US 20140373257A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2014/0373257 A1

(43) Pub. Date: Dec. 25, 2014

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(54) **LAYERED PROTECTIVE STRUCTURES**

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(21) Appl. No.: **14/315,080**

(22) Filed: **Jun. 25, 2014**

Related U.S. Application Data

(60) Provisional application No. 61/839,314, filed on Jun. 25, 2013.

Publication Classification

(51) **Int. Cl.**
A42B 3/12 (2006.01)
A42B 3/00 (2006.01)

(52) **U.S. Cl.**
CPC . ***A42B 3/125*** (2013.01); ***A42B 3/12*** (2013.01); ***A42B 3/00*** (2013.01)
USPC **2/414**

(57) **ABSTRACT**

Protective structures that may be used in various protective gear items, such as helmets and the like. In some embodiments, the protective structure may comprise a layered structure having three distinct layers. The various layers may be selected, arranged, and configured to provide for improved protection at multiple velocities, such as high velocity impacts and low velocity impacts. Some embodiments may also, or alternatively, be configured to provide improved protection and/or durability for multiple impacts at the same portion of the helmet over time.

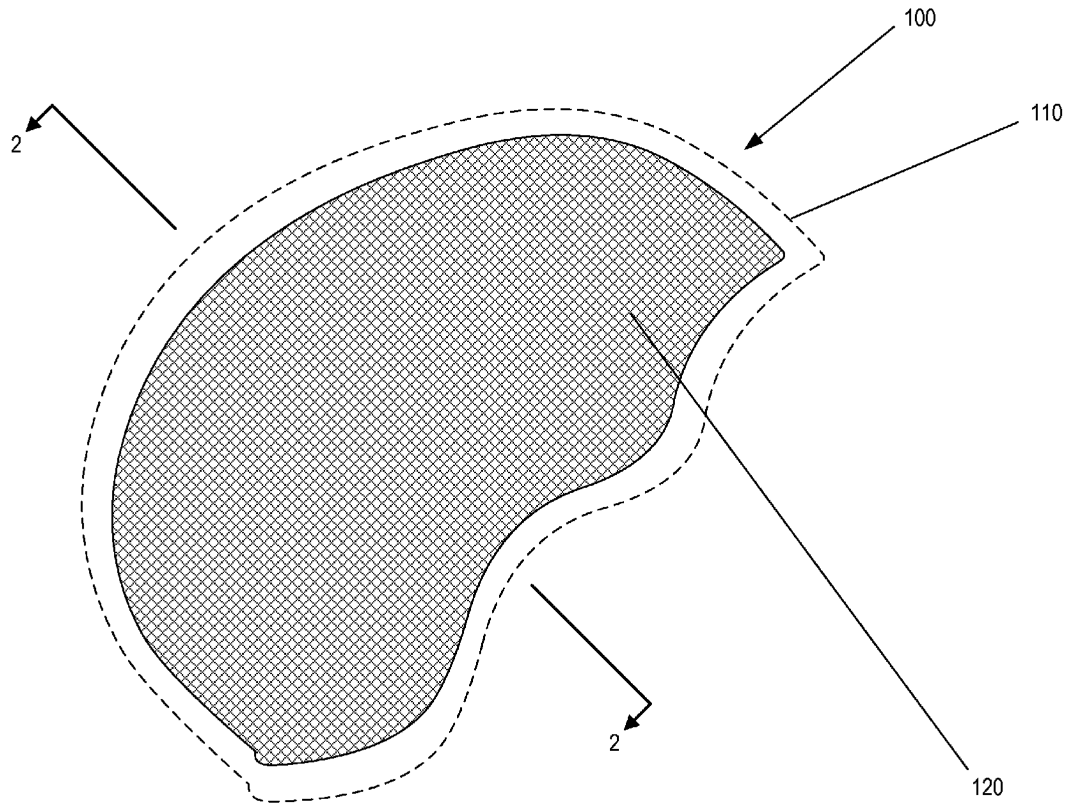
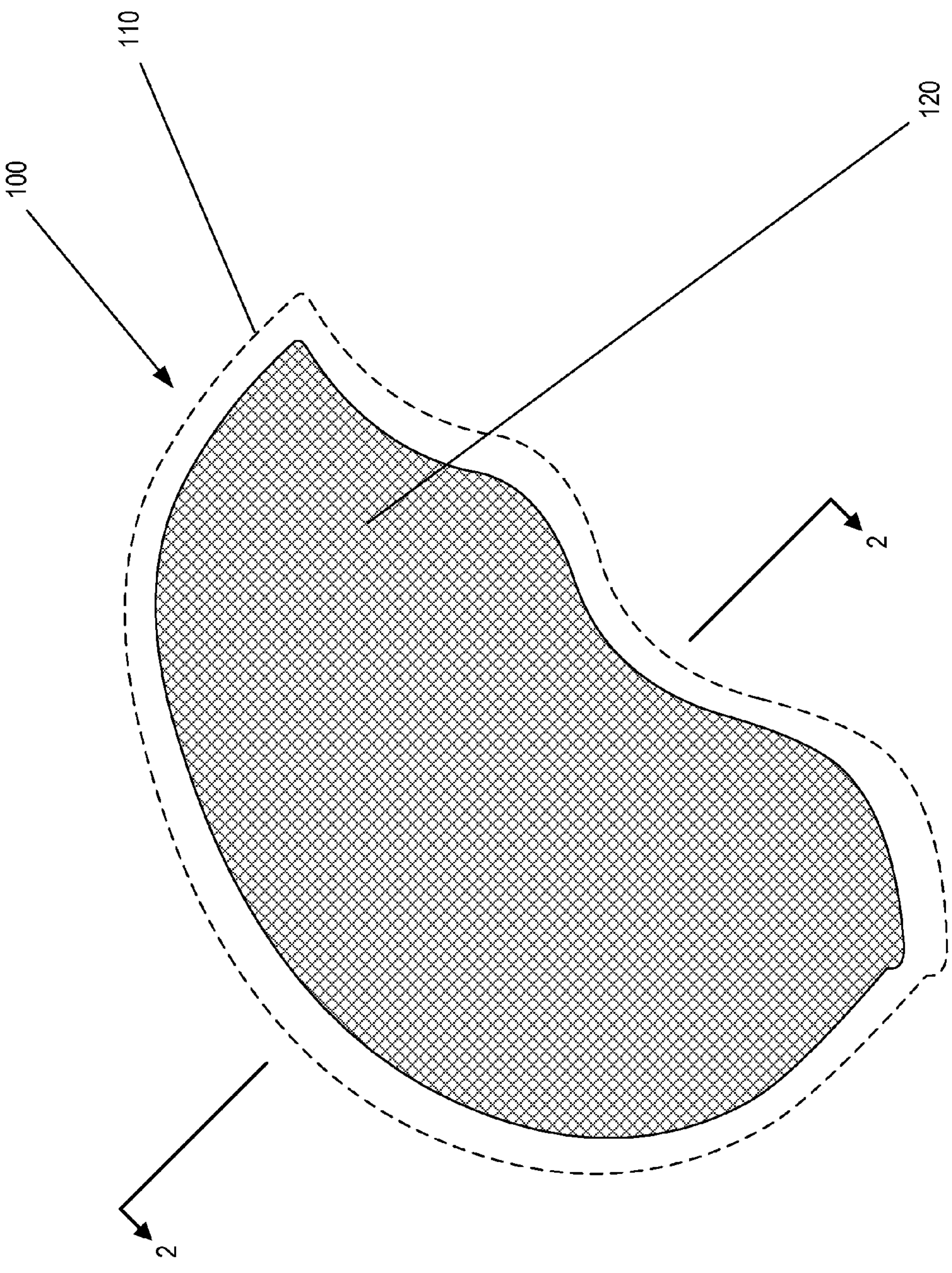


