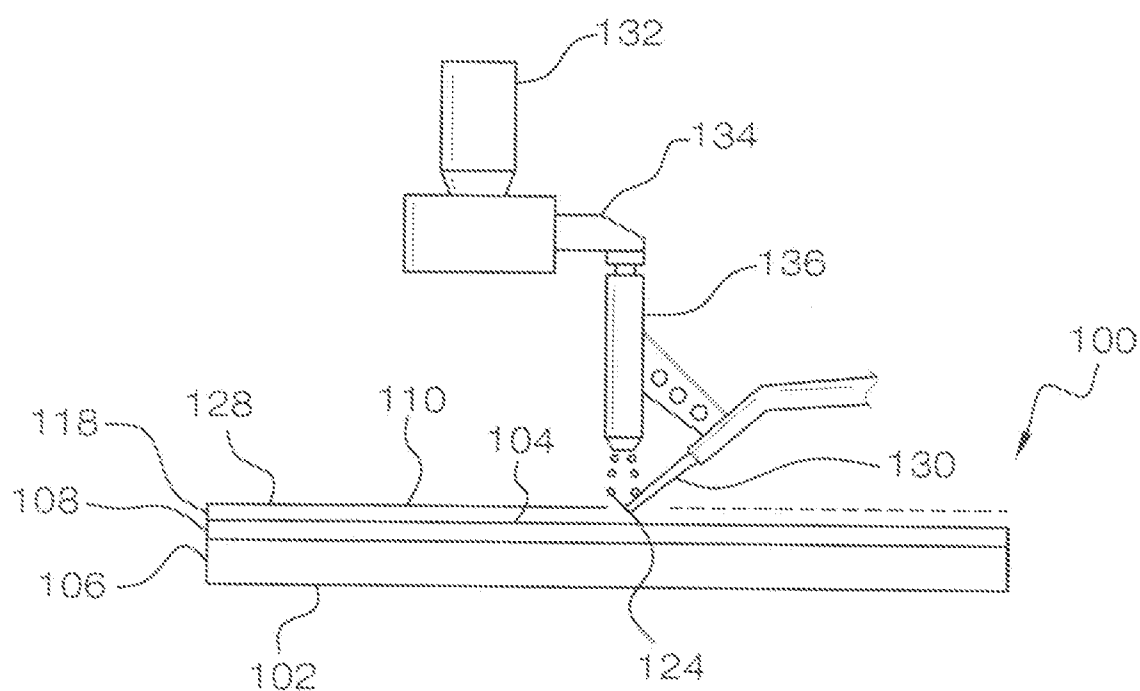


FIG. 5

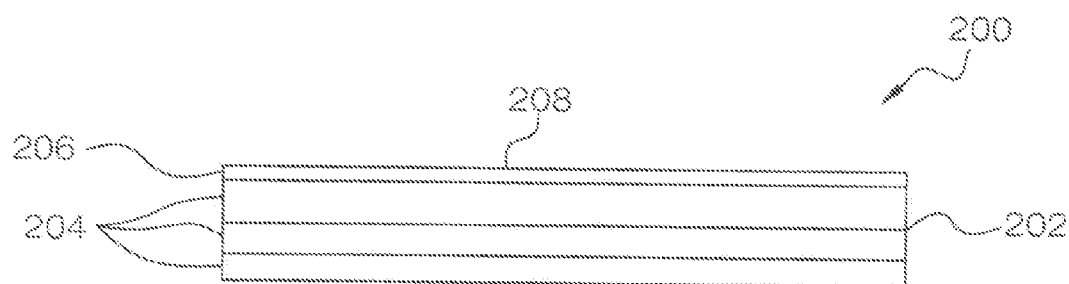


FIG. 6a

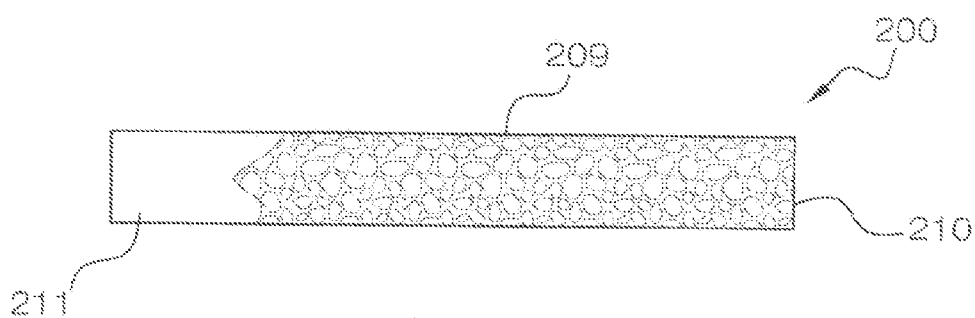


FIG. 7

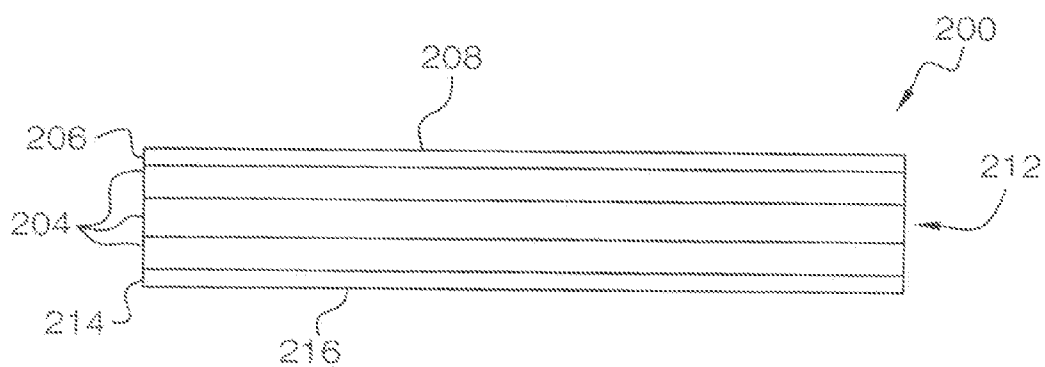


FIG. 6b

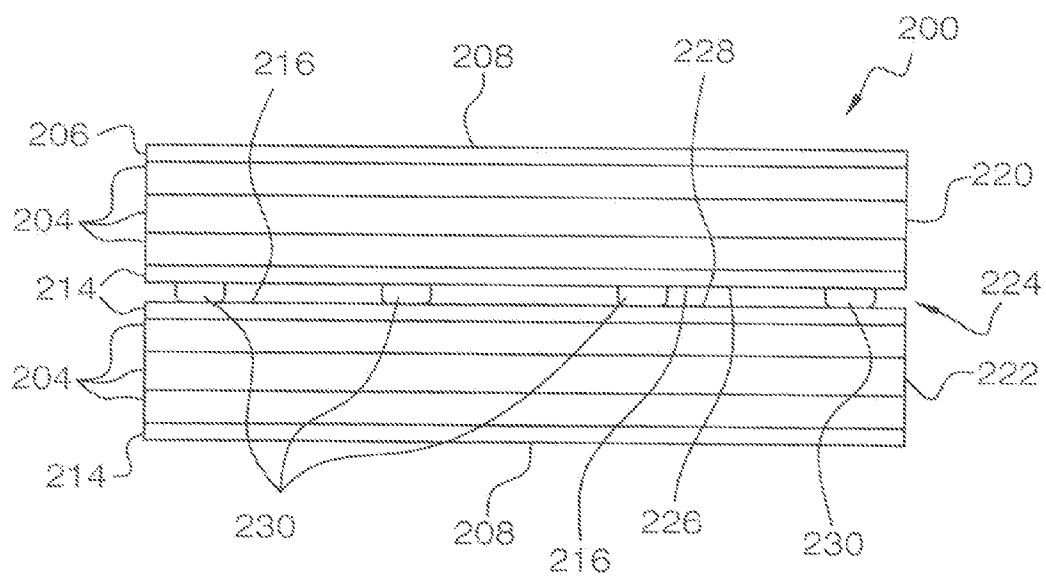


FIG. 6c

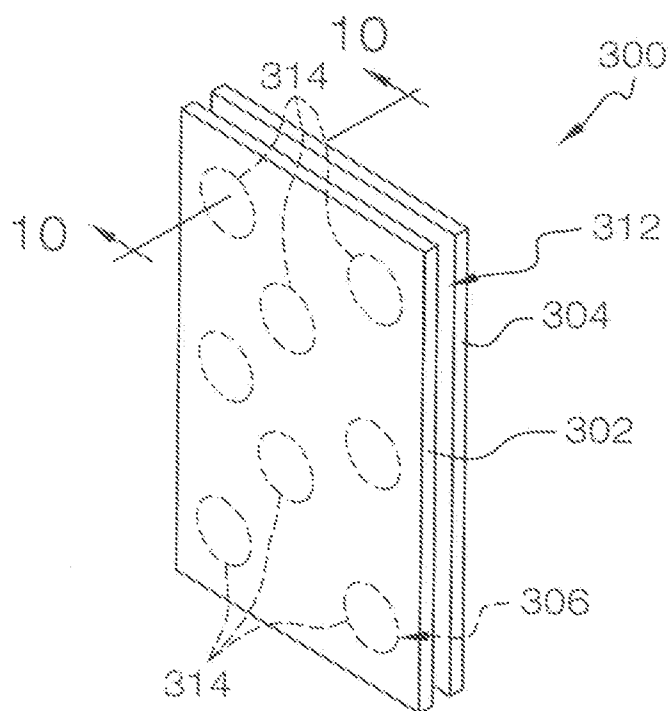


FIG. 8

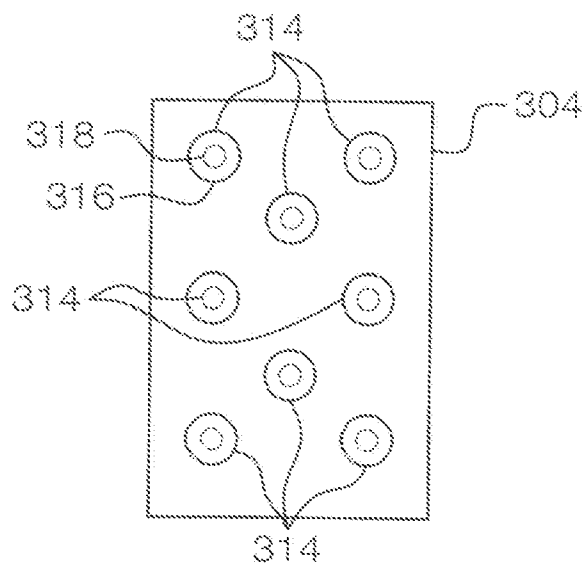


FIG. 9

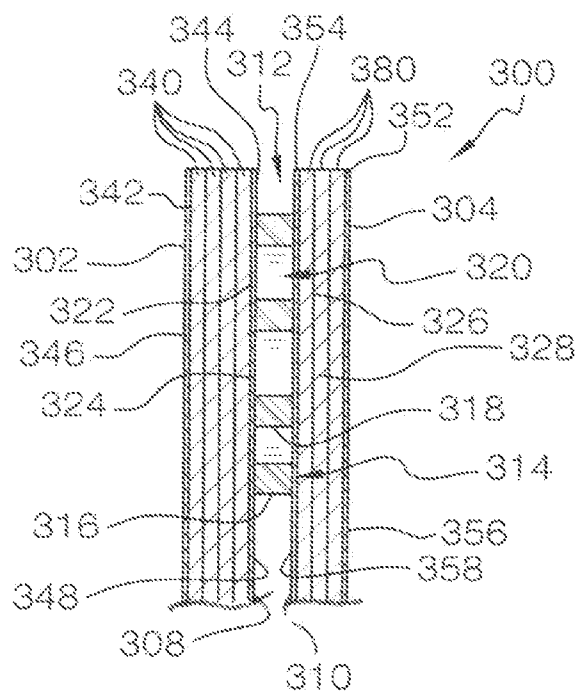


