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(54) SPORTS HELMET WITH COLLAPSIBLE MODULAR ELEMENTS

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(57) **ABSTRACT**

The present disclosure provides a helmet for a user's head, comprising a shell configured to at least partially surrounds the user's head, an energy-absorbing layer, and a plurality of collapsible modular elements that are individually removably attached to and detached from the helmet. Collapsible modular elements, as used herein, are elements attached to the helmet that collapse or otherwise crush and permanently deform or to temporarily deform upon receiving an impact force of a particular pre-determined amount. By collapsing, energy from the impact is more effectively absorbed instead of being transferred to the user of the helmet.

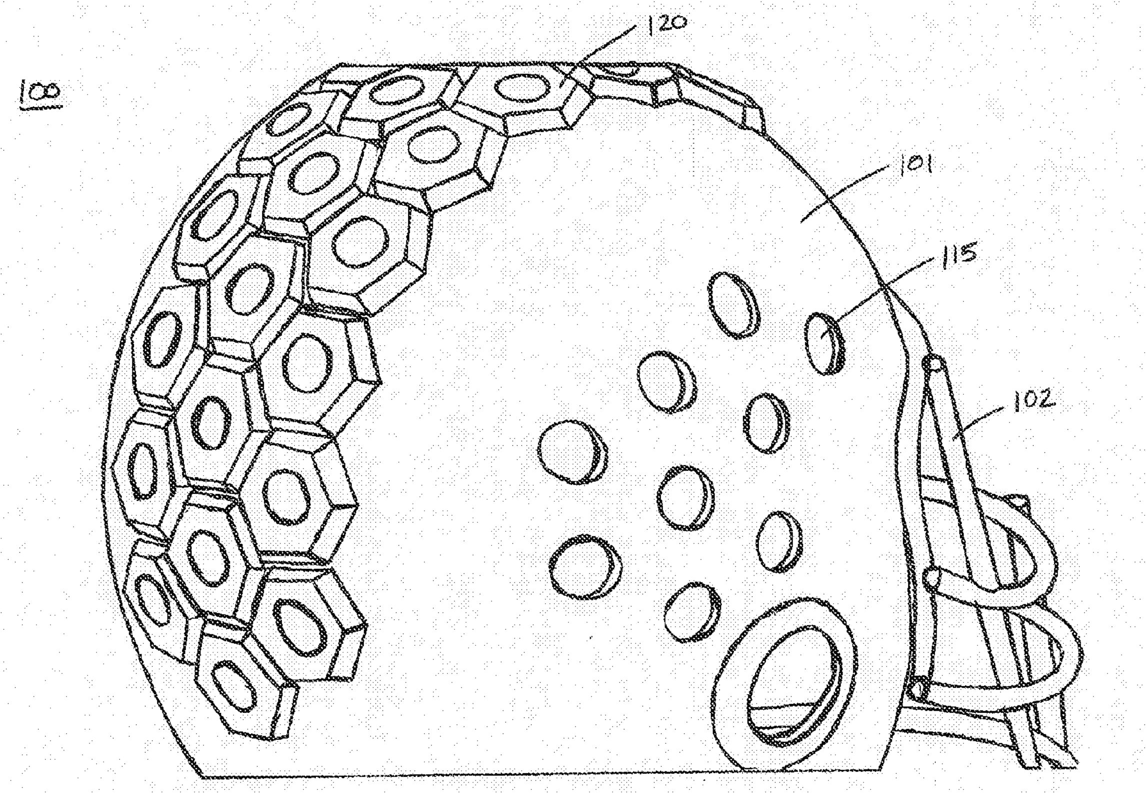


FIG. 1A

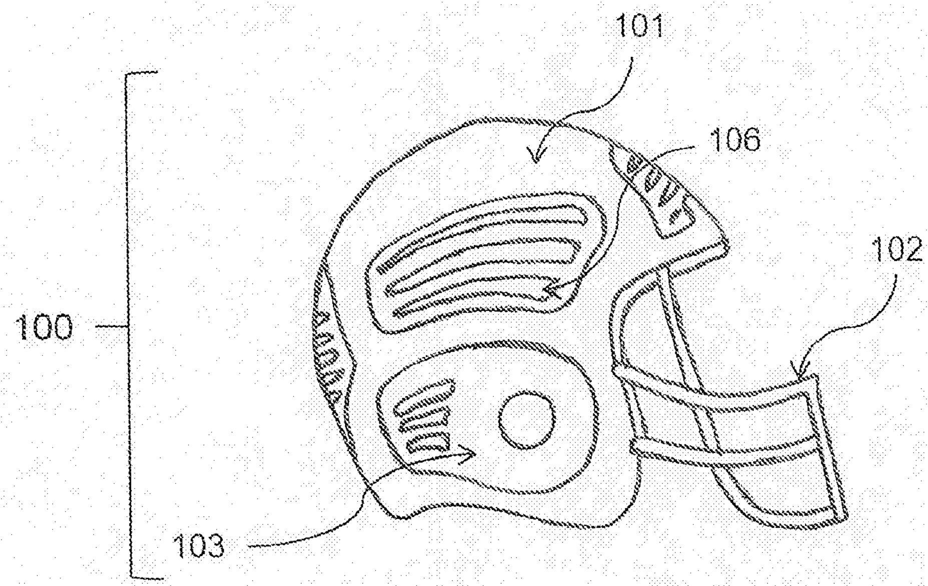


FIG. 1B

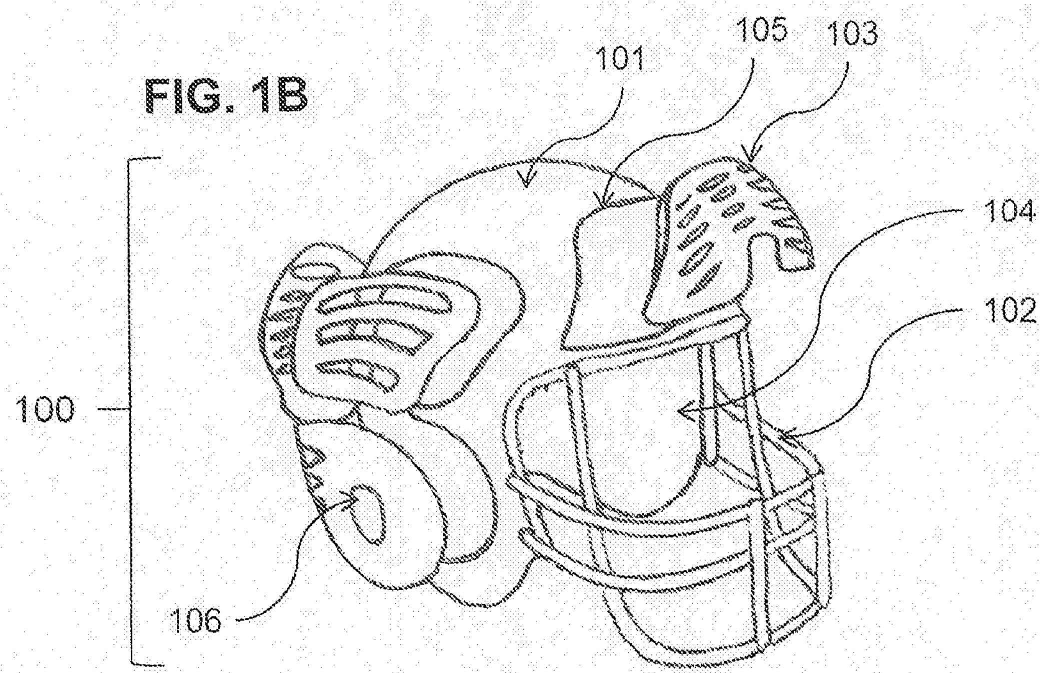


FIG. 2

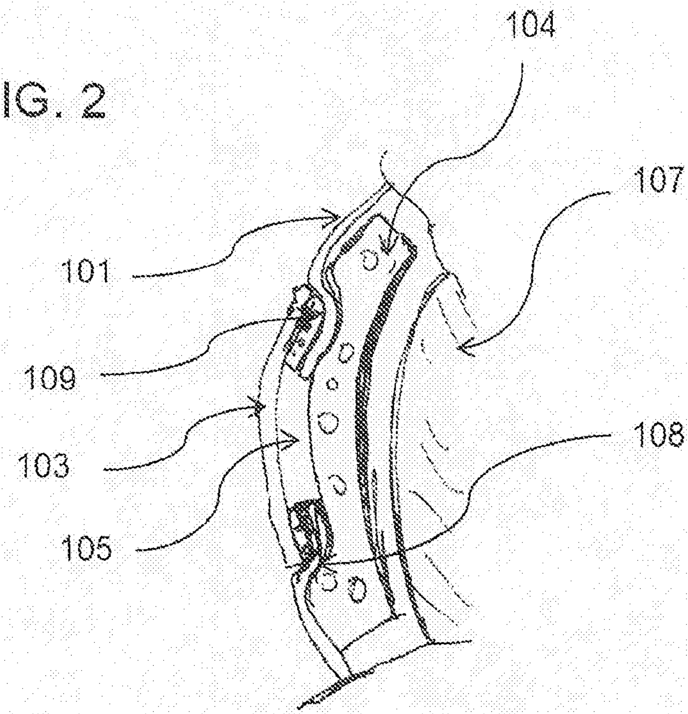


FIG. 3

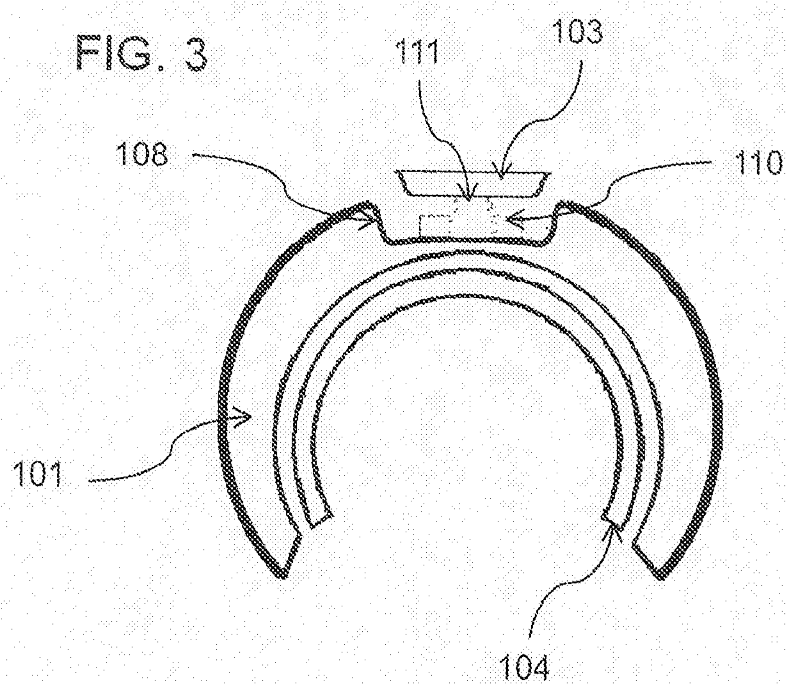


FIG. 4

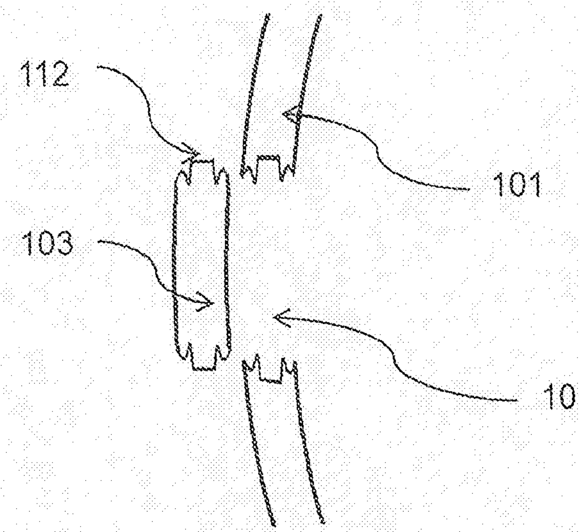
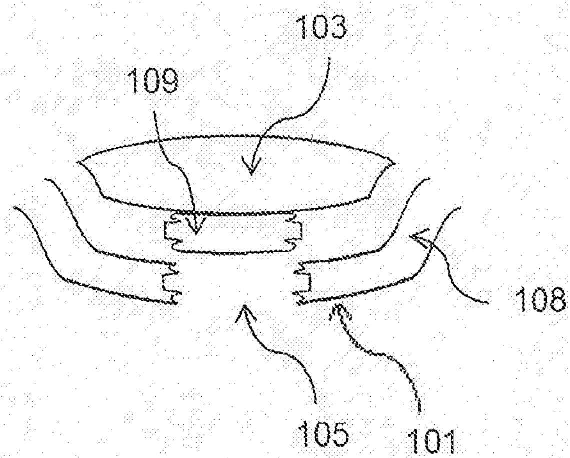