FIG. 1



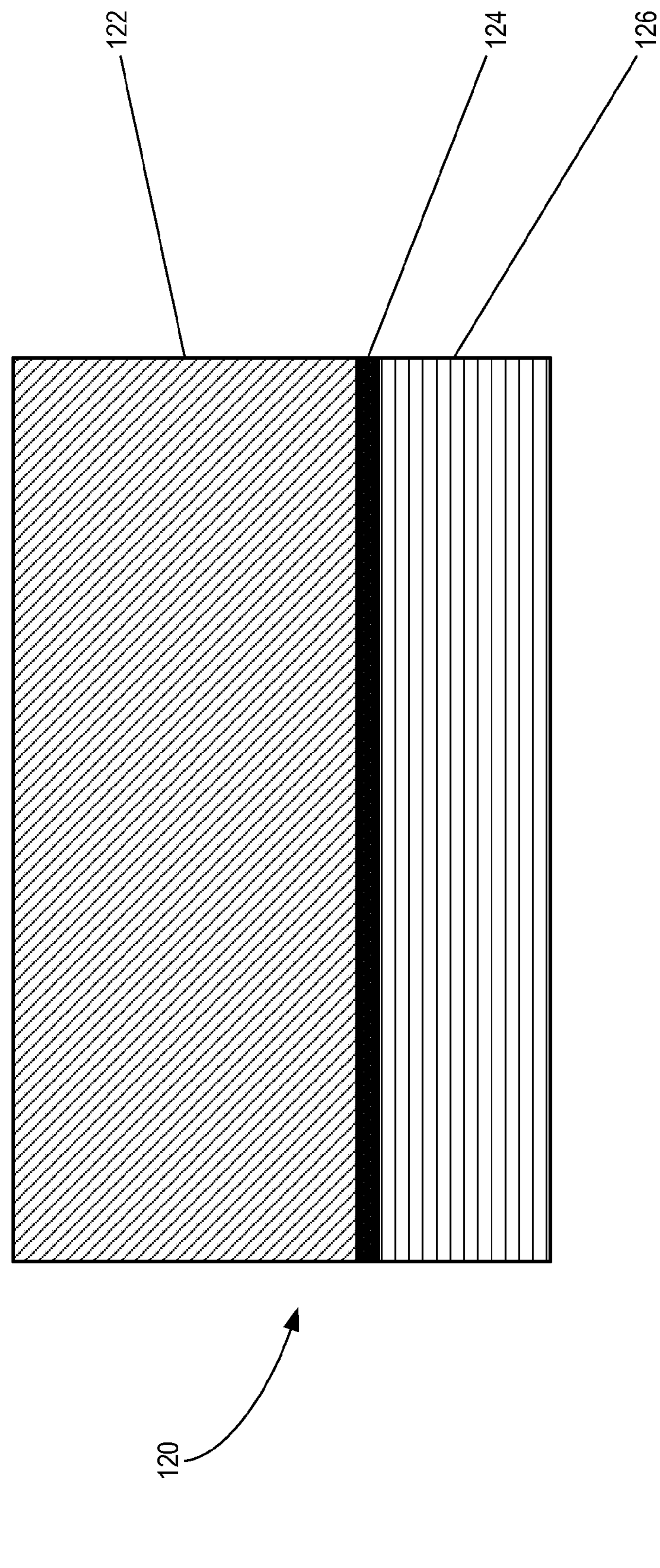


FIG. 2

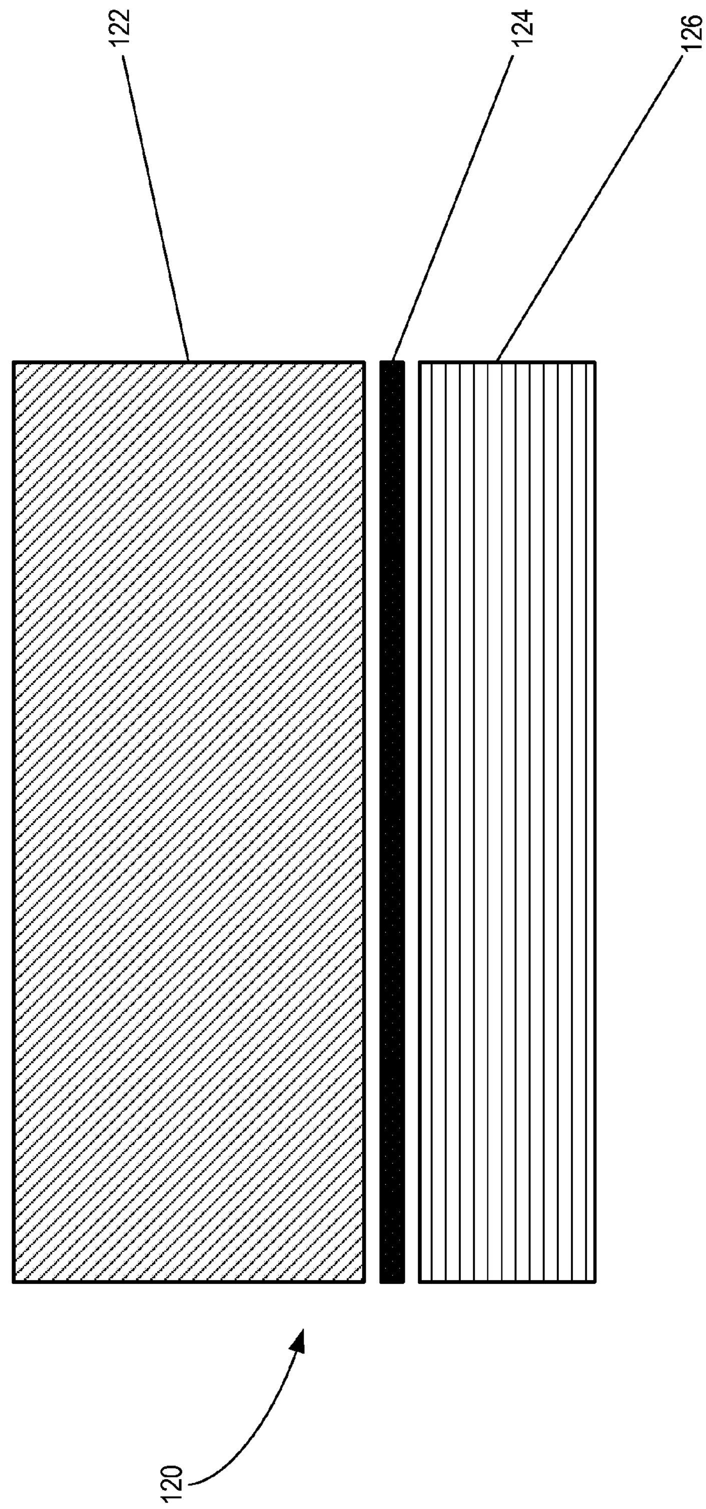
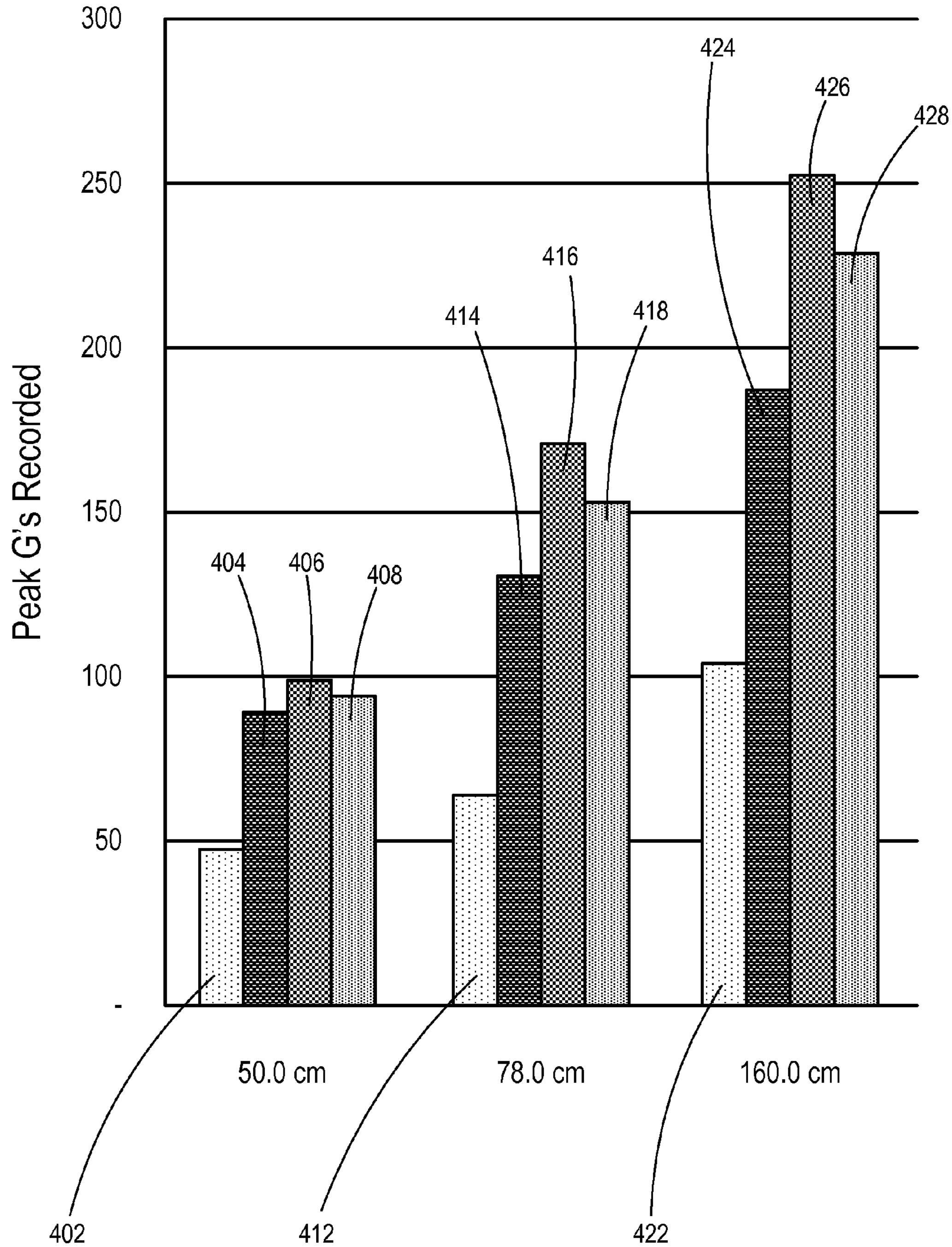