FIG. 10

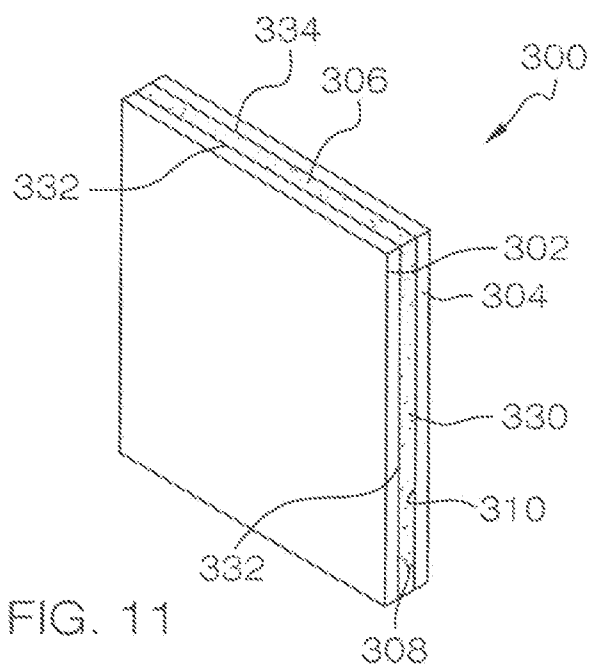


FIG. 11

BALLISTIC ARMOR PANEL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/155,274, filed Feb. 25, 2009, the entire of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to armor systems, and more particularly, relating to an armor system for defeating penetration by high velocity projectiles without back-face deformation.