FIG. 5



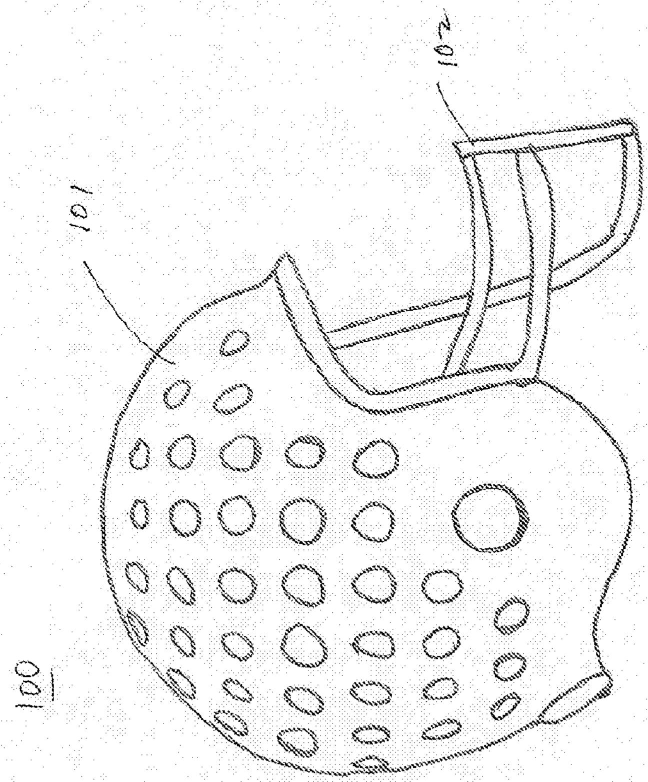


FIG. 6B

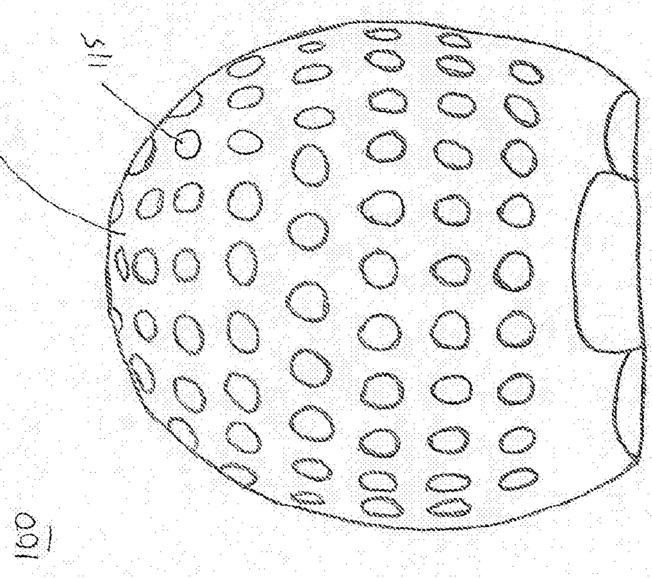


FIG. 6A

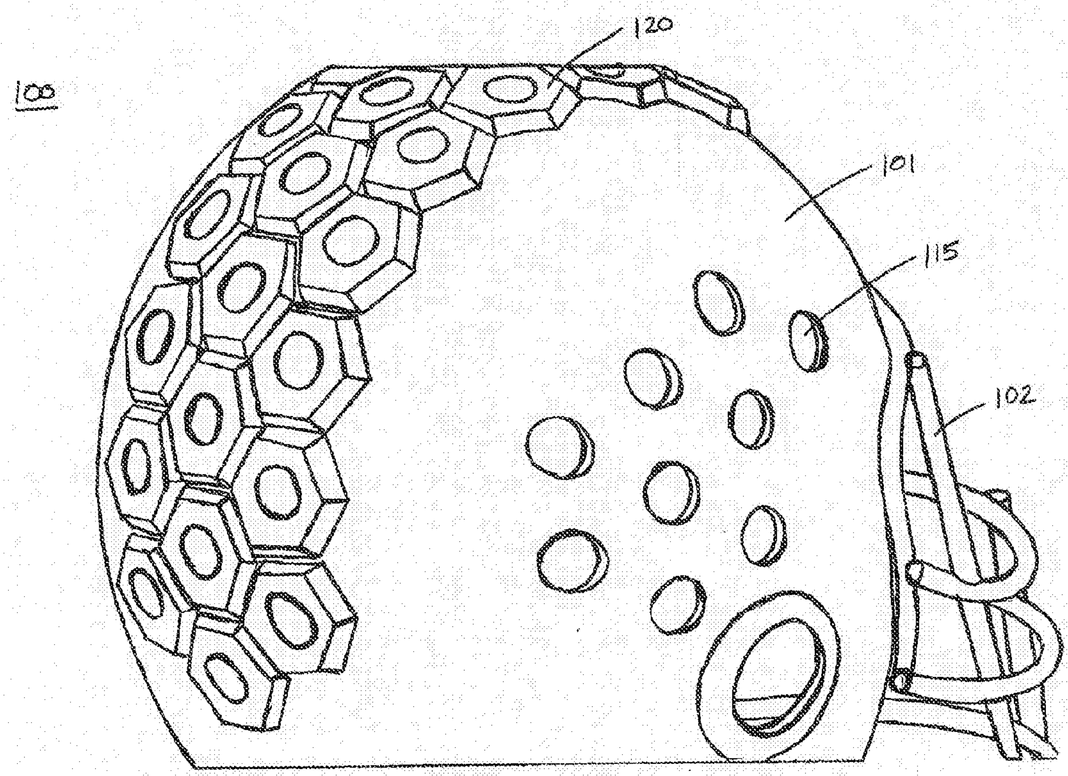


FIG. 7

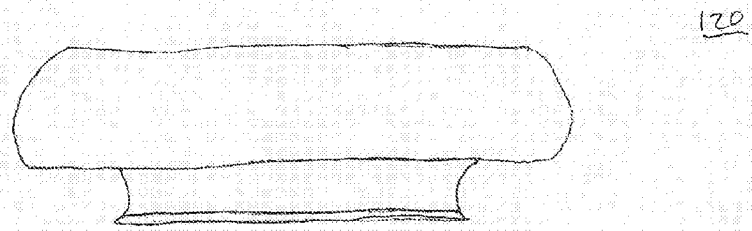


FIG. 8A

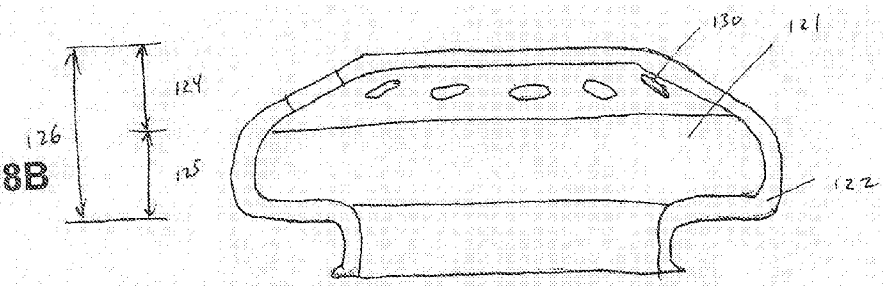


FIG. 8B

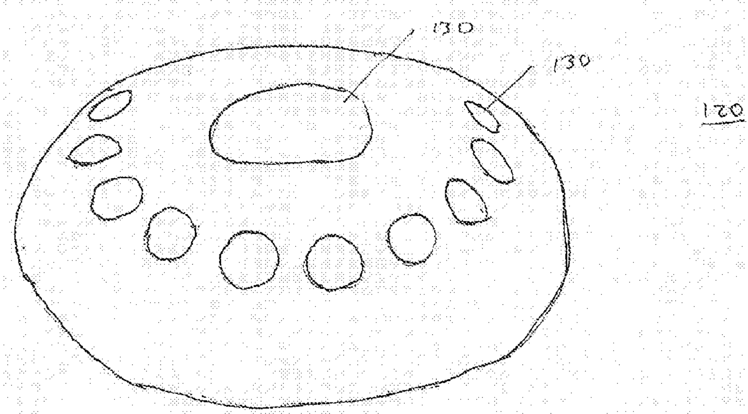


FIG. 8C

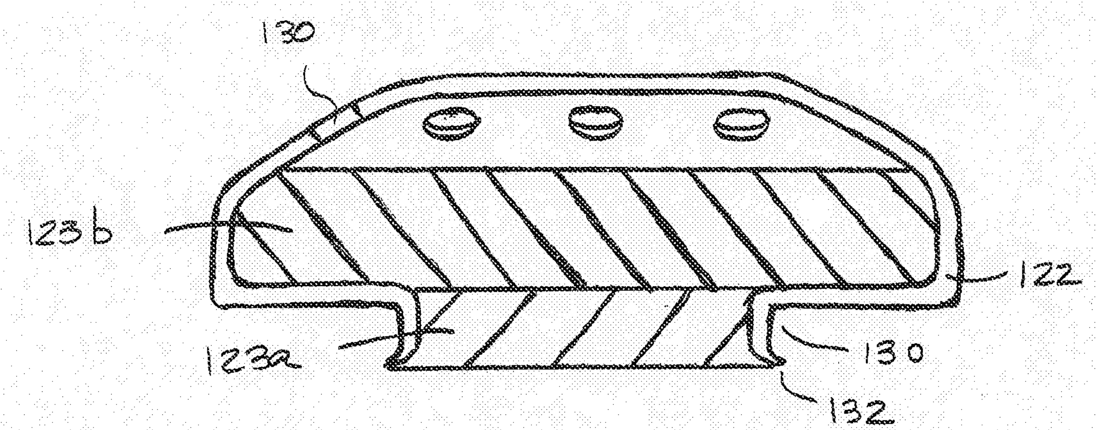


FIG. 9

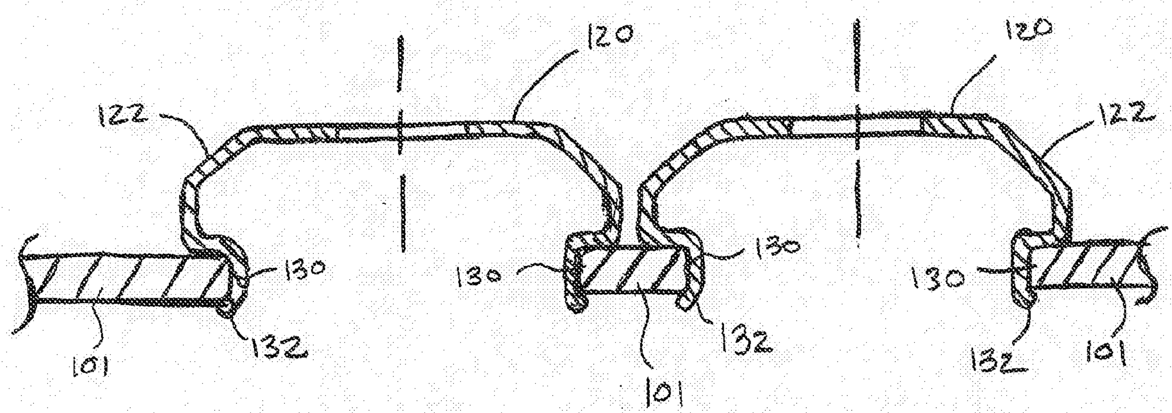


FIG. 10A

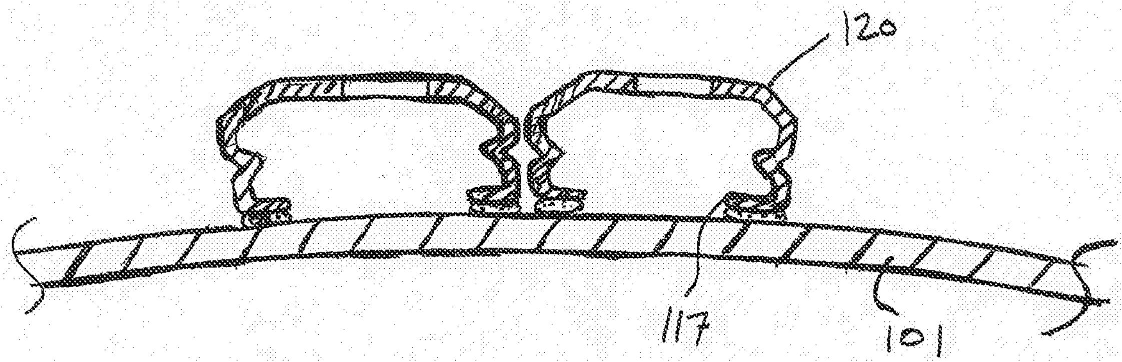


FIG. 10B

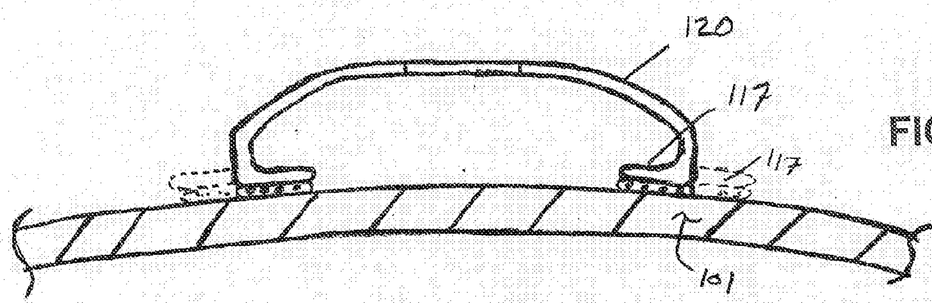


FIG. 11A