FIG. 3

FIG. 4



300
250
200
150
100
50
-
Peak G's Recorded
50.0 cm
78.0 cm
160.0 cm
402
404
406
408
412
414
416
418
422
424
426
428

FIG. 5

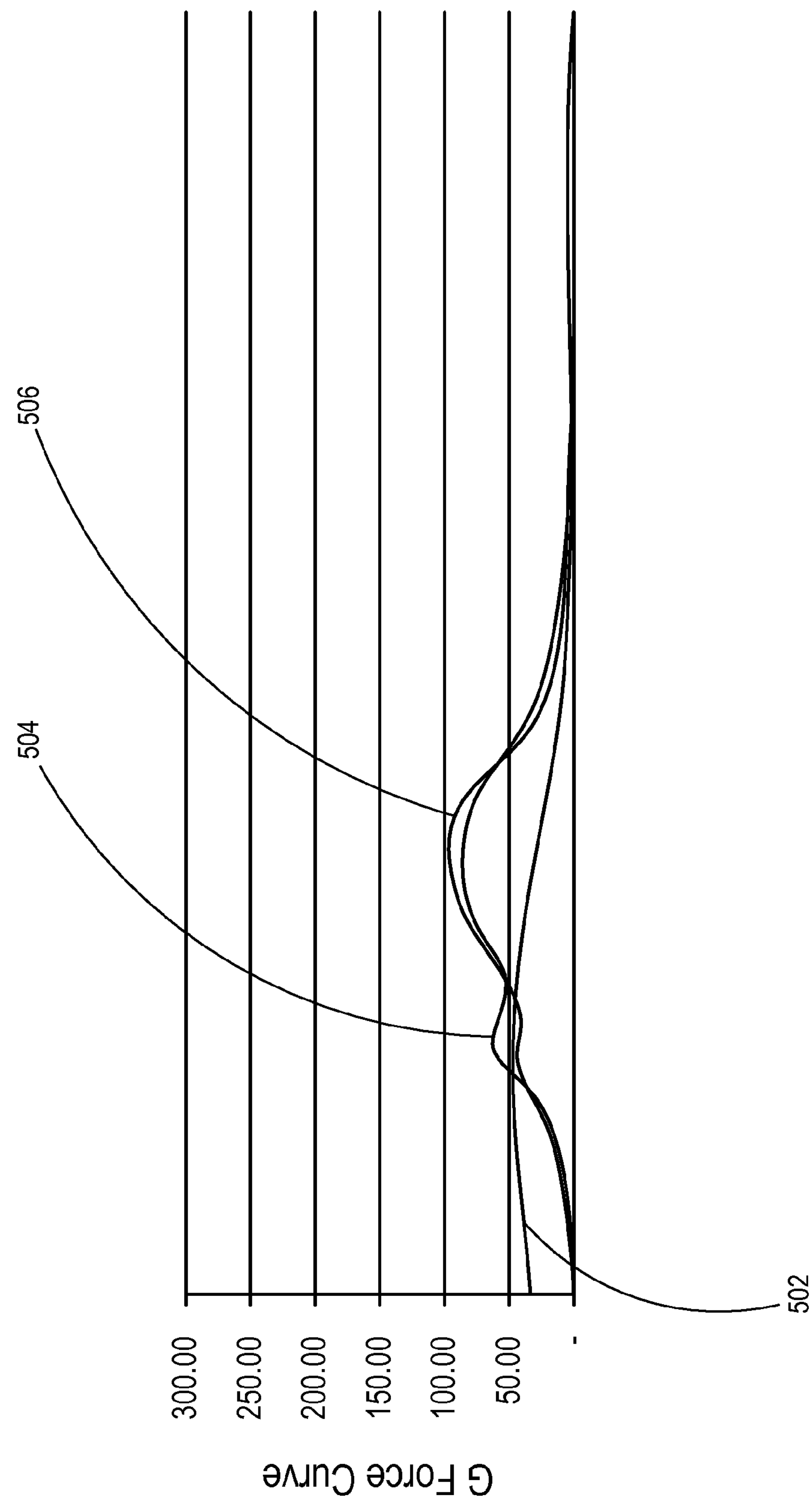


FIG. 6

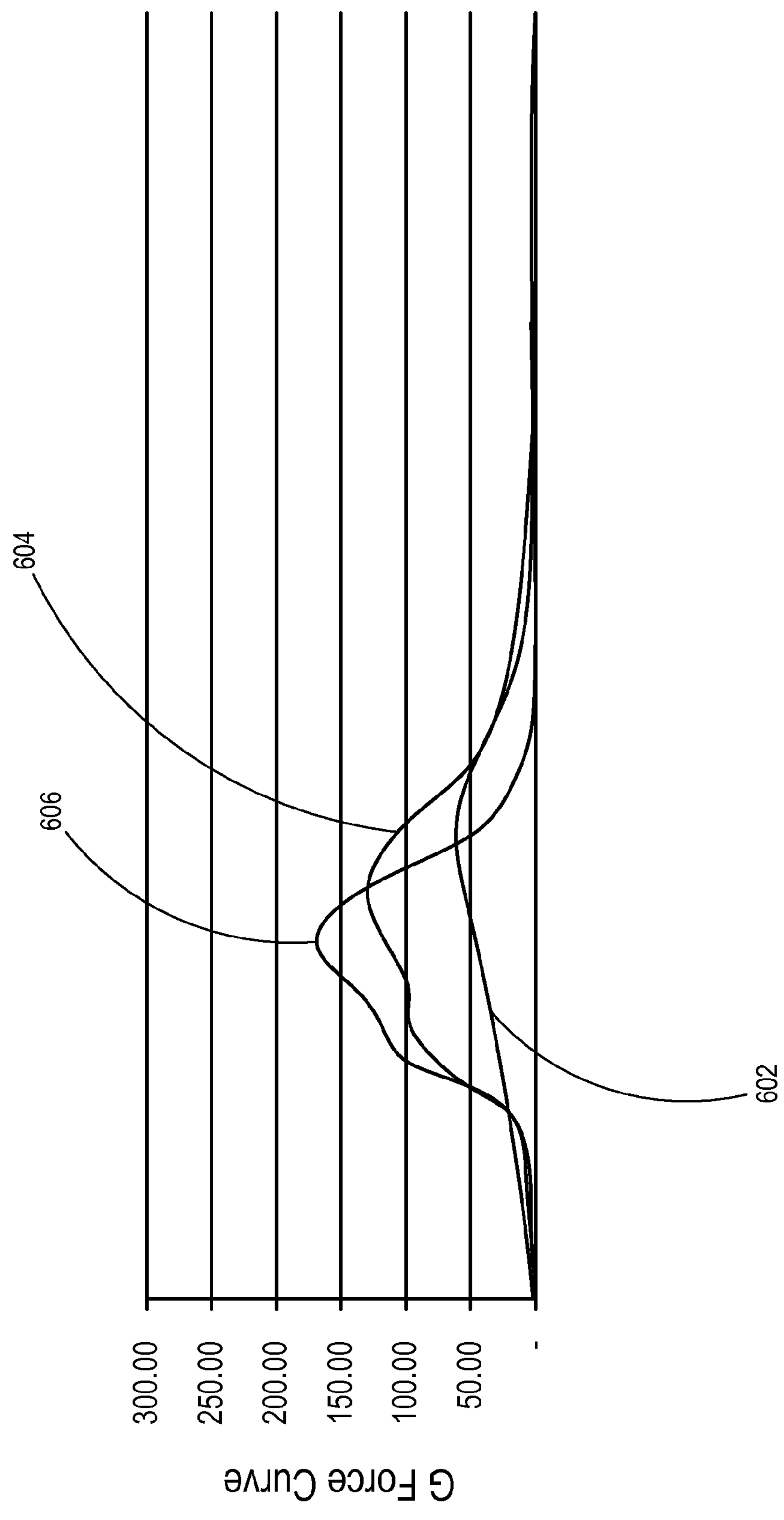


FIG. 7

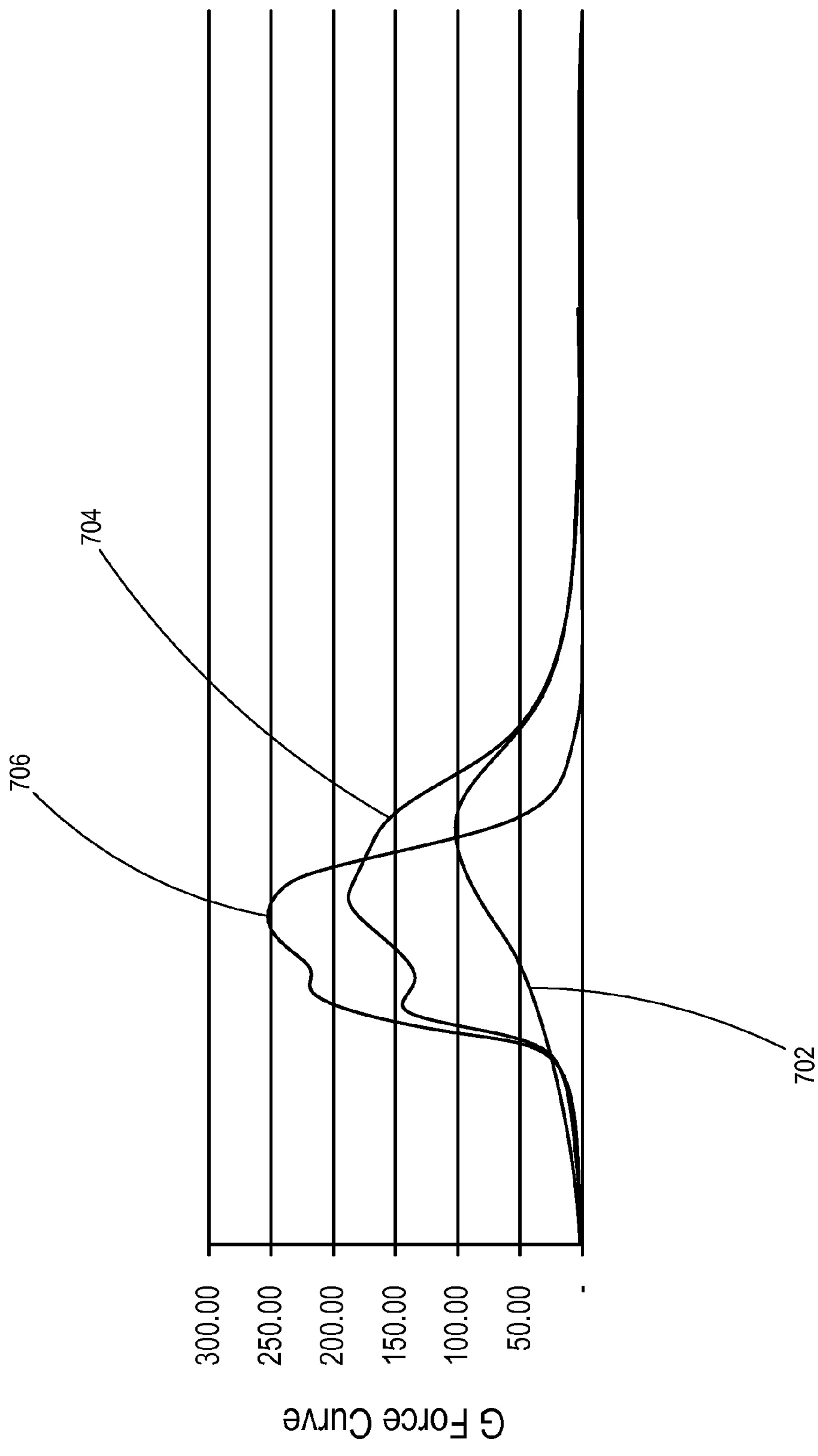
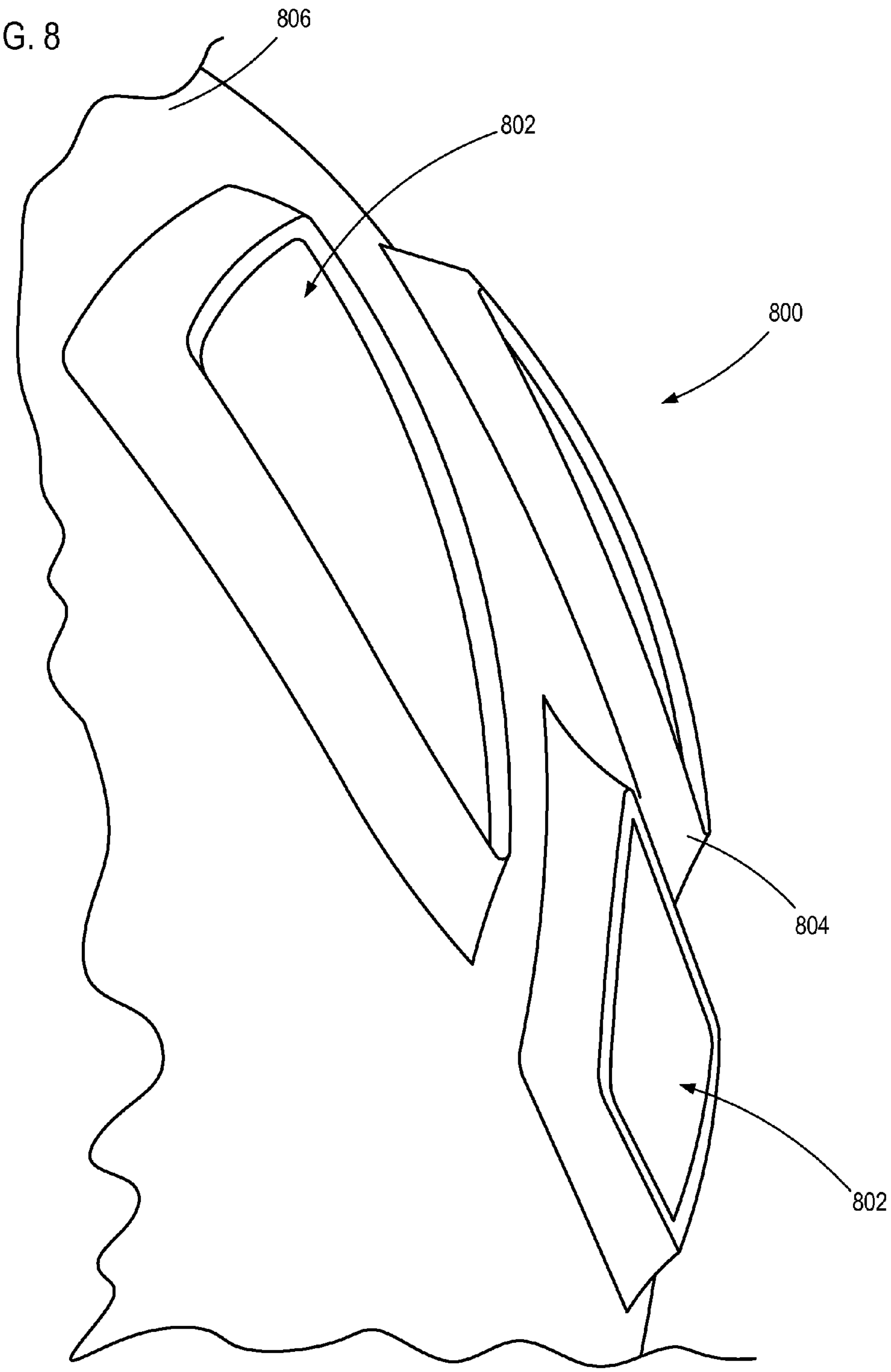