BACKGROUND OF THE INVENTION

[0003] Ballistic armor is subjected to a variety of projectiles designed to defeat the armor by either penetrating the armor with a solid or jet-like object or by inducing shock waves in the armor that are reflected in a manner to cause spalling of the armor such that an opening is formed and the penetrator (usually stuck to a portion of the armor) passes through, or an inner layer of the armor spalls and is projected at high velocity without physical penetration of the armor.

[0004] Ballistic projectile energy is the force that a projectile possesses when it impacts a body or surface. Ballistic energy of a projectile is defined as kinetic energy due to its motion and is equal to one half the mass of the projectile times the square of its speed. For the purposes of this application, when speaking of a projectile, we mean any object that is propelled by external sources (part of a 20 firearm cartridge) or an integral self propelled device (rocket).

[0005] When a projectile, such as a firearm bullet strikes an object, an enormous amount of kinetic energy is transferred into the object. If that object is a human body, severe or lethal damage typically occurs. Given that many rifle rounds travel in excess 2000 fps (feet per second), exceeding the speed of sound in air, and most pistol and revolver rounds 20 travel in excess of 1000 fps, and given that the speed of a projectile to penetrate skin occurs at 163 fps and to break bone occurs only at 213 fps, it is quite easy to understand why severe or lethal damage occurs so often in an unprotected human body when struck by a ballistic projectile, regardless of velocity. Accordingly, there is a widespread desire to develop armor systems to dissipate the total kinetic energy of a ballistic projectile for the purpose of protecting people, in both personal body armor systems and vehicle armor systems.

[0006] In addressing this desire, there has been many attempts, albeit unsuccessfully, to dissipate (i.e., stop) ballistic projectile energy in a variety of configurations and forms, utilizing a variety of monolithic and composite-based materials and systems.

[0007] In vehicle armor, most anti-armor projectiles can be defeated by armor of sufficient strength and thickness, extra armor thickness is heavy and expensive, adds weight to any armored vehicle using it which, in turn places greater strain on the vehicle engine, and drive train. There is only a limited definable amount of steel armor that can be incorporated into the design or modification of vehicles until such vehicle is rendered affectively useless.

[0008] Thus, there exists a need for an armor system that can defeat projectiles from anti-armor devices without requiring excess thickness of armor, and which is capable of defeating multiple close proximity strikes of projectiles. Preferably,

such armor system would be made from materials that can be readily fabricated and incorporated into a vehicle design at a reasonable cost, and even more preferably is scalable to meet anticipated threat levels.

[0009] In body or personal armor, reducing the weight of the armor system is extremely important. Heretofore, most of the weight reduction in personal armor systems has relied upon the use of ceramic plates in combination with high tensile strength fabrics like Kevlar®. Ceramic armor plates are desirable because they are a relatively light, very hard material that is effective at reducing projectile velocity and dispersing projectile energy latterly outward. However, ceramic armor plates are very brittle and shatter upon impact from a projectile, and are only capable of withstanding a single strike. Further, because ceramic armor plates are brittle they are prone to developing micro-cracks during handling, which can result in catastrophic failure of the plate. Accordingly, ceramic armor plates must be frequently inspected to ensure integrity, and have a high rejection.

[0010] Thus, there exists a need for a personal armor system including armor plates that have the benefits of ceramic armor plates but non of the drawbacks, and which are capable of taking multiple strikes.

SUMMARY OF THE INVENTION

[0011] The preferred embodiments of the present invention addresses these need by providing a ballistic armor system that in embodiments is suitable for vehicle armoring and for personal armor systems, that is scalable to meet threat levels, is capable of defeating multiple strikes on a single armor plate, and does not exhibit back-face deformation.

[0012] To achieve these and other advantages, in general, in one aspect, a ballistic armor strike face is provided. The ballistic armor strike face includes a base armor plate having an outwardly facing surface, and a hard layer deposited on the base armor plate to substantially overlay the outwardly facing surface. The hard layer is characterized by being comprised of a material containing between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, and further wherein the hard layer is deposited on the base armor plate in plurality of welded strips of the material.

[0013] In other embodiments, the ballistic armor strike face is further provided with a second hard layer deposited on the base armor plate to substantially overlay the hard layer. The second hard layer is characterized by being comprised of a matrix material with a particulate material disperse throughout the matrix material, and wherein the matrix material contains between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, and the particulate material is tungsten carbide of a mesh size between 16 and 24.

[0014] To achieve the above and other advantages, in general, in one aspect, an intermediate armor panel assembly is provided. The intermediate armor panel assembly includes multiple sheets of a first fibrous material and a sheet of a second fibrous material laminated together by a modified epoxy resin with the first sheet of a second fibrous material being exposed along an outward facing surface, and wherein the sheet of a second fibrous material is a sheet of peel ply.

[0015] To achieve the above and other advantages, in general, in one aspect a ballistic energy dispersion assembly is

provided. The ballistic energy dispersion assembly includes a first panel having opposed inward and outward facing surfaces; a second panel having opposed inward and outward facing surfaces; a spacing means interposed between the first and the second panels forming a gap between the inward facing surfaces of the first and second panels; the first panel is constructed of multiple layers of sheets of a fibrous material laminated together; and the second panel is constructed of multiple layers of sheets of a fibrous material laminated together.