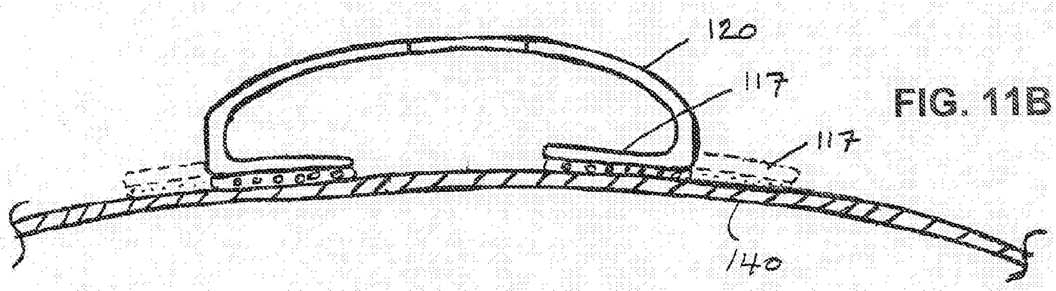


FIG. 11B

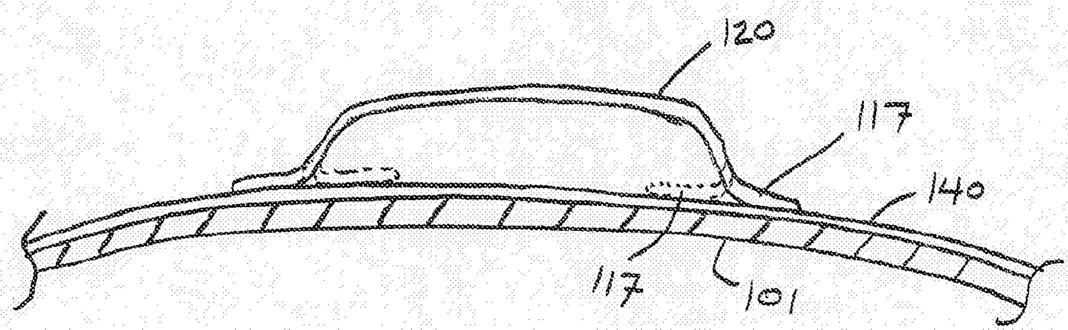


FIG. 12

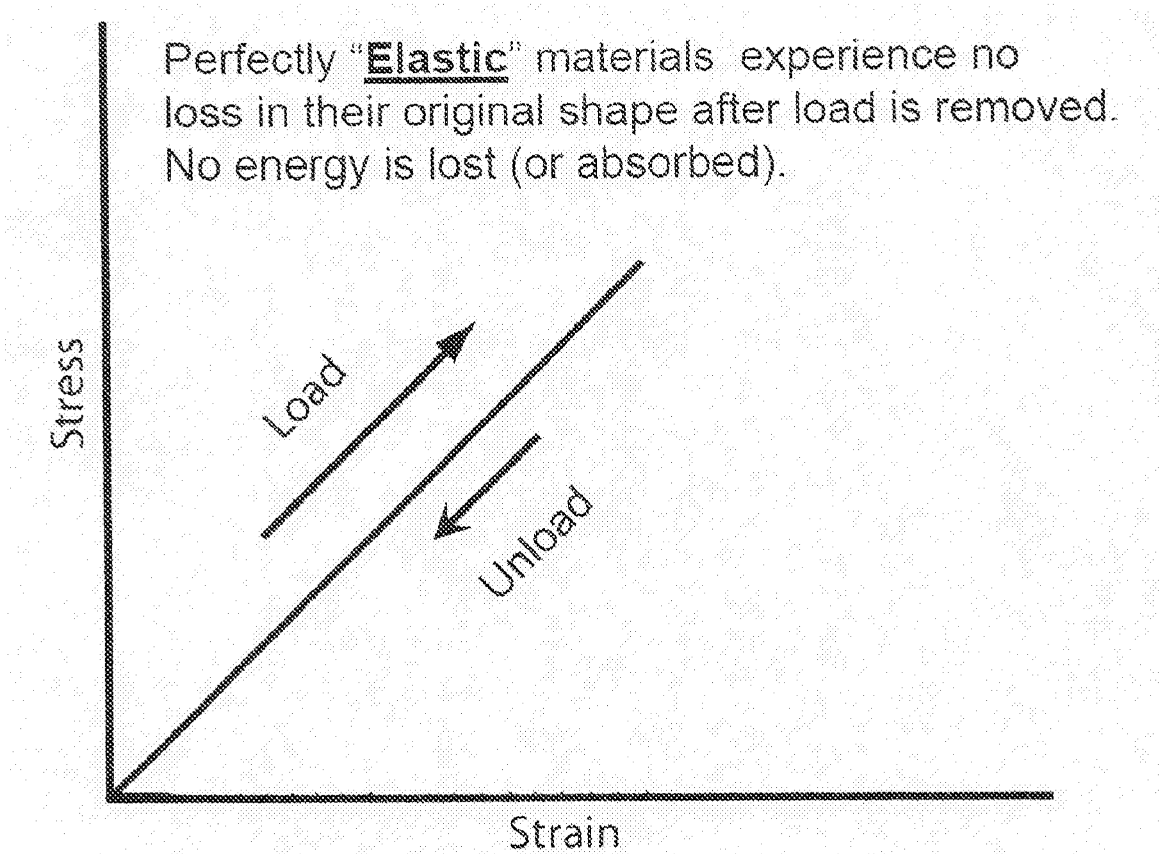

Perfectly "Elastic" materials experience no loss in their original shape after load is removed. No energy is lost (or absorbed).
Load
Unload
Stress
Strain

FIG. 13

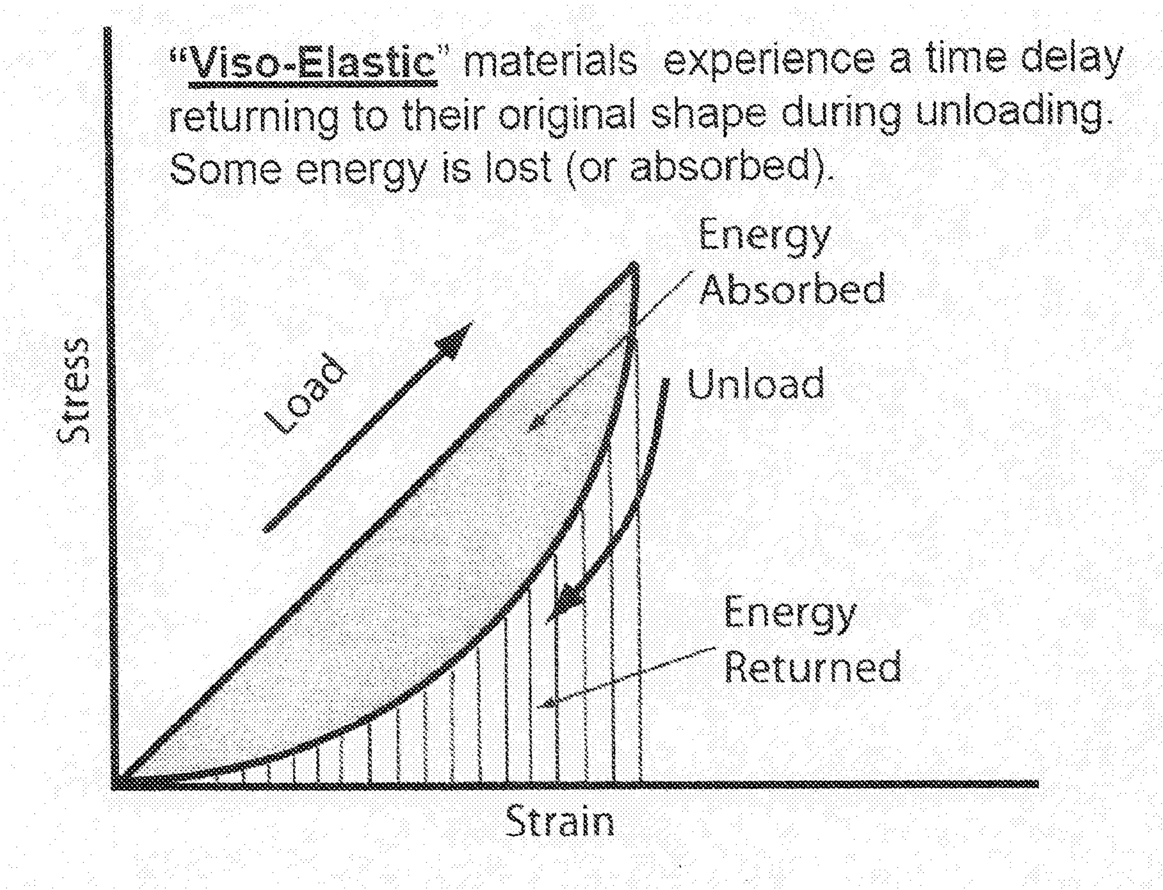

"Viso-Elastic" materials experience a time delay returning to their original shape during unloading. Some energy is lost (or absorbed).
Energy Absorbed
Load
Unload
Stress