FIG. 8



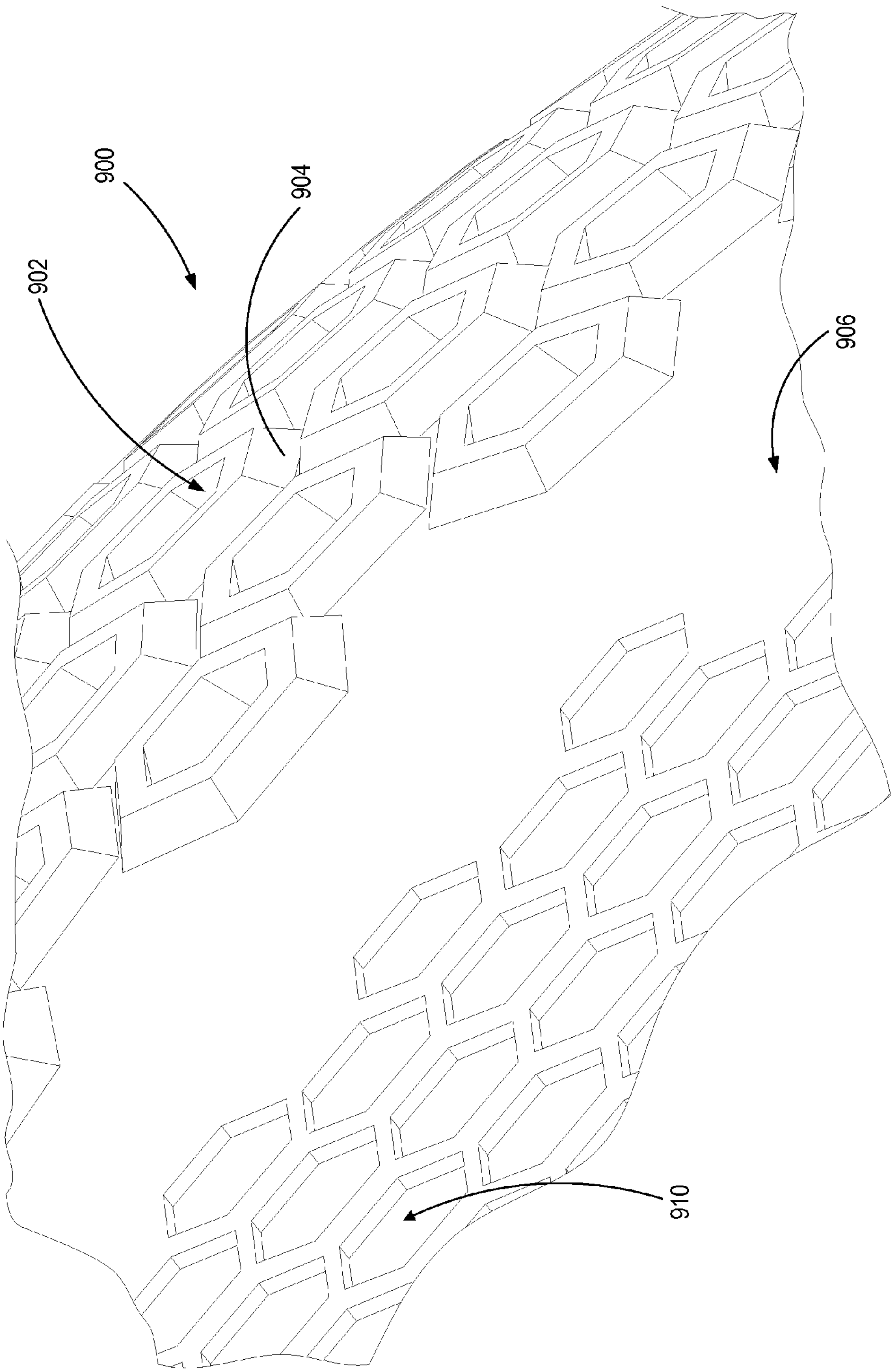


FIG. 9

LAYERED PROTECTIVE STRUCTURES

RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Patent Application No. 61/839,314 filed Jun. 25, 2013 and titled "LAYERED PROTECTIVE STRUCTURES FOR PROTECTIVE GEAR," which application is incorporated herein by reference in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Non-limiting and non-exhaustive embodiments of the disclosure are provided herein, including various embodiments of the disclosure illustrated in the figures listed below.

[0003] FIG. **1** depicts an embodiment of a helmet according to one embodiment.

[0004] FIG. **2** depicts a cross-sectional view of the layered, inner shell of FIG. **1** taken along line **2-2** in FIG. **1**.

[0005] FIG. **3** depicts an exploded view of the layered, inner shell of FIG. **2**.

[0006] FIG. **4** is a graph depicting the results of an impact case study involving a helmet incorporating a layered, inner shell according to one embodiment of the invention compared with other helmets not incorporating the inventive subject matter disclosed herein.

[0007] FIG. **5** is a graph depicting the g-forces associated with a first impact on a helmet incorporating a layered, inner shell according to one embodiment of the invention compared with other helmets not incorporating the inventive subject matter disclosed herein.

[0008] FIG. **6** is a graph depicting the g-forces associated with a second impact on a helmet incorporating a layered, inner shell according to one embodiment of the invention compared with other helmets not incorporating the inventive subject matter disclosed herein.

[0009] FIG. **7** is a graph depicting the g-forces associated with a third impact on a helmet incorporating a layered, inner shell according to one embodiment of the invention compared with other helmets not incorporating the inventive subject matter disclosed herein.

[0010] FIG. **8** depicts an embodiment of a middle layer usable with certain embodiments of layered protective structures, the middle layer comprising a plurality of crimped openings.

[0011] FIG. **9** depicts another embodiment of a middle layer usable with certain embodiments of layered protective structures.

[0012] In the following description, numerous specific details are provided for a thorough understanding of the various embodiments disclosed herein. The systems and methods disclosed herein can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In addition, in some cases, well-known structures, materials, or operations may not be shown or described in detail in order to avoid obscuring aspects of the disclosure. Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more alternative embodiments.

DETAILED DESCRIPTION

[0013] Embodiments may be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout. It will be readily understood that the elements, materials, and components of the present disclosure, as generally described and illustrated in the drawings herein, could be arranged and designed in a wide variety of different configurations and embodiments. Thus, the following more detailed description of the embodiments of the apparatus is not intended to limit the scope of the disclosure, but is merely representative of possible embodiments of the disclosure. In some cases, well-known structures, materials, or operations are not shown or described in detail in order to avoid obscuring aspects of the disclosure. Furthermore, the described features, structures, steps, or characteristics may be combined in any suitable manner in one or more alternative embodiments and/or implementations.

[0014] The present disclosure provides various embodiments of layered shell configurations that may be used in various protective gear items, such as helmets. In some embodiments, the layered shell may be configured to provide for improved protection at multiple velocities. For example, some embodiments may be configured to provide improved impact protection during relatively high velocity impacts and also relatively low velocity impacts. Some embodiments may be also, or alternatively, be configured to provide improved protection and/or durability for multiple impacts at the same portion of the helmet over time. Some embodiments may also allow for providing a substantially thinner layer of protective structure than traditional helmets or other protective gear, while still providing one or more of the improved impact protection features mentioned herein.

[0015] Some embodiments may comprise helmets, such as helmets for use in motorcycling, skiing, snowboarding, skateboarding, and the like, comprising an interior structure that provides significant reduction in g-force impacts to the head from high velocity and low velocity impacts. In some embodiments, the helmet may also, or alternatively, provide significantly more multiple impact protection than currently available protective interior structures.

[0016] Some embodiments may comprise a protective structure comprising multiple layers of different materials having different thicknesses and densities that are arranged and configured to interact with one another in a manner so as to cushion the head (in embodiments incorporated into helmets) and protect the head from impacts by dissipating energy from both the outside of the helmet (area of impact) and from the interior of the helmet by reducing the deceleration velocity of the head during an impact. Some embodiments, as described in greater detail below, may comprise three distinct layers each comprising different materials arranged relative to one another and comprising preselected thicknesses that improve impact protection.