[0016] To achieve the above and other advantages, in general, in one aspect a ballistic armor system is provided. The ballistic armor system includes a forwardly positioned strike face panel, wherein the strike face panel comprises a base armor plate having an outwardly facing surface; a hard layer deposited on the base armor plate to substantially overlay the outwardly facing surface; wherein the hard layer is characterized by being comprised of a material containing between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, and further wherein the hard layer is deposited on the base armor plate in plurality of welded strips of the material. An intermediately positioned armor panel assembly, wherein the armor panel assembly comprises multiple sheets of a first fibrous material and a sheet of a second fibrous material laminated together by a modified epoxy resin with the first sheet of a second fibrous material being exposed along an outward facing surface; and wherein the sheet of a second fibrous material is a sheet of peel ply. A rearwardly positioned energy dispersion assembly, wherein the energy dispersion assembly comprises a first panel having opposed inward and outward facing surfaces; a second panel having opposed inward and outward facing surfaces; a spacing means interposed between the first and the second panels forming a gap between the inward facing surfaces of the first and second panels; the first panel is constructed of multiple layers of sheets of a fibrous material laminated together; and the second panel is constructed of multiple layers of sheets of a fibrous material laminated together.

[0017] There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood and in order that the present contribution to the art may be better appreciated.

[0018] Numerous objects, features and advantages of the present invention will be readily apparent to those of ordinary skill in the art upon a reading of the following detailed description of presently preferred, but nonetheless illustrative, embodiments of the present invention when taken in conjunction with the accompanying drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of descriptions and should not be regarded as limiting.

[0019] As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

[0020] For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The accompanying drawings, which are included to provide further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate preferred embodiments of the invention and together with the description serve to explain the principles of the invention, in which:

[0022] FIG. 1 is a schematic, perspective view of a ballistic armor panel system constructed in accordance with the principles of the present invention;

[0023] FIG. 2 is a schematic cross-sectional view of one embodiment of a ballistic strike face in accordance with the principles of the present invention where the strike face includes a base armor plate with a very hard surface coating or overlay;

[0024] FIG. 3 is diagrammatic view illustrating the process for depositing the hard overlay on the base armor plate depicted in FIG. 2;

[0025] FIGS. 4a-4b are schematic, cross-sectional views of one embodiment of a ballistic strike face in accordance with the principles of the present invention where the strike face includes a base armor plate having deposited thereon several layers of very hard coatings or overlays;

[0026] FIG. 5 is diagrammatic view illustrating the process for depositing the top or second hard overlay on the base armor plate depicted in FIGS. 4a-4b;

[0027] FIG. 6a is a schematic, cross-sectional view of one embodiment of an armor panel assembly in accordance with the principles of the present invention where the armor panel assembly includes multiple plies or layers of sheets of first fibrous material and an exterior ply or layer of sheet of a second fibrous material laminated together;

[0028] FIG. 6b is a schematic, cross-sectional view of one embodiment of an armor panel assembly in accordance with the principles of the present invention;

[0029] FIG. 6c is a schematic, cross-sectional view of one embodiment of an armor panel assembly in accordance with the principles of the present invention;

[0030] FIG. 7 is a schematic, cross-sectional view of one embodiment of an armor panel assembly in accordance with the principles of the present invention where the armor panel assembly includes a body comprised of open cell metal foam material that is optionally encapsulated by a covering;

[0031] FIG. 8 is a schematic, perspective view of one embodiment of an energy dispersion assembly in accordance with the principles of the present invention where the energy dispersion assembly includes having a spacing means disposed between two panel assemblies, and where the spacing means comprises a plurality of spaced ring structures;

[0032] FIG. 9 is a schematic view of the energy dispersion assembly of FIG. 8 with one panel removed illustrating the plurality of spaced ring structures;

[0033] FIG. 10 is a schematic, cross-sectional view taken along line 10-10 in FIG. 8 illustrating a single ring structure; and

[0034] FIG. 11 is a schematic, perspective view of one embodiment of an energy dispersion assembly in accordance with the principles of the present invention where the energy

dispersion assembly includes having a spacing means disposed between two panel assemblies, and where the spacing means comprises at least one body comprised of an open cell metal foam material.

DETAILED DESCRIPTION OF THE INVENTION

[0035] Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings. Wherever possible, same reference numbers will be used throughout the drawings to refer to the same or like parts.

[0036] In accordance with the present invention, there is provided a ballistic armor panel system for defeating ballistic projectiles, including large caliber high velocity ammunition. The embodiments of the present invention have demonstrated to be successful at stopping multiple close grouped hits of large caliber, high velocity armor piercing ammunition from complete penetration through the armor panel system and with no back-face deformation. The embodiments of the present invention have demonstrated this success with a reduction in weight and thickness over current armor systems. The parameters of the ballistic armor panel system are easily scalable to particular service requirements and to particular threat levels. Embodiments of the present invention are suitable and desirable for vehicle armoring to provide a more effective armor system while reducing the weight of the vehicle, and thus reducing strain on the vehicle's drive train and suspension systems. Other Embodiments of the present invention are suitable and desirable for personal armor.

[0037] As here embodied, and depicted schematically in FIG. 1, there is a ballistic armor panel system 10, including a forwardly positioned ballistic strike face or armor plate 100, an intermediately positioned armor panel assembly 200, and a rearwardly positioned energy dispersion assembly 300. In the embodiment depicted, the armor panel assembly 200 is bonded to surface 102 of the armor plate 100, and is bonded to surface 302 of the energy dispersion assembly 300. In embodiments, the armor panel assembly 200 is bonded to surfaces 102 and 302 with a modified epoxy resin. The modified epoxy resin is an epoxy that has an increased toughness and ability to absorb energy by a dispersion of micro-particles of an elastomeric material throughout the resin. The micro-particles are of a size between 1 and 10 microns.

[0038] In other embodiments, mechanical fastening can be used to join the armor panel assembly 200 to the armor plate 100 and energy dispersion assembly 300. In other embodiments, the armor panel assembly 200 can be spaced from either or both the armor plate 100 and the energy dispersion assembly. In other embodiments, additional layers of armoring can be employed. In other embodiments, one or more of the armor panel assembly 100, the armor panel assembly 200, and the energy dispersion assembly 300 can be encapsulated by a covering material. The covering material could include, but is not limited to an elastomeric material, an elastomeric plastic material such as Rhino Lok® available from Rhino Hide, a composite fiber wrapping, resins, epoxies, and the like.

[0039] Armor plate 100 provides a ballistic strike face which is the first layer of the ballistic armor panel system 10 that is struck by a ballistic projectile. The purpose of armor plate 100 or the ballistic strike face is to absorb a portion of the energy of the projectile, to strip down the projectile by deforming it, and to significantly reduce its velocity. In some ballistic ammunition, ahead of the projectile is an elongated

jet of material moving at a higher velocity along the same trajectory. Because the jet is moving at a higher velocity and has a relatively small cross-sectional area, it poses a significant threat to armor systems. In this case, the armor plate 100, as the addition of purpose of deforming the leading edge of the jet, deflecting the jet, and absorbing some energy of the jet. This significantly increases the probability the projectile and/or jet will be defeated by the remaining portions of the armor system, as herein embodied.