Energy Returned
Strain

FIG. 14

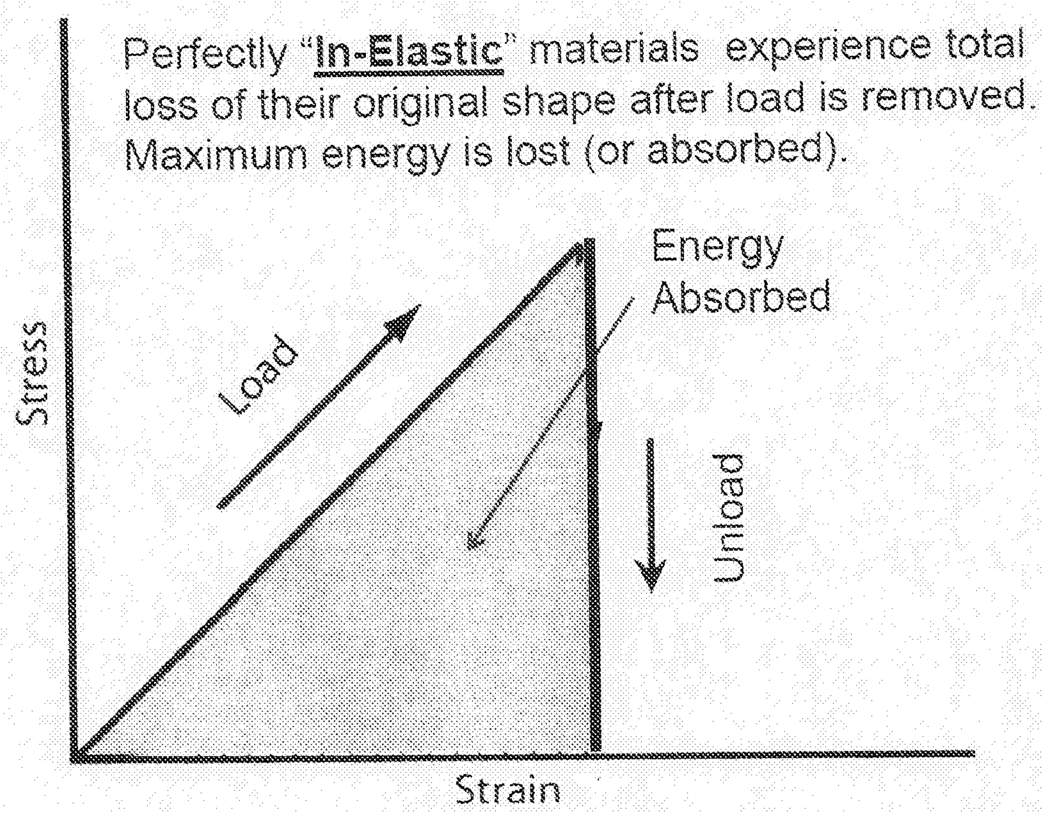

Perfectly "In-Elastic" materials experience total loss of their original shape after load is removed. Maximum energy is lost (or absorbed).
Energy Absorbed
Load
Unload
Stress
Strain

FIG. 15

SPORTS HELMET WITH COLLAPSIBLE MODULAR ELEMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part patent application of U.S. application Ser. No. 13/524,597 entitled "Modular Sports Helmet," filed on Jun. 15, 2012, which is incorporated herein by reference.