[0017] In some such embodiments, the outermost layer may comprise a relatively thick layer made up of a crushable foam material or another material having similar properties. The middle layer may comprise a relatively thin layer made up of a hard plastic material or another material having similar properties configured to spread energy from an impact across a larger area to dissipate the energy transfer to the head associated with the impact. The innermost layer may comprise a material having properties that allow it to compress and rebound, preferably with little deterioration in shock absorbing properties, such as an ethylene-vinyl acetate (EVA) foam or a non-newtonian foam such as a PORON® foam. Although the thickness of the inner layer may vary depending upon the desired or intended impact protection characteristics, preferably the thickness of the inner and outer layers are both substantially greater than the thickness of the middle layer of the protective structure. In some embodiments, the thickness of the inner layer may be in between that of the outermost layer and the middle layer of the protective structure.

[0018] Additional details of certain embodiments and implementations will now be discussed in greater detail with reference to the accompanying drawings. FIG. **1** depicts an embodiment of a helmet **100** according to one embodiment of the invention. Helmet **100** comprises an outer shell **110** and an inner protective structure comprising an inner shell **120**. As described in greater detail below, inner shell **120** may comprise a layered protective structure. In addition, inner shell **120** may be configured to conform to the shape, venting pattern, and/or retention system of outer shell **110**. In such embodiments, inner shell **120** may be configured to be retrofittable with an existing outer shell. Alternatively, inner shell **120** may be modular such that various different inner shells having differing impact protection characteristics may be inserted into a single outer shell in accordance with particular intended uses of the helmet or other protective gear. Of course, in other embodiments and implementations, the inner shell may be manufactured together with the outer shell.

[0019] FIG. **2** depicts a cross-sectional view of an embodiment of a layered protective structure comprising an inner shell that may be used in a helmet or another item of protective gear. As shown in this figure, the depicted inner shell **120** comprises three separate layers, each made up of a different material having different properties, thicknesses, and/or densities. In certain preferred embodiments, each of the three layers is made up of a different material, comprises a different thickness, and comprises a different density.

[0020] More particularly, inner shell **120** comprises an outer layer **122**, a middle layer **124**, and an inner layer **126**. Preferably, the materials and thicknesses of the three layers are selected and arranged to interact with one another during an impact so as to improve impact protection characteristics. In some embodiments, the materials and thicknesses of the three layers may be selected and arranged to interact with one another during an impact so as to improve impact protection characteristics associated with both high velocity and low velocity impacts. Additionally, or alternatively, the materials and thicknesses of the three layers may be selected and arranged to interact with one another during an impact so as to improve impact protection characteristics associated with repeated impacts at the same, or at least generally the same, location on the helmet over time.

[0021] In some preferred embodiments, the density of the material(s) making up middle layer **124** is greater than the density of the material(s) making up either of the other two layers. Middle layer may comprise a relatively rigid, hard material, such as a hard plastic material. In some such embodiments, the density of outer layer **122** is greater than the density of inner layer **126**. It has been discovered that such configurations result in an improved energy transfer and absorption between the three layers that results in improved impact protection.

[0022] In some embodiments, outer layer **122** may comprise a material having energy absorption characteristics, such as a foam material. Preferably, outer layer **122** comprises a compressible material. In some such embodiments, outer layer **122** may comprise a crushable foam material. Examples of suitable materials for outer layer **122** that have desired energy absorption characteristics include EPS (expanded polystyrene) and EPP (expanded polypropylene). In some preferred embodiments, the density of the material making up outer layer **122** may be between about 20 g/l and about 85 g/l. In some such embodiments, the density of the material making up outer layer **122** may be between about 40 g/l and about 85 g/l. In some such embodiments, the density of the material making up outer layer **122** may be between about 30 g/l and about 80 g/l. In some such embodiments, the density of the material making up outer layer **122** may be between about 20 g/l and about 40 g/l. In some such embodiments, the density of the material making up outer layer **122** may be between about 60 g/l and about 85 g/l.

[0023] In some preferred embodiments, the thickness of outer layer **122** may be between about 5 mm and about 30 mm. In some such embodiments, the thickness of outer layer **122** may be between about 10 mm and about 30 mm. In some such embodiments, the thickness of outer layer **122** may be between about 10 mm and about 20 mm. It appears that these ranges and materials provide for improved protection from low velocity impacts, high velocity impacts, and multiple impacts.

[0024] In some embodiments, middle layer **124** may comprise a relatively rigid, non-compressible, and thinner layer of material. For example, middle layer **124** may comprise an acrylonitrile butadiene styrene (ABS) plastic or another material with similar properties, such as a fiberglass, carbon fiber material, and the like. In some preferred embodiments, middle layer **124** may comprise a thickness of between about 1 mm and about 2 mm. As described in greater detail below, preferably middle layer **124** is configured and arranged to isolate and/or spread forces and accompanying energy associated with exterior impacts from/across inner layer **126**. Middle layer **124** may also be configured to serve as a barrier to protect against penetration by sharp objects, such as rocks, wood splinters, and the like. Middle layer **124** may comprise an at least substantially smooth surface, and may further, or alternatively, comprise a support in the form of a supported edge crimp, which may be useful for ventilation. Such a crimp or crimps may also be useful in increasing the rigidity of middle layer **124** and/or improving the functionality of the protective structure by improving the ability of the middle layer **124** to spread or otherwise distribute forces between the outer layer **122** and the inner layer **126**, as discussed below in connection with FIG. **8**.

[0025] In some embodiments, inner layer **126** comprises a compressible, resilient material, preferably configured to avoid crushing deformation that would be associated with certain preferred embodiments of outer layer **122** during high velocity impacts. Suitable materials include, for example, ethylene-vinyl acetate (EVA) foam or a non-newtonian foam such as a PORON® foam. In some preferred embodiments, inner layer **126** comprises a softer material than the material making up either of the other two layers, so as to provide cushion to a head or other body portion during an impact. In some preferred embodiments, inner layer **126** may comprise a thickness of between about 3 mm and about 20 mm. In some such embodiments, inner layer **126** may comprise a thickness of between about 5 mm and about 15 mm. In some such embodiments, inner layer **126** may comprise a thickness of between about 5 mm and about 10 mm. In embodiments comprising an inner layer of EVA, such material making up the inner layer **126** may have a SHORE-A hardness value of between about 20 and about 70.

[0026] FIG. **3** depicts an exploded view of the layered, inner shell of FIG. **2**. As can be better seen in this figure, middle layer **124** is substantially thinner than either of the other two layers. In addition, as mentioned above, in some embodiments, outer layer **122** may be thicker than inner layer **126**. As also mentioned above, in certain preferred embodiments, outer layer **122** comprises a crushable material, inner layer **126** comprises a material than is resiliently deformable such that crushing or permanent deformation is less likely to occur in inner layer **126** than in outer layer **122**, and middle layer **124** comprises a rigid, non-deformable material configured to absorb and isolate certain impacts from outer layer **122** to inner layer **126** and/or spread such impacts across a greater area from outer layer **122** to inner layer **126** to dissipate the forces associated with the impacts.

[0027] This combination of layers of different materials having preselected properties better protects against both high and low velocity impacts to a helmet or other protective gear item. In some embodiments, this combination of layers of different materials having preselected properties also provides improved protection against multiple low-velocity impacts. Without being limited by theory, it is thought that these improvements, and others, may be obtained as follows.

[0028] During relatively high velocity impacts, outer layer **122**, which provides impact absorption from the impact arriving from the outside of the helmet, deforms and/or crushes the crushable foam or other similar material making up outer layer **122**, thereby absorbing and releasing energy from the impact. For purposes of this disclosure, "high velocity" impacts should be considered to encompass those defined by the ASTM vertical drop specifications for helmets and "low velocity" impacts should be considered those at or less than one-half of those defined by the ASTM vertical drop specifications for helmets, which may vary depending on the intended use of the helmet. The middle layer **124** then isolates, or at least reduces, the impact and energy transferred to the inner layer **126**. Middle layer **124** may also be configured to spread the impact energy across a larger area of inner layer **126**, thereby resulting in significantly lower energy transfer to the head and increased time of head deceleration.

[0029] Again, without being limited by theory, during relatively low velocity impacts, inner layer **126** may compress as the head pushes into the foam or other material making up inner layer **126**, thereby decelerating the head. The outer layer **122** may provide limited, but important, energy absorption, and may spread the low velocity impact across a larger area, thereby reducing its transfer towards the head. The middle layer **124** may both isolate the exterior impact from the inner layer **126** and isolate the interior layer impact from the outer layer **122**.

[0030] It is thought that the inventive structures disclosed herein also provide improved protection from multiple, low velocity impacts and improved durability resulting from such impacts. More particularly, without being limited by theory, it appears that, since the inner layer **126** primarily functions to decelerate the head during such impacts (for embodiments in which the layered protective structure comprises a helmet), the use of compressible, resilient foam materials, or other materials with similar properties, allows inner layer **126** to maintain its absorption properties through repeated compressions and expansions while conforming back to its original shape, thereby enhancing durability as well as impact protection.