[0040] As depicted schematically in FIG. 1, the armor plate 100 is a relatively thin metal plate with a very hard material on its outer surface, to induce fracture and deformation of a projectile striking the armor plate.

[0041] With reference to FIG. 2, there is schematically depicted, an armor plate 100 according to a first embodiment. In this embodiment, the armor plate 100 comprises a base armor layer 106 and a ballistic-resistant armor layer such as hard layer 108. The base armor layer 106 has an outwardly facing surface 104 and an opposed inwardly facing surface 102. Surfaces 102 and 104 may be parallel and may be flat surfaces. The base armor layer 106 consists of a malleable, non-brittle and non-ductile material such as, but not limited to, mild steel. Alternatively, the base armor layer 106 could consist of a lower carbon steel or of a higher carbon steel.

[0042] The ballistic-resistant armor layer or hard layer 108 substantially covers the outward facing surface 104 of the base armor layer 106, and forms a strike surface 110. The hard material is chosen to have high hardness in order to fracture and deform a projectile upon impact and to have a sufficient toughness to resist against shattering from projectile impact. The material of the hard layer is chosen to have a hardness of between 58-65 on the Rock C scale. In an embodiment, the hard layer 108 is of a chromium carbide material of an austenitic structure containing between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, with the rest being iron.

[0043] In FIG. 3, there is schematically depicted a weld overlay process used to deposit the material of the hard layer 108 to overlay the outward facing surface 104 of the base armor layer 106. The weld overlay process involves a conventional open arc MIG welder 112 to apply or deposit successive, side-by-side beads or strips 114 of weld overlay material (dashed lines indicating were remaining strips are to be deposited). The interface edges of adjacent strips 114 are coalesced together during deposition forming a continuous hard layer 108 across surface 104. The welder 112 can be an automated open arc MIG welder such that is programmed to oscillate the weld wire 116 back-and-forth laterally as the weld wire is traversed back-and-forth longitudinally across the base surface to form strips 114. In a preferred embodiment, the weld wire 116 is oscillated back-and-forth about 1.5 inches creating strips 114 each having a width of about 1.5 inches, and a thickness of about 0.125 inches. The thickness of hard layer 108 can be increased by depositing strips 114 successively in multiple layers on the base armor layer 106. The weld overlay process, uses between a ¼ inch and ½ inch open arc wire with a voltage between 28 and 54 volts, and with an amperage between 400 and 650 amps.

[0044] The weld wire 116 comprises the weld overlay material of the hard layer 108 as described above. Specifically, the weld wire 116 is comprised of a weld overlay material containing between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, with the rest being iron.

[0045] In a first test example, a ballistic strike face **100** included a base armor layer **102** of mild steel in plate form having a thickness of 0.25 inches and a hard layer **108** of 0.125 inches. The ballistic strike face **100** was manufactured using the weld overlay process to deposit a 0.125 inch hard later on a base plate dimensioned 4x8 feet with a 0.25 thickness. Once the entire base plate was overlayed and cooled, it was run through a straightening roller set and then coupons of one-foot by one-foot each were cut from the base plate using a plasma cutter.

[0046] With reference to FIG. 4, there is schematically depicted, an armor plate **100** according to a second embodiment. In this embodiment, in addition to the base armor layer **106**, and the ballistic-resistant armor layer or hard layer **108** of the first embodiment described above, a second hard layer **118** is provided. The second hard layer **118** is substantially overlaid surface **110** of the hard layer **108**, and provides a strike face **120**. The second hard layer **118** comprises a matrix material **122** having therein a dispersion of granular particles **124** of a very hard material. The matrix material **122** is of a chromium carbide material of an austenitic structure containing between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, with the rest being iron. The granular particles **124** are comprised of Tungsten Carbide and have a mesh size of about 16 between about 24.

[0047] Second hard layer **118** is deposited to overlay surface **110** of hard layer **108** using a weld overlay process that is similar to the weld overlay process used to deposit the material of the hard layer **108**, as described above and depicted in FIG. 3. Particularly, with reference to FIG. 5, the second hard layer **118** is deposited using a weld overlay process including an open arc MIG welder **126** to apply or deposit successive, side-by-side beads or strips **128** of weld overlay material (dashed lines indicating were remaining strips are to be deposited). The interface edges of adjacent strips **128** are coalesced together during deposition forming a continuous second hard layer **118** across surface **110**. The welder **126** can be an automated open arc MIG welder such that is programmed to oscillate the weld wire **130** back-and-forth as the weld wire is traversed across the base surface to form strips **128**. In a preferred embodiment, the weld wire **130** is oscillated back-and-forth about 1.5 inches creating strips **128** each having a width of about 1.5 inches, and a thickness of about 0.125 inches. Granular Tungsten carbide particles **124** contained in hopper **132** are dispersed into the weld pool at the trailing edge of each strip **128** as the strip is deposited by a metering dispenser **134** through a drop tube **136**. The weld overlay process, uses between a $\frac{7}{64}$ inch and $\frac{1}{8}$ inch open arc wire with a voltage between 28 and 54 volts, and with an amperage between 400 and 650 amps.

[0048] The weld wire **130** comprises the matrix material **122** of the second hard layer **118** as described above. Specifically, the weld wire **130** is comprised of a weld matrix material containing between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, with the rest being iron.

[0049] As here embodied, and depicted schematically in FIG. 1, armor panel assembly **200** is positioned intermediate of armor plate **100**, and energy dispersion assembly **300**. The purpose of armor panel assembly **200** is to further attenuate,

and absorb the energy of a ballistic projectile penetrating the armor plate **100**, and to catch or otherwise stop the solid projectile from further penetration through the ballistic armor panel system **10**.

[0050] With reference to FIG. 6a, there is schematically depicted, an armor panel assembly **200** according to a first embodiment. In the first embodiment, the armor panel assembly **200** comprises a fibrous armor panel **202** containing multiple layers or plies of sheets of fibrous material. The fibrous armor panel assembly **202** attenuates the energy of the penetrating material of the ballistic projectile by resisting the enlargement of an opening therein by virtue of the extremely high tensile strengths of the fibers comprising the fibrous sheets. In a first example, as depicted in FIG. 6a, the fibrous armor panel **202** contains multiple sheets **204** of a first fibrous material, and a sheet **206** of a second fibrous material. Sheets **204** and **206** are laminated together with sheet **206** being exposed along one surface **208**. The fibrous armor panel **202** is positioned in the armor panel system **10** such that sheet **206** is facing forwardly, i.e. sheet **206** is positioned to be first struck by projectile material passing through armor plate **100**. Sheets **204** and **206** can be bonded or otherwise laminated together by an epoxy resin. The sheets **204** and **206** can be laminated together using a vacuum bag sealing method; however, other lamination methods could reasonably be used. In accordance with this embodiment, sheets **204** are of a glass fiber having a high tensile strength such as, but not limited to S-2 Glass® fiber manufactured by AGY. However, one or more of sheets **204** could be of Kevlar®. Additionally, more or less of sheets **204** can be included.