FIELD OF INVENTION

[0002] This invention relates generally to a high-performance helmet incorporating a collapsible modular design to achieve, among other things, improvements in energy absorption and cost efficiencies. The characteristics of the disclosure may be particularly useful in high-impact sports such as football, lacrosse, hockey, baseball, softball, cycling, skating, skiing, polo, and the like, as well as other non-sports applications where protection of a user is important.

BACKGROUND OF THE INVENTION

[0003] Many current helmet designs are essentially plastic, formed shells with some variation of energy-absorbing material, such as foams, air pads, or a combination of both, placed inside or external to the shell.

[0004] To optimize performance, many helmet designs attempt to balance competing functional features against an overall challenge of cost containment. In this regard, attempts are made to design helmets that not only sustain the required impacts of their specific sport, but to provide adequate ventilation, to be capable of periodic repainting or refinishing, and frequently, to accommodate or support a separate face mask. Attempts to incorporate other criteria such as weight, stand-off distance from the user head contours ("helmet profile"), and overall comfort have been made as well. However, such attempts create compromises where certain features dominate the design, and the other criteria are reduced to various degrees.

[0005] For example, conventional football helmets are designed to protect players from catastrophic brain injuries caused by severe impacts and to function effectively with multiple impacts without cracking. This leads to designs where typically less than 20% of the total helmet mass is related to energy absorption, and thus, over 80% of the helmet mass behaves more like a spring, which effectively transfers the energy instead of absorbing it.

[0006] Moreover, many helmet designs are based on a common design element such as the molded plastic shell. The helmets outer shell is designed to be capable of being refinished several times during its useful life, but if a key element is damaged during use, and thus not functional, the helmet has to be replaced in whole. Replacement may be necessary due to damage, old age, or to having been refinished too many times. In any event, this type of helmet is designed take multiple hits without failure, to last a long time, and to be refinished for cosmetic purposes.

[0007] Another class of helmets are designed to fail strategically during a severe impact, essentially giving up their structure during the event and thus absorbing the energy of the impact through the strategic "failure" of the material. For example, bicycle helmets fall within this category. They are designed to be discarded after a severe crash, as the structural foams that the helmets are made of "crush" and absorb the energy of a severe impact. The designs are very efficient at absorbing energy, however they are not designed to withstand multiple impacts.

[0008] Multi-hit helmet designs can often be described as having two-stage energy absorption. In this respect, a hard, outer shell helps distribute the impact load ("Stage 1") and the materials inside to the helmet handle the majority of the "absorption" of the impact loads ("Stage 2").

[0009] Due to the needs of creating a shell that is tough, durable, long-lasting, well-ventilated, low-profile, lightweight, and capable of handling multiple impacts, of being refinished, and of functioning in high and low temperatures, many helmets are constructed with polycarbonate or ABS plastic molded shells that are thick and rigid.

[0010] These thick, rigid shells do not dissipate much energy during an impact, and as such, transfer much of it to the absorption materials inside the helmet. Therefore, Stage 1 of the energy absorption mechanism is largely ineffective, and the bulk of energy absorption is accomplished by the Stage 2 design elements, namely foams and air pads inside the hard shell. However, these Stage 2 elements generally function in an elastic or slightly visco-elastic manner, and with reference to FIGS. **13** and **14**, they are at best moderately effective for absorbing energy.

[0011] Moreover, they tend to have design elements that are designed for comfort, which allow them to also work under low impact loads, or design elements that are intended to work under high impact loads However, these Stage 2 design elements do not function well for both high and low impact loads. This type of multi-hit helmet designed is intended to work under severe (high) impact loads and to be less effective (with regard to energy absorption) when subjected to moderate or low impact loads. Under those conditions, the helmet effectively passes most of the load (and energy) to the player wearing it.

[0012] Thus, technology that incorporates more energy absorption strategies is desirable because it can potentially decrease the incidence of athlete injury caused by traumatic head injuries, concussions, or repetitive head trauma. Additionally, technology that can realize different properties of different materials is desirable. Further, technology that allows partial replacement of helmet components is desirable because it may decrease the cost of helmet refurbishment and replacement.

SUMMARY OF THE INVENTION

[0013] While the ways in which the present disclosure addresses the disadvantages of the prior art will be discussed in greater detail below, in general, the present disclosure provides a helmet for a user's head, comprising a shell, which may be rigid or compliant, configured to at least partially surround the user's head, optionally, an energy-absorbing layer, and one or more collapsible modular elements that are individually removably attached to the helmet. Collapsible modular elements, as used herein, are elements (that typically respond in an in-elastic, or highly visco-elastic, manner) attached to the helmet that collapse or otherwise crush and permanently deform or to temporarily deform upon receiving an impact force of a particular pre-determined amount. By collapsing, as illustrated in FIG. **15**, the energy from the impact is more effectively absorbed instead of being transferred to the user of the helmet.

[0014] For example, the collapsible modular elements may be comprised of a thin wall surface surrounding an empty volume. The collapsible modular element collapses into the empty volume at a particular impact force. Alternatively, the volume may be filled with one or more energy absorption materials (first, second, etc.), optionally, in one or more layers.

[0015] In this regard, the collapsible modular elements may be "tuned" so as to have different regions that collapse at different impact forces, so as to provide more than one impact absorption capability (e.g., higher vs. lower impact forces). For example, the thin wall material thickness may vary so that different portions of the collapsible modular elements collapse at different impact forces. Similarly, by choosing multiple materials to fill the volume, varying impact energy absorption may be accomplished.

[0016] The collapsible modular elements can be adhered to an outer surface of the shell, such as "hard or rigid" shells used in conventional plastic helmets or to "soft or compliant" shells used in new helmet designs. Alternatively, the shell or compliant layer sections may have one or more apertures for receiving, attachment and releasably holding the collapsible modular elements or providing ventilation. These apertures can be an effective attachment option as well as a way to add additional energy absorption, while minimizing the weight added to the helmet.

[0017] A thin wall surface of a collapsible modular element can be configured with a depression to engage the shell proximate a corresponding aperture for receiving and releasably holding the collapsible modular elements in the aperture.

[0018] The collapsible modular elements can create a variable stand-off height relative to the helmet, so that the collapsible modular elements absorb energy in a region between the shell and the stand-off height. A higher stand-off height will generally improve energy absorption while a lower stand-off height will have less resistance from users who seek to minimize the overall outer helmet profile.

[0019] The collapsible modular elements may thus provide additional stages of impact energy absorption and may be adapted to optimize performance for a specific sport or function by varying characteristics such as size, location, weight, material, method of attachment, and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1***a* is a side view of a modular football helmet in accordance with an exemplary embodiment of the present disclosure.

[0021] FIG. **1***b* is a perspective view of a modular football helmet in accordance with an exemplary embodiment of the present disclosure and illustrating the removable panels when released from the apertures.

[0022] FIG. **2** is a close-up cross-sectional view of a helmet with a depression and aperture, and a modular panel attached to the helmet in accordance with an embodiment of the present disclosure.

[0023] FIG. **3** is a cross-sectional view of a helmet with a depression, a modular panel, and an attachment mechanism, in accordance with an embodiment of the present disclosure.

[0024] FIG. **4** is a close-up cross-sectional view of a helmet shell with an aperture, a modular panel, and an attachment mechanism located on the perimeter edge of the panel and aperture in accordance with an embodiment of the present disclosure.

[0025] FIG. **5** is a close-up cross-sectional view of a helmet shell with an aperture and a depression, a modular panel, and an attachment mechanism located in the depression in accordance with an embodiment of the present disclosure.

[0026] FIG. **6***a* is a rear view of a football helmet with apertures for removably receiving collapsible modular elements in accordance with an embodiment of the present disclosure.

[0027] FIG. **6***b* is a side view of a football helmet with apertures for removably receiving collapsible modular elements in accordance with an embodiment of the present disclosure.

[0028] FIG. **7** is a partial perspective view of a football helmet with apertures for removably receiving collapsible modular elements showing the collapsible modular elements in some of the apertures in accordance with an embodiment of the present disclosure.

[0029] FIG. **8***a* is a side view of a collapsible modular element in accordance with an embodiment of the present disclosure.

[0030] FIG. **8***b* is a cross-sectional side view of a collapsible modular element in accordance with an embodiment of the present disclosure.

[0031] FIG. **8***c* is a perspective view of a collapsible modular element in accordance with an embodiment of the present disclosure.

[0032] FIG. **9** is a cross-sectional side view of a collapsible modular element with layers of energy absorbing materials shown therein in accordance with an embodiment of the present disclosure.

[0033] FIG. **10***a* is a cross-sectional side view of two collapsible modular elements inserted in corresponding apertures in a shell of a helmet in accordance with an embodiment of the present disclosure.

[0034] FIG. **10***b* is a cross-sectional side view of two collapsible modular elements adhered to the shell of a helmet in accordance with an embodiment of the present disclosure.