[0031] Through testing, it has been determined that the embodiments and inventive concepts described herein significantly improve g-force management (reduced g forces) from high velocity impacts consistent with, for example, motorsports, as well as low velocity impacts, relative to existing helmet technology. Additionally, the embodiments and inventive concepts described herein may provide improved g-force management and/or durability from repeated impacts. These experimental results are summarized in the examples listed below.

Example 1

[0032] Tests were performed on several currently available helmets within the motorcycle, bike, snow sport, and skateboard industries at specific speeds, drop heights and anvils. FIG. **4** is a graph depicting the results of these experiments and comparing peak g-forces for helmets at three different drop heights. The graph compares the results of these tests for a helmet incorporating a layered, inner shell according to one embodiment of the invention disclosed herein compared with a best result from among a selection of currently-available helmets from leading manufacturers, a worst result from among such helmets, and an average result from among such helmets.

[0033] The results indicate that the design described herein results in significantly superior g force reduction compared to currently available helmets. More particularly, as shown in FIG. **4**, at a first drop from about 50 cm (about 3.09 m/s impact speed), an embodiment of the invention recorded a peak g-force of less than 50 (as shown at **402**). A best result from among the other helmets is shown at **404**, a worst result from among the other helmets is shown at **406**, and the average result from among the other helmets is shown at **408**. As can be seen from comparing these results, an embodiment of a helmet according to the invention achieved a result in terms of g forces at 50 cm that is about half of most other industry helmets.

Example 2

[0034] The results from a second test at a drop height of about 78 cm (about 3.89 m/s impact speed) are even more dramatic in illustrating the improvements available from incorporating the inventive concepts described herein into helmets and/or other protective gear. As shown in FIG. **4**, an embodiment of the invention recorded a peak g force just over 50 (as shown at **412**). A best result from among the other helmets at 78 cm is shown at **414**, a worst result from among the other helmets is shown at **416**, and the average result is shown at **418**. As can be seen from comparing these results, an embodiment of a helmet according to the invention achieved a result in terms of g forces at 78 cm substantially better than the other helmets tested.

Example 3

[0035] The results from a third test at a drop height of about 160 cm (about 5.59 m/s impact speed) illustrate that the benefits from incorporating the inventive concepts described herein into helmets and/or other protective gear continue for high velocity impacts. As again shown in FIG. **4**, an embodiment of the invention recorded a peak g-force of about 100 (as shown at **422**). A best result from among the other helmets at 160 cm is shown at **424**, a worst result from among the other helmets is shown at **426**, and the average result is shown at **428**. As can be seen from comparing these results, an embodiment of a helmet according to the invention achieved a result in terms of g forces at a drop height of about 160 cm that is less than half of the average result from among the other helmets, just over one-half of the best helmet, and about two-fifths of the worst helmet.

[0036] As illustrated by each of the above-referenced examples, helmets incorporating protective structures according to the invention may achieve substantially-improved performance over related helmets for all three impact velocities. In fact, as also illustrated by each of these experimental working examples, helmets incorporating protective structures according to the invention experienced g-forces for each of the three drop heights that were less than or equal to about 100 g's, which is currently considered to be the desired threshold for concussion avoidance.

[0037] Despite this improved performance, some embodiments may be configured to provide such protection with a smaller thickness than most other protective structures. Indeed, in some embodiments, the combined thickness of the three layers of the protective structure may be less than about 30 mm. In some such embodiments, the combined thickness of the three layers may be less than or equal to about 24 mm. Indeed, the helmet used in the above-referenced test results had a thickness of only about 24 mm, including the exterior shell of the helmet, at its thickest point. The helmet used in this testing comprised an outer layer of EPS foam having a thickness of about 10 mm, a middle layer of ABS plastic having a thickness of about 1 mm, and an inner layer of EVA foam having a thickness of about 11 mm.

[0038] FIG. **5** is a graph depicting the g-forces associated with a first impact at a height of about 20 inches on a helmet incorporating a layered inner shell according to one embodiment of the invention compared with other helmets at the same height not incorporating the inventive subject matter disclosed herein. The data depicted in FIG. **5** corresponds with and represent the same experiment used to obtain the results depicted in the leftmost portion of the bar graph of FIG. **4**.

[0039] The g forces associated with the helmet incorporating a layered inner shell according to one embodiment of the invention is shown at line **502**. Similarly, the g forces associated with two other helmets (neither of which obtained the worst result shown in FIG. **4**) are shown at lines **504** and **506**, respectively.

[0040] As shown in FIG. **5**, the helmet incorporating a layered, inner shell according to one embodiment of the invention exhibited a g-force curve that indicates the ability to much more effectively spread the forces due to helmet impact over time, and to lower the peak forces experienced by a user/wearer of the helmet. More particularly, the g-force curve at **502** is much more flat than either of the other two curves and peaks at a number about half of either of the other two curves.

[0041] FIG. **6** is a graph depicting the g-forces associated with a second impact at the same site as the first impact referenced in FIG. **5** at a height of about 31 inches on the helmet incorporating a layered inner shell according to the embodiment of the invention used in the experiment represented in the curve of FIG. **5** compared with two other helmets also used to obtain the results illustrated in FIG. **5**.

[0042] The g forces associated with the helmet incorporating a layered inner shell according to the embodiment of the invention used in the experiment depicted in FIG. **5** is shown at line **602**. Similarly, the g forces associated with the two other helmets used in the same experiment are shown at lines **604** and **606**, respectively.

[0043] As shown in FIG. **6**, the helmet incorporating a layered inner shell according to one embodiment of the invention exhibited a g-force curve that further demonstrates the ability of this protective structure to much more effectively spread the forces due to helmet impact over time, and to lower the peak forces experienced by a user/wearer of the helmet. More particularly, the g-force curve at **602** is much more flat than either of the other two curves and peaks at a number less than half of either of the other two curves.

[0044] FIG. **7** is a graph depicting the g-forces associated with a third impact at the same site as the first and second impacts referenced in FIGS. **5** and **6** at a height of about 63 inches on the helmet incorporating a layered inner shell according to the embodiment of the invention used in the experiments represented in the curves of FIGS. **5** and **6** compared with two other helmets also used to obtain the results illustrated in FIGS. **5** and **6**.

[0045] The g forces associated with the helmet incorporating a layered inner shell according to the embodiment of the invention used in the experiment depicted in FIG. **7** is shown at line **702**. Similarly, the g forces associated with the other two helmets used in the same experiment are shown at lines **704** and **706**, respectively.

[0046] As shown in FIG. **7**, the helmet incorporating a layered inner shell according to one embodiment of the invention exhibited a g-force curve that further demonstrates the ability of this protective structure to much more effectively spread the forces due to helmet impact over time, and to lower the peak forces experienced by a user/wearer of the helmet. More particularly, the g-force curve at **702** is much more flat than either of the other two curves and peaks at a number well below either of the other two curves.

[0047] It should be noted that, upon reviewing and comparing FIGS. **4-7**, the embodiment of the invention used in the experiments substantially outperformed the competition. This helmet was also able to substantially reduce peak g-forces during all test criteria, including high velocity impacts obtained at drop speeds of about 5.6 m/s, which is the same velocity as the European Committee for Standardization EN1077 standard, to less than or equal to about 100 g's. This is important since this amount of force has been considered an approximate threshold for avoiding concussions. Thus, some embodiments of the invention may be able to avoid even a concussion with respect to impacts that for many other helmets would likely result in serious injury. Moreover, this helmet was able to achieve such performance while also providing a relatively small thickness profile (about 24 mm).

[0048] FIG. **8** depicts an embodiment of a middle layer **800** comprising a plurality of openings **802** configured to be used in a layered protective structure. Each of the openings **802** is defined by a plurality of crimped walls **804**, which extend from a surface **806** of middle layer **800**. In the depicted embodiment, each of the various crimps/walls **804** extends from surface **806** at an angle of about 45 degrees. However, it is contemplated that in alternative embodiments, the walls defining openings **802** may extend from a curved or flat surface defining a middle layer of a layered protective structure at angles ranging from about 35 degrees to about 90 degrees. It is also contemplated that in certain other preferred embodiments, the walls defining openings **802** may extend from a curved or flat surface defining a middle layer of a layered protective structure at an angle of about 90 degrees.