[0051] Sheet **206** is a peel ply fabric sheet. Peel ply fabric sheets are optionally used in the manufacture of laminates as a release material against the top surface of the laminate where a clean, textured finish is required for subsequent bonding or painting of the laminate. Once the laminate is cured, the peel ply sheet is removed to expose the textured underlying laminate surface. The Applicant has discovered a fibrous armor panel **202** with a peel ply fabric sheet that has not been removed and is positioned to first receive impact from a projectile results in a controlled delamination of fibers of the underlying fabric sheet material. The controlled delamination provides a reduced spalling of the underlying fabric sheet material, reduced breaking of the fibers of the underlying fabric sheet material, reduced penetration of the ballistic material, and increased lateral energy dispersion over a larger generalized area than that of the impact point, resulting in the solid projectile being stopped from further penetration beyond the fibrous armor panel **202** when combined with the armor plate **100** and energy dispersion assembly **300** as embodied herein. The Applicant has found the following peel plies to be suitable and provide desired results: Release Ply F, Release Ply Super F, and Release Ply Super A, each are available from AIRTECH. However, other peel plies that have not yet been tested could provide desired results.

[0052] In one embodiment, sheets **204** and **206** are laminated using a modified epoxy resin containing a dispersion of micro-particles of an elastomeric material throughout the resin. The micro-particles are of a size between 1 and 10 microns. The modified epoxy resin has an increased toughness and ability to absorb energy by the dispersion of micro-particles of an elastomeric material throughout the resin.

[0053] A second example of an armor panel assembly **200** is depicted in FIG. 6b where a fibrous armor panel **212** contains multiple sheets **204** of a first fibrous material, and sheets

206 and **214** of a second fibrous material. Sheets **204**, **206** and **214** are laminated together with sheet **206** exposed along surface **208** and sheet **214** opposite sheet **206** and being exposed along surface **216**. In other words, sheets **206** and **214** are laminated together with intermediate sheets **204** on opposite surfaces of thereof. As in the first example described above and depicted in FIG. 6a, Sheets **204**, **206** and **214** can be bonded or otherwise laminated together by an epoxy resin. Sheets **204**, **206** and **214** can be laminated together using a vacuum bag sealing method; however, other lamination methods could reasonably be used. In accordance with this embodiment, sheets **204** are of a glass fiber having a high tensile strength such as, but not limited to S-2 Glass® fiber manufactured by AGY. However, one or more of sheets **204** could be of Kevlar®. Additionally, more or less of sheets **204** can be included. Sheets **206** and **214** are peel ply fabric sheet as described above.

[0054] A third example of an armor panel assembly **200** is depicted in FIG. 6c. In this example, the armor panel assembly **200** includes a first fibrous armor panel **220** and a second fibrous armor panel **222** separated from the first fibrous armor panel **220** by a space or gap **224**. The gap **224** can be continuous between facing surfaces **226** and **228** of panels **220** and **222**, respectively. A plurality of discreet spot bonds **230** between surfaces **226** and **228** resiliently secure panels **220** and **222** together for relative movement. Spot bonds **230** also act as spacer elements forming gap **224** between panels **220** and **222**. Preferably, the gap **224** is between 0.125 inches and 0.5 inches. Spot bonds **230** can comprise an elastomeric adhesive, such as elastomeric adhesive available under the name **5200** from 3M, or the like. Panels **220** and **222** can comprise either of the fibrous armor panels **202** and **212** as described above and depicted in FIGS. 6a and 6b, respectively. More specifically, as depicted here, each of panels **220** and **222** are comprised of fibrous armor panel **212**, and each contain multiple sheets **204** of a first fibrous material, and sheets **206** and **214** of a second fibrous material. Sheets **204**, **206** and **214** are laminated together with sheet **206** exposed along surface **208** and sheet **214** opposite sheet **206** and being exposed along surface **216**. As depicted herein, panels **220** and **222** are arranged with surfaces **216** inwardly facing towards one another, and providing surfaces **226** and **228**, respectively. However, nothing herein should limit or prevent panels **220** and **222** being arranged with opposite surfaces **208** and **216** inwardly facing towards one another, or with surfaces **208** inwardly facing towards one another.

[0055] With reference to FIG. 7, there is schematically depicted, an armor panel assembly **200** according to a second embodiment. In this embodiment, the armor panel assembly **200** comprises an armor panel **210** comprising a body **209** of an open-cell metal foam material. Generally, a metal foam is a cellular structure consisting of a solid metal containing a large volume fraction of gas-filled pores. The pores can be sealed (closed-cell foam), or they can form an interconnected network (open-cell foam). In a preferred embodiment, the open-cell metal foam is an open cell nanocrystalline Ni—Fe alloy foam having metal grain sizes between 5 nm and 100 nm, is available from Integran Technologies, USA, Inc., Pittsburgh, Pa.

[0056] There have been prior attempts of using a closed-cell metal foam material of aluminum. Closed-cell metal foam, and specifically closed-cell aluminum metal foam does not work well in armor panel assemblies due to its small range of elastic deformation. Meaning the forces applied to a body

of closed-cell aluminum metal foam from an impact with a ballistic projectile deforms the body beyond the elastic deformation range of the material and body structure into its plastic deformation range, and resulting in a permanently deformed body with the inability to absorb any additional strikes. The Applicant has discovered the use of an open cell nanocrystalline Ni—Fe alloy foam, such as the one available from Integran Technologies, USA, Inc., Pittsburgh, Pa., provides a body with a large elastic deformation range, and demonstrates success in absorbing high applied forces from multiple impacts of ballistic projectiles.