[0035] FIG. **11***a* is a cross-sectional side view of a collapsible modular element adhered to the surface of a shell of a helmet in accordance with an embodiment of the present disclosure.

[0036] FIG. **11***b* is a cross-sectional side view of a collapsible modular element adhered to the surface of a compliant layer of a helmet in accordance with an embodiment of the present disclosure.

[0037] FIG. **12** is a cross-sectional side view of a collapsible modular element adhered to a compliant layer on the surface of a shell of a helmet in accordance with an embodiment of the present disclosure.

[0038] FIG. **13** is a graph illustrating a stress-strain curve of an elastic material.

[0039] FIG. **14** is a graph illustrating a stress-strain curve of a visco-elastic material.

[0040] FIG. **15** is a graph illustrating a stress-strain curve of an in-elastic material.

DETAILED DESCRIPTION

[0041] The following description is of an exemplary embodiment of the invention only, and is not intended to limit the scope, applicability, or configuration of the disclosure in any way. Rather, the following description is intended to provide a convenient illustration for implementing various embodiments of the disclosure. As will become apparent, various changes may be made in the function and arrangement of the elements described in these embodiments without departing from the scope of the disclosure as set forth in the claims.

[0042] For example, in the context of the present disclosure, the apparatus hereof finds particular use in connection with sports helmets such as football helmets, baseball helmets, hockey helmets, and the like. Additionally, the specific characteristics of each embodiment of the present disclosure are adapted to be optimized for performance in a particular sport. However, generally speaking, numerous applications of the present disclosure may be realized.

[0043] For example, although sports helmets are primarily used in conjunction with participation in an athletic activity, their general purpose is to protect the user's head from impact related trauma. Accordingly, as used herein, the term "helmet" means any head-protective apparatus which at least partially surrounds the user's head. Briefly, by way of non-limiting example, other helmets for motorcycle, automobile, recreational vehicles, military and the like, as well as other protective gear, such as elbow pads, knee pads, thigh pads, shin guards, shoulder pads, chest and back protectors and the like, may likewise benefit from the present disclosure, and use of the term "helmet" is not intended to limit the scope, applicability, or configuration of the disclosure in any way.

[0044] Likewise, numerous materials may be used to achieve each element of the apparatus disclosed herein. Generally speaking, elements of the disclosure may be made of various materials and composites, including polyethylene, polycarbonate plastic, ABS plastic, carbon fiber, metals, ceramics, polystyrene foam, vinyl nitrile foam, and thermoplastic urethane foam. That being said, although an exhaustive list of materials is not included herein, one skilled in the relevant art will appreciate that various conventional plastics and energy-absorbing materials may be used, all of which fall within the scope of the present disclosure.

[0045] Additionally, various materials may be combined to obtain the most attractive characteristics of existing (or as yet unknown) plastics, energy-absorbing materials, and composite materials, and may be incorporated into the helmet elements disclosed herein, whose combined performance characteristics may potentially increase impact energy absorption or cost efficiency.

[0046] As noted above, in conventional sports helmets, impact energy is dissipated in two stages, as accomplished by a hard, outer shell and an inner, energy-absorbing layer. In accordance with the present disclosure, additional stages of impact energy absorption can be achieved through incorporation of collapsible modular design elements.

[0047] For example, a helmet may be improved with the addition of various modular elements, such as collapsible modular elements, panels, face masks, or the like, releasably attached to a shell, which surrounds a conventional, energy-absorbing layer. As used herein, "collapsible modular elements" means generally in-elastic elements (though highly visco-elastic and elastic materials may also fall within the scope of the present disclosure) that collapse or otherwise crush and permanently deform or to temporarily deform upon receiving an impact force of a particular pre-determined amount, and by collapsing, energy from the impact force is more effectively absorbed instead of being transferred elsewhere, such as to or through the shell and other components of the helmet to the user of the helmet.

[0048] For example, FIG. **14** illustrates a stress-strain curve showing the improved energy absorption of this type of visco-elastic materials. The energy absorbed is defined as the integration of the area under the stress/strain curve. It can also be described by a material that has a large hysteresis loop, which generally refers to materials that have a loss in their response to stress by not returning in a linear manner from a strain standpoint. Another way to describe it as material that has a permanent "set" when loaded.

[0049] Thus, the collapsible modular elements can provide additional energy absorption by intentional deformation or release, thereby potentially decreasing the incidence of injury. Additionally, collapsible modular elements may be optionally removed and replaced after severe impacts, permanent deformation, ordinary wear and tear, or for any other reason. Collapsible modular design may improve cost efficiencies by decreasing the cost of helmet refurbishment and the frequency of helmet replacement.

[0050] Additionally, the mechanism attaching various modular elements to the helmet may itself provide further stages of impact energy absorption. High-strain rate-sensitive materials can help "tune" the level of energy (e.g., increase or decrease the amount of energy) required to remove a modular element. As such, the attachment mechanism may be made of various materials to meet the particular requirements of a specific sport, as determined by the types of impact the helmet is likely to receive. For example, a modular element that is separated from a rigid outer shell by an attachment mechanism made of a high-strain, moderate stiffness material may provide improved energy absorption for high load, short duration impacts.

[0051] For example, a baseball batter's helmet may have panels or collapsible modular elements that permanently deform, thereby converting the kinetic impact energy of the ball to strain energy in the panel or collapsible modular element upon an impact such as that caused by a fastball pitch. Deformed panels/collapsible modular elements may be removed from the helmet and replaced. Alternatively, energy from a fastball pitch may be dissipated when the ball strikes a rigid panel/collapsible modular elements, and an attachment mechanism made of moderate stiffness material designedly releases the panel/collapsible modular elements from the helmet.

[0052] The above being noted, in accordance with an embodiment of the present disclosure, a helmet comprises a shell, an energy-absorbing layer, and at least one energy-absorbing panel and/or a collapsible modular element, which is removably attached to the helmet. In embodiments with panels, the panels themselves may be made of a plurality of collapsible elements. Briefly, these features of the present disclosure are provided in order that the detailed description herein will be better understood and appreciated; however, the present disclosure can also comprise additional features, which will be subsequently described herein.

[0053] For example, with reference to FIGS. **1***a* and **1***b,* **6***a* and **6***b,* and **7**, a helmet **100** comprises a shell **101**, which may be adapted to absorb impact energy. The shell **101** at least partially surrounds the user's head and provides the structural base of the helmet **100**. The shell **101** may be hard and rigid, and its outer surface may be adapted to be painted, resurfaced, or refinished, potentially to accommodate graphic elements.

[0054] In various embodiments, the shell **101** may be made with materials such as ABS plastic, polycarbonate plastic, or the like. However, the shell **101** may be made of any number of plastics, energy-absorbing materials, or composite materials. Further, the shell's physical characteristics, such as flexibility, hardness, weight, and shape, may be varied in any way necessary to accomplish the desired performance characteristics while still falling within the scope of the present disclosure.

[0055] In an exemplary embodiment of the present disclosure, and with reference to FIGS. **1***a* and **1***b,* **6***a* and **6***b,* and **7** the shell **101** is shaped like a conventional football helmet and is located on the exterior of the helmet **100**, typically contiguous with an inner, energy-absorbing layer **104**. However, the shell **101** may be shaped to accommodate the needs of any particular sport, or more generally, in any way that at least partially surrounds the user's head. Further, the shell **101** need not constitute the outermost layer of the helmet **100**, but may be located anywhere to accomplish energy absorption.

[0056] The layer **104** may be adapted to further absorb energy. The layer **104** may be more energy-absorbent than the shell **101**, and may be comprised of foam lining, foam pads, air pads, or any combination thereof. That being said, the layer **104** may be comprised of any apparatus that effectively absorbs impact energy and generally cushions the user's head.

[0057] Foam lining and foam pads generally may be made of polystyrene foam, vinyl nitrile foam, or thermoplastic urethane foam. Air pads generally may comprise bladders adapted to be filled with air and may be made of vinyl or a similarly flexible plastic material. That being said, the layer **104** may be made of any material that is sufficiently adapted to absorb impact energy.

[0058] The layer **104** may be located inside the shell **101**, and may be contiguous with the inner surface of the shell **101**. In embodiments comprising foam pads or air pads, the pads may be placed strategically inside the helmet **100** to meet the specific requirements of a particular sport, or to optimize characteristics such as energy absorption, user comfort, and helmet profile. That being said, the layer **104** need not be contiguous with the shell **101**, and other elements may be interposed between the shell **101** and the layer **104**.

[0059] In accordance with the present disclosure, still further energy absorption may be accomplished by modular elements.

[0060] For example, one or more panels or collapsible modular elements may be releasably attached to the helmet, potentially providing more effective energy absorption than the hard, outer shell of conventional helmets. Accordingly, improved energy absorption may increase the helmet's ability to prevent injury. Further, the optional ability to remove and replace panels or other collapsible modular elements may improve cost efficiencies by decreasing the cost of helmet refurbishment and the frequency of helmet replacement.

[0061] Panels may be intentionally collapsible as a means of achieving improved energy absorption and of providing a visual indicator of impact. Collapsible panels may be designed to permanently deform upon severe impact or to temporarily deform. Alternatively or in conjunction with deformation, the panels may achieve improved energy absorption by intentionally detaching from the helmet upon impact, thereby dissipating impact energy as strain energy.

[0062] That being said, although an exhaustive list of means for absorbing or dissipating energy is not included herein, one skilled in the relevant art will appreciate that various means may be used, all of which fall within the scope of the present disclosure.