[0049] The openings **802** may correspond with vent openings in the outer shell of, for example, a helmet. However, in addition to serving this venting purpose, providing a crimp on a middle layer of a layered protective structure may serve to improve the function of the protective structure. As such, it is contemplated that, in some embodiments, such a middle layer may comprise one or more crimped walls even if such walls do not necessarily define an opening in the middle layer. In other words, in some embodiments, one or more crimps or similar structures may be provided to increase rigidity or otherwise improve the function of a layered protective structure, such as by improving the ability of the middle layer to spread forces between one or more inner and/or outer layers, irrespective of whether such structures also define openings, such as vent openings.

[0050] FIG. **9** depicts another embodiment of a middle layer **900** usable with certain embodiments of layered protective structures. Middle layer **900** comprises a plurality of openings **902** defined by crimped walls **904**. Each of the openings **902** is defined by a plurality of crimped walls **904** that extend from a surface **906** of middle layer **900**. In the depicted embodiment, each of the various crimps/walls **904** extends from surface **906** at an angle of about 45 degrees. However, it is contemplated that in alternative embodiments, the walls defining openings **902** may extend from a curved or flat surface defining a middle layer of a layered protective structure at angles ranging from about 35 degrees to about 90 degrees.

[0051] As depicted in FIG. **9**, openings **902** are also arranged in a honeycomb fashion adjacent to one another. In other words, each of openings **902** forms a hexagonal shape and each opening **902** (other than those positioned at a periphery of the honeycomb structure) is positioned adjacent to six other such openings **902** to form a honeycomb structure. However, other embodiments are contemplated in which openings **902** are formed from other polygonal or non-polygonal shapes.

[0052] Openings **902** may, in some embodiments, may be aligned with vent openings in the outer shell of, for example, a helmet. As mentioned above, the raised/crimped structures surrounding openings **902** may be provided to increase rigidity or otherwise improve the function of a layered protective structure, such as by improving the ability of the middle layer to spread forces between one or more inner and/or outer layers.

[0053] Middle layer **900** also comprises a second honeycomb structure comprising non-crimped openings **910**. Openings **910** may, like openings **902**, be formed as hexagons or other polygons and may be arranged such that each side of the polygonal opening is positioned adjacent to a corresponding side of an adjacent polygonal opening **910**.

[0054] Additional tests were performed using embodiments described herein, the results of which further establish significant improvement relative to existing helmet technology. These further experimental results are summarized in the additional examples listed below.

Example 4

[0055] Tests were performed on several currently available helmets at specific drop heights to assess peak linear acceleration, peak angular acceleration, and Head Injury Criterion ("HIC"), which is a commonly-used measure of the likelihood of head injury resulting from an impact with a helmet. Table 1 below summarizes the results of these experiments at a drop height of 51 cm.

TABLE 1

	Linear (g)	Rotational (krad/s/s)	HIC
Base	63.9	3.5	105.9
MIPS	62.8	2.6	117.2
Embodiment	43.8	3.5	55.0

[0056] The table above compares the results of tests at a drop height of 51 cm for a helmet incorporating a layered, inner shell according to one embodiment of the invention disclosed herein ("Embodiment") compared with those from a typical, off-the-shelf helmet ("Base") and those from a particular, high-end brand of helmet (MIPS).

[0057] Table 2 below summarizes the results of these experiments at a drop height of 77 cm.

TABLE 2

	Linear (g)	Rotational (krad/s/s)	HIC
Base	83.4	6.5	183.1
MIPS	91.5	3.9	242.6
Embodiment	56.2	4.7	96.3

[0058] Table 3 below summarizes the results of these experiments at a drop height of 206 cm.

TABLE 3

	Linear (g)	Rotational (krad/s/s)	HIC
Base	151.5	6.6	886
MIPS	146.3	5.1	783
Embodiment	114.7	4.6	572

[0059] These results indicate that the design described herein results in significantly better HIC scores, which translate to fewer and less severe injuries.

[0060] The foregoing specification has been described with reference to various embodiments. However, one of ordinary skill in the art will appreciate that various modifications and changes can be made without departing from the scope of the present disclosure. Accordingly, this disclosure is to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope thereof. Likewise, benefits, other advantages, and solutions to problems have been described above with regard to various embodiments. However, benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, a required, or an essential feature or element. The scope of the present invention should, therefore, be determined only by the following claims.

1. A helmet, comprising:

a layered protective structure shaped to fit over a head of an individual, the layered protective structure comprising:

a first layer;

a second layer positioned internally of the first layer, wherein the second layer comprises a more rigid and less compressible material than the first layer, and wherein a thickness of the second layer is less than a thickness of the first layer; and

a third layer positioned internally of the second layer, wherein the third layer comprises a compressible, resilient material configured to compress and rebound upon being deformed, and wherein a thickness of the third layer is greater than a thickness of the second layer.

2. The helmet of claim **1**, wherein the first layer comprises a crushable material.

3. The helmet of claim **2**, wherein the crushable material comprises a crushable foam material.

4. The helmet of claim **3**, wherein the crushable foam material comprises at least one of expanded polystyrene and expanded polypropylene.

5. The helmet of claim **1**, wherein the second layer comprises a plastic material.

6. The helmet of claim **1**, wherein the second layer comprises at least one of acrylonitrile butadiene styrene plastic, fiberglass, and carbon fiber material.

7. The helmet of claim **1**, wherein the third layer comprises at least one of an ethylene-vinyl acetate foam and a non-newtonian foam.

8. The helmet of claim **1**, wherein the second layer comprises a plurality of openings each defined by a plurality of crimped walls.

9. The helmet of claim **1**, wherein the first layer is positioned adjacent to the second layer, and wherein the second layer is positioned adjacent to the third layer.

10. The helmet of claim **1**, wherein the first layer has a density greater than a density of the third layer.

11. The helmet of claim **1**, further comprising an outer shell positioned adjacent to the layered protective structure such that the layered protective structure is positioned within the outer shell.

12. A layered protective structure for both high and low velocity impacts configured to be used in a protective gear item, the layered protective structure comprising:

an outer layer comprising a first density;

an inner layer comprising a compressible, resilient material configured to compress and rebound upon being deformed by an impact, wherein the inner layer comprises a second density, and wherein the second density is less than the first density; and

a middle layer positioned in between the inner layer and the outer layer, wherein the middle layer comprises a rigid material configured to spread energy from an impact across a larger area on the inner layer to dissipate energy transfer through the inner layer from the impact, wherein the middle layer comprises a third density, and wherein the third density is greater than the first density and the second density.

13. The layered protective structure of claim **12**, configured to permanently deform upon receipt of a high velocity impact, wherein the outer layer is configured to avoid permanent deformation upon receipt of low velocity impacts.

14. The layered protective structure of claim **12**, wherein the middle layer comprises a material configured to inhibit penetration into the middle layer by impacts with sharp objects.

15. The layered protective structure of claim **12**, wherein the outer layer has a thickness of between 3 mm and 30 mm.

16. The layered protective structure of claim **15**, wherein the outer layer has a thickness of between 10 mm and 20 mm.

17. The layered protective structure of claim **12**, wherein the outer layer has a density of between 30 g/l and 80 g/l.

18. The layered protective structure of claim **12**, wherein the inner layer has SHORE-A hardness value of between 20 and 70.

19. The layered protective structure of claim **12**, wherein the middle layer has a thickness of between 1 mm and 2 mm.

20. The layered protective structure of claim **12**, wherein the inner layer has a thickness of between 3 mm and 20 mm.

21. The layered protective structure of claim **20**, wherein the inner layer has a thickness of between 5 mm and 10 mm.

22. The layered protective structure of claim **12**, further comprising an outer shell positioned to encase the layered protective structure therein.

23. A helmet, comprising:

an outer shell; and

an inner shell comprising a layered protective structure positioned within the outer shell, the layered protective structure comprising:

an outer layer comprising a crushable foam material having a density of between about 20 g/l and about 85 g/l, wherein a thickness of the outer layer is between about 5 mm and about 30 mm;

an inner layer comprising a compressible, resilient material configured to compress and rebound upon being deformed by an impact, wherein a thickness of the inner layer is between about 5 mm and about 15 mm, and wherein the inner layer comprises a material having a SHORE-A hardness value of between about 20 and about 70; and

a middle layer comprising at least one of acrylonitrile butadiene styrene plastic, fiberglass, and carbon fiber material, wherein a thickness of the inner layer is between about 1 mm and about 2 mm.

24. The helmet of claim **23**, wherein the inner layer comprises at least one of an ethylene-vinyl acetate foam and a non-newtonian foam.

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