[0057] With reference no to FIG. 8, there is schematically depicted, an energy dispersion assembly **300** according to a first embodiment. The purpose of the energy dispersion assembly **300** is to absorb and disperse any residual energy that is transmitted through armor panel assembly **200** from an impact of a ballistic projectile in a lateral and outwardly direction toward the periphery of the energy dispersion assembly. In the first embodiment, energy dispersion assembly **300** includes a first panel **302** spaced from a second panel **304** by a spacing means **306** thereby forming a gap **312** between the facing surfaces **308** and **310** of the first and second panels, respectively. In one aspect, each panel **302** and **304** comprise a laminate of multiple layers of sheets of fibrous material. The first panel **302** may include 3 to 10 plies (layers) of 28 oz. sheets of S-2 Glass® fiber laminated together using the modified epoxy resin described herein above. Alternatively, the first panel **302** may include 5 plies (layers) of 100 oz. sheets of S-2 Glass® fiber laminated together using the modified epoxy resin. The second panel **304** may include 3 to 10 plies (layers) of 28 oz. sheets of S-2 Glass® fiber laminated together using the modified epoxy resin described herein above.

[0058] With specific reference to FIG. 10, in one embodiment, panel **302** contains multiple sheets **340** of a first fibrous material, and sheets **342** and **344** of a second fibrous material. Sheets **340**, **342** and **344** are laminated together with sheet **342** exposed along surface **346** and sheet **344** opposite sheet **342** and being exposed along surface **348**. In other words, sheets **342** and **344** are laminated together with intermediate sheets **340** on opposite surfaces of thereof. Sheets **340**, **342** and **344** can be bonded or otherwise laminated together by an epoxy resin. Sheets **340**, **342** and **344** can be laminated together using a vacuum bag sealing method; however, other lamination methods could reasonably be used. In accordance with this embodiment, sheets **340** are of a glass fiber having a high tensile strength such as, but not limited to S-2 Glass® fiber manufactured by AGY. However, one or more of sheets **340** could be of Kevlar®. Additionally, more or less of sheets **340** can be included. Sheets **342** and **344** are peel ply fabric sheet as described above.

[0059] Likewise, in the same embodiment, panel **304** contains multiple sheets **350** of a first fibrous material, and sheets **352** and **354** of a second fibrous material. Sheets **350**, **352** and **354** are laminated together with sheet **352** exposed along surface **356** and sheet **354** opposite sheet **352** and being exposed along surface **358**. In other words, sheets **352** and **354** are laminated together with intermediate sheets **350** on opposite surfaces of thereof. Sheets **350**, **352** and **354** can be bonded or otherwise laminated together by an epoxy resin. Sheets **350**, **352** and **354** can be laminated together using a vacuum bag sealing method; however, other lamination methods could reasonably be used. In accordance with this embodiment, sheets **350** are of a glass fiber having a high

tensile strength such as, but not limited to S-2 Glass® fiber manufactured by AGY. However, one or more of sheets 350 could be of Kevlar®. Additionally, more or less of sheets 350 can be included. Sheets 352 and 356 are peel ply fabric sheet as described above.

[0060] With further reference to FIGS. 9 and 10, the spacing means 306 comprises a plurality of ring structures 314 positioned within gap 312. The spacing means 306 serves both as an elastic energy absorber and a spacer that permits most of the residual energy from the ballistic projectile to dissipate laterally or partially reverse in direction. Each ring structure 314 includes an outer ring 316, and an inner ring 318 of a diameter that is less than the outer ring, thereby creating an annular space 320 between in the inner and outer rings. The thickness of each of the outer and inner rings 316 and 318 can be between 0.125 inches and 0.25 inches. The outer and inner rings 316 and 318 can be of an elastomeric material having a durometer of between 30 to 70 on the Shore A scale. Faces 322 and 324 of the outer and inner rings 316 and 318, respectively, are attached to face 308 of the first panel 302 with an appropriate adhesive or bonding agent. Likewise, faces 326 and 328 of the outer and inner rings 316 and 318, respectively are attached to face 310 of the second panel 304 with an appropriate adhesive or bonding agent. An appropriate adhesive can include the adhesive 5200 available by 3M, or the like. Other adhesives or bonding agents could be used.

[0061] All of the residual energy of the ballistic projectile that remains after the armor plate 100 and the armor panel assembly 200 is absorbed and dissipated by the energy dispersion assembly 300. Accordingly, no back-face deformation occurs the second panel 304.

[0062] With reference to FIG. 11, there is schematically depicted, an energy dispersion assembly 300 according to a second embodiment. In this embodiment, the spacing means 306 comprises a single body 330 of open-cell metal foam (FIG. 12) or multiple bodies 330 of metal foam (FIG. 13) arranged within gap 312. The open cell metal foam can be open cell nanocrystalline Ni—Fe alloy foam having metal grain sizes between 5 nm and 100 nm, such as the metal foam available from Integran Technologies, USA, Inc., Pittsburg, Pa. In FIG. 11, face 332 of body 330 is attached to face 308 of the first panel 302 with an appropriate adhesive or bonding agent.

[0063] In a first test example, the a ballistic armor panel system 10 included a forwardly positioned ballistic strike face or armor plate 100, an intermediately positioned armor panel assembly 200, and a rearwardly positioned energy dispersion assembly 300. The armor plate 100 included a base armor layer 106 of mild steel having a thickness of 0.25 inches with a hard layer overlay 108 with a thickness of 0.0125 inches. The armor panel assembly 200 included the general structure depicted in FIG. 6c and described above, with a first fibrous armor panel 220 including three fibrous sheets 204 of S-2 Glass® fiber of 28 oz weight, a fibrous sheet 206 of F Peel Ply, and a fibrous sheet 214 of F peel ply laminated together with a modified epoxy resin, and a second fibrous armor panel 222 including three fibrous sheets 204 of S-2 Glass® fiber of 28 oz weight, a fibrous sheet 206 of F Peel Ply, and a fibrous sheet 214 of F peel ply laminated together with a modified epoxy resin. The energy dispersion assembly 300 included the general structure depicted in FIGS. 8-10, and accordingly described above, with the first panel 302 including four fibrous sheets 340 of S-2 Glass® fiber of 28 oz weight, a fibrous sheet 342 of F Peel Ply, and a fibrous sheet 344 of F

peel ply laminated together with a modified epoxy resin, and with the second panel 304 including three fibrous sheets 350 of S-2 Glass® fiber of 28 oz weight, a fibrous sheet 352 of F Peel Ply, and a fibrous sheet 354 of F peel ply laminated together with a modified epoxy resin.

[0064] In a second test example, everything remained the same as in the first test example, except the a ballistic armor panel system 10 included an armor plate 100 having a base armor layer 106 of mild steel having a thickness of 0.375 inches with a hard layer 108 overlay with a thickness of 0.375 inches.