[0063] Panels may be made of various materials or composites, including polycarbonate plastic, ABS plastic, carbon fiber, metals, ceramics, and the like. Different properties and their concomitant benefits may be realized through use of materials that vary in stiffness, strength, weight, flexibility, hardness, energy-absorption ability, cost, or any other characteristic. That being said, although an exhaustive list of materials is not included herein, one skilled in the relevant art will appreciate that various conventional plastics and energy-absorbing materials may be used, all of which fall within the scope of the present disclosure.

[0064] Panels may be strategically located on the helmet to increase energy absorption. Panels may be located on the exterior of the shell, may be interposed between the shell and the layer, or may be located on the inner surface of the layer. Additionally, panels may be located strategically to meet the specific requirements of a particular sport.

[0065] For example, in the present exemplary embodiment, a football helmet, panels **103** may be located on portions of the helmet **100**, such as the anterior, posterior, and lateral faces, which are likely to receive impacts as a result of tackling. In one alternate embodiment, a baseball batter's helmet, panels may be located on portions of the helmet, such as the posterior and lateral faces, which are likely to receive impacts as a result of pitching. That being said, those skilled in the relevant art will appreciated that the panels' location may vary depending on the particular requirements of each helmet, and the embodiments described herein is not intended to limit the scope of the present disclosure.

[0066] Additionally, the shell may comprise depressions or apertures, and panels may be located therein. Apertures and depressions may decrease the helmet's weight, may optimize performance, may be an element of aesthetic design, may accommodate collapsible modular elements of the helmet, or may be adapted for any other function.

[0067] For example, a shell may be shaped like a conventional bicycle helmet, comprising multiple apertures of varied size and shape, designed to decrease helmet weight and increase aerodynamic performance. Alternatively, a shell may be comprised of multiple depressions to decrease helmet profile, thereby increasing aesthetic quality and self-recognition, as measured by the user's ability to pass a mirror test. In the exemplary embodiment of the present disclosure, the shell **101** comprises six apertures **105**, each adapted to releasably hold an energy-absorbing panel **103**, or alternatively, a plurality of collapsible modular elements.

[0068] With reference now to FIG. **4**, a panel **103** may be located in an aperture **105** of the shell **101**. In another embodiment and with reference to FIG. **3**, a panel **103** may be located in a depression **108** of the shell **101**. In yet another embodiment and with reference to FIG. **5**, a panel **103** may be located in both a depression **108** and an aperture **105** of the shell **101**, such that the aperture **105** is formed at the bottom of the depression **108** and is adapted to releasably hold the panel **103** in place.

[0069] That being said, a panel need not be located in a depression or aperture, and the size, shape, and number of apertures or depressions may vary depending on the particular helmet characteristics desired, or the specific requirements of a particular sport. Additionally, and in accordance with the present disclosure, the shell may or may not comprise apertures, and it may or may not comprise depressions.

[0070] Further, a panel which is located in a depression or aperture may or may not have the same three-dimensional profile as the depression or aperture. However, panels sharing the three-dimensional profile of a depression can potentially decrease the helmet profile and create a continuous outer surface of the helmet that is aesthetically pleasing.

[0071] With reference to FIG. **2**, a panel **103** may be located in a depression **108** formed in the shell **101** partially surrounding the user's head **107**, such that the distance from the outer surface of the panel **103** to the inner surface of the attachment mechanism **109** is approximately equivalent to the depth of the depression **108**. In another embodiment and with reference to FIG. **4**, a panel **103** that sits in an aperture **105** may share substantially the same surface profile as the aperture **105** in which it fits, so as to minimize helmet profile and create a continuous outer surface of the helmet that is aesthetically pleasing.

[0072] That being said, the depth, orientation, and profile of a panel located in either a depression or an aperture may vary. In the present exemplary embodiment, a helmet **100** comprises panels **103**, which are located in apertures **105** of approximately equivalent orientation and profile. However, apertures, depressions, and panels may take any number of sizes, shapes, and configurations, and the exemplary embodiment described herein is not intended to limit the scope of the present disclosure. As will be appreciated, the specific requirements of a particular sport may require panels of varying depth, profile, and orientation for optimal energy absorption.

[0073] Panels themselves may additionally comprise one or more vents of varying size and shape. Panel vents may function to increase ventilation and airflow, thereby improving user comfort. Panel vents may also increase energy absorption, increase aerodynamic performance, increase aesthetic appeal, or decrease weight, among other things. In the present exemplary embodiment, a helmet **100** comprises panels **103** with panel vents **106** which are generally oval in shape and are orientated parallel to one another. That being said, panel vents may take any number of sizes, shapes, and orientations, and the exemplary embodiment described herein is not intended to limit the scope of the present disclosure.

[0074] Panels may be releasably attached to the helmet to accomplish any of several functions. For example, releasable attachment improve energy absorption; it may allow panel replacement in the event of deformation after impact; it may allow panel reattachment in the event of intentional detachment after impact; and it may allow panel replacement in the event of helmet damage, regular wear and tear, or for any other reason. Accordingly, improved energy absorption may increase the helmet's ability to prevent injury. Further, the optional ability to remove and replace panels may improve cost efficiencies by decreasing the cost of helmet refurbishment and the frequency of helmet replacement

[0075] With reference to FIG. **2**, a panel **103** may be releasably attached to the shell **101** by a panel attachment mechanism **109**. The attachment mechanism **109** may be made of various high-strain, rate-sensitive materials which increase energy absorption through planned failure at specific loads, as determined by the types of impact the helmet is likely to receive.

[0076] The panel attachment mechanism **109** can be adapted to hold a panel **103** securely in place on the shell **101**, but to intentionally release the panel **103** with application of sufficient force, and thereafter, to optionally receive a panel, again holding it in place. Further, the panel attachment mechanism **109** may be adapted to join a panel with the shell interior, the shell exterior **101**, a shell depression **108**, a shell aperture **105**, the layer **104**, or any other locus on the helmet.

[0077] Additionally, the panel attachment mechanism may comprise channel supports adapted to attach a panel to the helmet. The channel support members may be semi-rigid and adapted to interlock with one another upon application of sufficient force. The channel support members are further adapted to release upon subsequent applications of sufficient impact force.

[0078] In one embodiment and with reference to FIG. **3**, two channel support members **110**, **111** can be respectively located in a depression **108** on the exterior surface of the shell **101** and on the proximal surface of a panel **103**. In another embodiment and with reference to FIG. **4**, channel supports **112** may be located on the perimeter edges of a panel **103** and a shell aperture **105**, respectively.

[0079] In other embodiments, the panel attachment mechanism may include a slide-locking mechanism, a hook and slot mechanism, a magnetic mechanism, an adhesive, or the like. It will be appreciated that, although an exhaustive list is not included herein, one skilled in the relevant art will appreciate that various attachment mechanisms may be used, all of which fall within the scope of the present disclosure.

[0080] In accordance with the present disclosure, still further energy absorption may be accomplished by providing a plurality of collapsible modular elements. For example, with reference to FIGS. **6***a*, **6***b* and **7**, one or more collapsible modular elements **120** may be releasably attached to the helmet, potentially providing more effective energy absorption than the hard, outer shell of conventional helmets. Further, the optional ability to remove and replace collapsible modular elements **120** can create a new type of helmet that has the high efficiency energy absorption capability of "throw away" helmets (like bicycle helmets) while retaining multi-hit capability, while also improving the cost efficiencies by decreasing the cost of helmet refurbishment and the frequency of helmet replacement.

[0081] Additionally, as described in more detail below, in embodiments having apertures in the shell **101** for receiving collapsible modular elements, material is removed from shell **101**, decreasing the mass of the shell **101**. A 1 to 2 inch circle of a typical football helmet shell typically weights between 5-10 grams, while a thin walled collapsible modular element weighs less than that, even when filled with additional energy absorbing materials as described herein, resulting in improvements in overall weight.

[0082] Collapsible modular elements **120** may be intentionally collapsible as a means of achieving improved energy absorption and of providing a visual indicator of a severe impact. Collapsible modular elements **120** may be designed to permanently deform upon severe impact or to temporarily deform and return to their normal shape. Alternatively or in conjunction with deformation, the collapsible modular elements **120** may achieve improved energy absorption by intentionally detaching from the helmet **100** upon impact, thereby dissipating some of the impact energy as strain energy in "tearing loose" the connection.

[0083] As described in more detail below, the collapsible modular elements **120** can be adhered to an outer surface of the shell itself or to a compliant layer. Alternatively, the shell may have a plurality of apertures for receiving and releasably holding the collapsible modular elements.

[0084] With reference now to FIGS. **8***a*, **8***b*, **8***c*, **9**, **10***a*, **11***a* and **11***b* an exemplary collapsible modular element **120** is shown. The illustrated collapsible modular element **120** is a thin walled structure of a suitable inelastic, elastic, or visco-elastic walls **122** that is collapsible. For example, now known or as yet unknown polymers, may be suitable. In the noted Figs., collapsible modular element **120** is generally "puck shaped" with a generally elliptical (here, circular) shape, though other shapes may also be used. For example, with brief reference back to FIG. **7**, collapsible modular element **120** is hexagonal. However, it should be appreciated that any number of shapes, symmetrical or asymmetrical, may be used and fall within the scope of the present disclosure. For example, squares, triangles, octagons and the like, as well as oblong and irregular shapes may be substituted.

[0085] One benefit of the ability to choose various shapes is the ability of the collapsible modular elements **120** to nest together to create a reasonably "smooth" outer surface. For example, the individual hexagonal collapsible modular elements **120** in FIGS. **7**, **10***a*, and **10***b* align to create continuity with minimal gaps, in a pattern that provides a larger surface area for improved protection coverage while still allowing for individual replacement. Further still, by using different designs, configurations and colors, the collapsible modular elements **120** provide numerous possible design configurations, patterns, logos, as well as words and pictures.

[0086] In various embodiments, the collapsible modular elements **120** may be comprised of a thin wall surface that surrounds an empty volume **121**. The collapsible modular element **120** collapses into the empty volume **121** at a particular impact force. Alternatively, with reference to FIG. **9**, the volume **121** may be filled with one or more energy absorption materials (first, second, etc.), optionally in one or more layers **123***a*, **123***b*, etc. and by choosing multiple materials to fill the volume **121** to varying levels, varying the impact energy absorption levels may be accomplished. Whether filled or empty, the collapsible modular elements **120** may be adhered to the outer surface of shell **101** or a compliant layer **140** (as discussed below), or be secured via apertures **115** or other suitable means (as also discussed below).

[0087] The collapsible modular elements **120** may be "tuned" so as to have different regions that collapse at different impact forces, so as to provide more than one impact absorption capability (e.g., higher vs. lower impact forces). For example, the wall **122** materials and thickness may vary so that different portions of the collapsible modular elements collapse at different impact forces. For example, and upper portion **124** of collapsible modular element **120** may have a smaller thickness than a lower portion **125** of collapsible modular element **120**, such that the smaller thickness collapses at a lower impact force than the larger thickness.

[0088] Similarly, by providing holes **130** of varying amounts, sizes and shapes that pass all the way through or partially through the wall **122**, the impact force required to collapse any particular portion of the collapsible modular element **120** can be controlled. Additionally, whether or not the holes **130** change the impact force required to collapse any particular portion of the collapsible modular element **120**, the holes **130** may also provide ventilation to the helmet **100** by allowing air to flow between the user, the helmet **100** and the outside elements.

[0089] With reference to FIGS. **6***a* and **6***b*, the shell may have a plurality of apertures **115** for receiving and releasably holding the collapsible modular elements **120**. Collapsible modular element **120** may include an attachment mechanism for securing the collapsible modular element **120** to the helmet **100**. For example, with reference to FIGS. **8***a*, **8***b*, **8***c*, **9**, and **10** collapsible modular element **120** contains a neck or depression **130** with a perimeter substantially the same size as aperture **115**. At the lowest edge of collapsible modular element **120** a lip **132** is provided that is slightly bigger than aperture **115**, and as such, a collapsible modular element **120** can be inserted into aperture **115** by elastically deforming the lip **132**, and when the lip **132** returns to its original shape, collapsible modular element **120** is retained in aperture **115** in a "snap fit" manner. As will be appreciated, any number of attachment mechanism may be used to releasably secure collapsible modular element **120** to the helmet **100**.

[0090] In alternative embodiments, the collapsible modular elements **120** can be attached to a "soft shell" compliant layer **140** which functions as a helmet itself (e.g., a soccer helmet) or, in some embodiments the compliant layer **140** can be adhered to the outside of a conventional "hard shell" **101**. The compliant layer **140** is any suitably soft, flexible material.

[0091] For example, as noted above, the collapsible modular elements **120** can be adhered to an outer surface of the shell **101**. For example, with reference to FIG. **11***a*, a collapsible modular element **120** is removably adhered to the "hard shell" **101** (or as illustrated in FIG. **11***b*, a compliant "soft shell" layer **140**) by any suitable means, such as "peel and stick" adhesive, hook and loop, suction, or the like. Inwardly or outwardly (or both) extending flanges **117** may be provided to provide a greater surface area for attaching the collapsible modular element **120** to the shell **101** or the compliant layer **140**.

[0092] When the compliant layer **140** is adhered to the outside of a conventional hard shell **101**, it preferably sized to a particular helmet **100** (though other embodiments may include sizes capable of fitting a variety of helmets **100** and sizes of the same), which is placed over a helmet **100** and secured thereto by any suitable means (e.g., adhesives, hook and loop, snaps, etc.).For example, with reference to FIG. **12**, the collapsible modular elements **120** are shown adhered to a compliant layer **140** which is in turn attached to the shell **101**. As noted in connection with adherence directly to the shell **101**, the collapsible modular element **120** may be removably adhered to the compliant layer **140** by any suitable means, such as "peel and stick" adhesive, hook and loop, suction, or the like.

[0093] In any of the foregoing embodiments as well as those not specifically described herein, the collapsible modular elements can create a stand-off height **126** relative to the helmet (e.g. region **126** in FIG. **8**) so that the collapsible modular elements **120** absorb energy in a region between the shell **101** and the stand-off height **126**.

[0094] The collapsible modular elements may thus provide additional stages of impact energy absorption and may be adapted to optimize performance for a specific sport or function by varying characteristics such as size, location, weight, material, method of attachment, and the like.

[0095] Still further energy absorption may be achieved by a face mask, releasably attached to the helmet. Accordingly, improved energy absorption may increase the helmet's ability to prevent injury. Further, the optional ability to remove and replace the face mask may improve cost efficiencies by decreasing the cost of helmet refurbishment and the frequency of helmet replacement.

[0096] The face mask may be intentionally collapsible as a means of achieving improved energy absorption. A collapsible face mask may be designed to permanently deform upon severe impact or to temporarily deform. Alternatively or in conjunction with deformation, the face mask may achieve improved energy absorption by intentionally detaching from the helmet upon impact, thereby dissipating impact force as kinetic energy. That being said, although an exhaustive list of means for absorbing or dissipating energy is not included herein, one skilled in the relevant art will appreciate that various means may be used, all of which fall within the scope of the present disclosure.

[0097] As with other components described herein, facemask may be made of various materials or composites, including polycarbonate plastic, ABS plastic, carbon fiber, metals, ceramics, and the like. The specific requirements of the facemask can determine the type of material used, and the material used may vary in weight, flexibility, hardness, energy-absorption ability, cost, or any other characteristic. That being said, although an exhaustive list of materials is not included herein, one skilled in the relevant art will appreciate that various conventional plastics and energy-absorbing materials may be used, all of which fall within the scope of the present disclosure.

[0098] In the exemplary embodiment of the present disclosure, a face mask **102** may be adapted to be releasably attached to the helmet **100** by a helmet attachment mechanism similar to the panel attachment mechanism described herein. The face mask **102** may be configured as a conventional football helmet face mask and may be releasably attached to the exterior surface of the shell **101** along the perimeter of the shell's anterior edge. Alternatively, the face mask **102** may be attached to the shell **101**, to the layer **104**, to a panel **103**, or to any other locus on the helmet **100**. That being said, the location of the face mask attachment mechanism, as well as the configuration and orientation of the face mask, may be adapted to meet the requirements of any sport.

[0099] Additionally, the attachment mechanism described herein may be adapted to attach other collapsible modular helmet elements, as required by any particular sport. Other collapsible modular helmet elements may include a chin strap, unitary face shield, visor, strap and ratchet apparatus, or the like.

[0100] Finally, in the foregoing specification, the disclosure has been described with reference to specific embodiments. However, one skilled in the art appreciates that various modifications and changes can be made without departing from the scope of the present disclosure as set forth in the claims below. Accordingly, the specification is to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of the present disclosure.

[0101] Likewise, benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the 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, required, or essential feature or element of any or all of the claims. As used herein, the terms "comprises" and "comprising," or any variations thereof, are intended to constitute a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements, but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

I claim:

1. A helmet for a user's head, comprising:

a shell configured to at least partially surrounds the user's head,

an energy-absorbing layer,

a plurality of collapsible modular elements, wherein the collapsible modular elements are each individually removably attached to and detached from the helmet.

2. A helmet according to claim **1**, wherein the collapsible modular elements are adhered to an outer surface of the shell.

3. A helmet according to claim **1**, further comprising a compliant layer, and wherein the collapsible modular elements are adhered to an outer surface of the compliant layer.

4. A helmet according to claim **1**, wherein the shell has a plurality of apertures for receiving and releasably holding the collapsible modular elements.

5. A helmet according to claim **4**, wherein the collapsible modular elements further comprise a neck for engaging the shell and attaching the collapsible modular elements to the shell.

6. A helmet according to claim **1**, wherein at least one of the collapsible modular elements is comprised of a thin wall surface surrounding a volume.

7. A helmet according to claim **6**, wherein the volume is empty.

8. A helmet according to claim **6**, wherein the volume is at least partially filled with a first energy absorption material.

9. A helmet according to claim **8**, wherein the volume is at least partially filled with a second energy absorption material.

10. A helmet according to claim **9**, wherein the first and second energy absorption materials are layered.

11. A helmet according to claim **1**, the collapsible modular elements create a stand-off height relative to the helmet.

12. A helmet according to claim **11**, the collapsible modular elements absorb energy in a region between the shell and the stand-off height.

13. A helmet according to claim **1**, further comprising at least one of a contiguous layer of foam and air pads on an inner surface of the shell.

14. A helmet for a user's head, comprising:

a compliant layer configured to at least partially surrounds the user's head,

a plurality of collapsible modular elements, wherein the collapsible modular elements are each individually removably attached to and detached from the compliant layer.

15. A helmet according to claim **14**, wherein at least one of the collapsible modular elements is comprised of a thin wall surface surrounding a volume.

16. A helmet according to claim **15**, wherein the volume is empty.

17. A helmet according to claim **15**, wherein the volume is at least partially filled with a first energy absorption material.

18. A helmet according to claim **17**, wherein the volume is at least partially filled with a second energy absorption material.

19. A helmet according to claim **18**, wherein the first and second energy absorption materials are layered.

20. A helmet according to claim **14**, the collapsible modular elements create a stand-off height relative to the helmet and the collapsible modular elements absorb energy in a region between the compliant layer and the stand-off height.

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