[0065] In a third test example, everything remained the same as in the first test example, except the a ballistic armor panel system 10 included an armor plate 100 having a base armor layer 106 of mild steel having a thickness of 0.625 inches with a hard layer 108 overlay with a thickness of 0.25 inches.

[0066] In a fourth test example, everything remained the same as in the first test example, except the a ballistic armor panel system 10 included an armor plate 100 having a base armor layer 106 of mild steel having a thickness of 0.375 inches, a hard layer overlay 108 with a thickness of 0.25 inches, and a top hard layer overlay of 0.25 inches.

[0067] A number of embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A ballistic armor strike face panel, comprising:
a base armor plate having an outwardly facing surface;
a hard layer deposited on said base armor plate to substantially overlay said outwardly facing surface; and
wherein said hard layer is characterized by being comprised of a material containing between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, and further wherein said hard layer is deposited on said base armor plate in plurality of welded strips of said material.
2. The ballistic armor strike face panel of claim 1, wherein said material is chromium carbide in an austenitic matrix.
3. The ballistic armor strike face panel of claim 1, wherein said base armor layer is mild steel.
4. The ballistic armor strike face panel of claim 1, wherein said hard layer is further characterized by said welded strips formed by an open arc MIG welding process with a weld wire size of a minimum of 0.110 inches being automatically traversed across said strike surface while said weld wire is oscillated back and forth.
5. The ballistic armor strike face panel of claim 1, further comprising:
a second hard layer deposited on said base armor plate to substantially overlay said hard layer; and
wherein said second hard layer is characterized by being comprised of a matrix material with a particulate material dispersed throughout said matrix material, and wherein said matrix material contains between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, and said particulate material is tungsten carbide of a mesh size between 16 and 24.

6. An armor panel assembly, comprising:
multiple sheets of a first fibrous material and a sheet of a second fibrous material laminated together by a modified epoxy resin with said first sheet of a second fibrous material being exposed along an outward facing surface; and wherein said sheet of a second fibrous material is a sheet of peel ply.
7. The armor panel assembly of claim 6, wherein at least one sheet of said multiple sheets of a first fibrous material is a sheet of glass fiber.
8. A ballistic energy dispersion assembly, comprising:
a first panel having opposed inward and outward facing surfaces;
a second panel having opposed inward and outward facing surfaces;
a spacing means interposed between said first and said second panels forming a gap between said inward facing surfaces of said first and second panels;
said first panel is constructed of multiple layers of sheets of a fibrous material laminated together; and
said second panel is constructed of multiple layers of sheets of a fibrous material laminated together.
9. The ballistic energy dispersion assembly of claim 8, wherein said gap is continuous between said facing surfaces of said first and said second panels.
10. The ballistic energy dispersion assembly of claim 8, wherein said spacing means comprises:
a plurality of separate ring structures positioned within said gap and in contact with said inward facing surfaces of said first and said second panels.
11. The ballistic energy dispersion assembly of claim 10, wherein each of said plurality of separate ring structures comprises:
an outer ring having interior peripheral edge; and
an inner ring having an outer peripheral edge, said inner ring positioned within said outer ring with said outer peripheral edge spaced from said interior peripheral edge.
12. The ballistic energy dispersion assembly of claim 11, wherein:
said outer ring and said inner ring are comprised of an elastomeric material having a durometer of between 30 to 70 on the A scale.
13. The ballistic energy dispersion assembly of claim 8, wherein:
said multiple layers of sheets of a fibrous material of said first panel are each sheets of a glass fiber; and
said multiple layers of sheets of a fibrous material of said second panel are each sheets of a glass fiber.
14. The ballistic energy dispersion assembly of claim 8, wherein said spacing means comprises:
a body of an open cell metal foam.
15. The ballistic energy dispersion assembly of claim 14, wherein said open cell metal foam is an open cell nanocrystalline Ni—Fe alloy foam.
16. The ballistic energy dispersion assembly of claim 15, wherein said open cell metal foam has a metal grain size between 5 nm and 100 nm.
17. A ballistic armor system comprising:
a forwardly positioned strike face panel, wherein said strike face panel comprises a base armor plate having an outwardly facing surface; a hard layer deposited on said base armor plate to substantially overlay said outwardly facing surface; wherein said hard layer is characterized by being comprised of a material containing between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, and further wherein said hard layer is deposited on said base armor plate in plurality of welded strips of said material;
- an intermediately positioned armor panel assembly, wherein said armor panel assembly comprises multiple sheets of a first fibrous material and a sheet of a second fibrous material laminated together by a modified epoxy resin with said first sheet of a second fibrous material being exposed along an outward facing surface; and wherein said sheet of a second fibrous material is a sheet of peel ply; and
- a rearwardly positioned energy dispersion assembly, wherein said energy dispersion assembly comprises a first panel having opposed inward and outward facing surfaces; a second panel having opposed inward and outward facing surfaces; a spacing means interposed between said first and said second panels forming a gap between said inward facing surfaces of said first and second panels; said first panel is constructed of multiple layers of sheets of a fibrous material laminated together; and said second panel is constructed of multiple layers of sheets of a fibrous material laminated together.
18. The ballistic armor system of claim 17, wherein said strike face panel further comprises:
a second hard layer deposited on said base armor plate to substantially overlay said hard layer; and
wherein said second hard layer is characterized by being comprised of a matrix material with a particulate material disperse throughout said matrix material, and wherein said matrix material contains between 5.0 wt % and 7.0 wt % of carbon, a maximum of 2.0 wt % of manganese, a maximum of 2.0 wt % of silicon, between 25.0 wt % and 35.0 wt % of chromium, and a maximum of 3.0 wt % of molybdenum, and said particulate material is tungsten carbide of a mesh size between 16 and 24.
19. The ballistic armor system of claim 17, wherein said gap is continuous between said facing surfaces of said first and said second panels of said energy dispersion assembly.
20. The ballistic armor system of claim 19, wherein said spacing means comprises:
a plurality of separate ring structures positioned within said gap and in contact with said inward facing surfaces of said first and said second panels.
21. The ballistic armor system of claim 20, wherein each of said plurality of separate ring structures comprises:
an outer ring having interior peripheral edge; and
an inner ring having an outer peripheral edge, said inner ring positioned within said outer ring with said outer peripheral edge spaced from said interior peripheral edge.
22. The ballistic armor system of claim 21, wherein:
said outer ring and said inner ring are comprised of an elastomeric material having a durometer of between 30 to 70 on the A scale.