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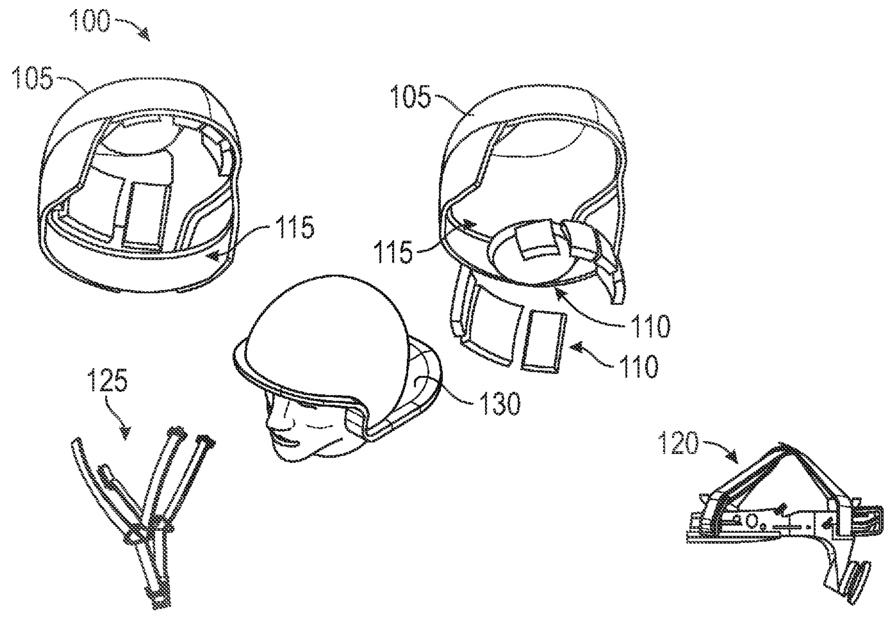

FIG. 1A

(57) Abstract: The disclosed embodiments are directed to helmet systems including a helmet shell, energy-absorbing suspension pads, and an adjustable retention system, further including fluorescent and retroreflective trim, ear covers, and a face shield or visor or both. The configuration can be configured to pass NFPA standard tests, which can include helmet shell impact and thermal tests, and penetration tests. In addition, the helmet can be designed to facilitate the integration of other ancillary accessories such as communication and lighting systems.

WO 2024/081236 A1

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PROTECTIVE HELMET

CROSS REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the priority and benefit under 35 U.S.C. §119(e) of U.S. Provisional Patent Application Serial No. 63/414,766, filed October 10, 2022, entitled "PROTECTIVE HELMET." U.S. Provisional Patent Application Serial Number 63/414,766 is herein incorporated by reference in its entirety.

STATEMENT OF GOVERNMENT RIGHTS

[0002] The invention described in this patent application was made with Government support under Contract Number 70RSAT21CB0000023 awarded by the U.S. Department of Homeland Security. The Government has certain rights in the invention.

TECHNICAL FIELD

[0001] Embodiments are generally related to protective equipment. Embodiments are further related to helmets. Embodiments are further related to fire and heat resistant helmets. Embodiments are further related to ballistic helmets.

BACKGROUND

[0002] The use of head protection for first responders and military personnel is well known. For example, law enforcement officers, managing a crowd or a riot, first responders, firefighters, etc. may be subject to numerous hazards, including unexpected threats, such as throwing bricks, construction materials, laser, etc., and other ballistic threats, from an aggressive crowd. It is standard operating procedure for law enforcement officers to use head protection when called to an emergency situation. Likewise, fire fighters, search and rescue, and other first responders may be similarly subject to situations and environments with elevated risk of head trauma.

[0003] In addition, law enforcement or military personnel involved in civilian operations are also subject to circumstances with elevated risk of head trauma. For example, such operations often involve circumstances where gunfire, ordnance, shrapnel, or other such hazards are present.

[0004] Traumatic Brain Injury (TBI) occurs mainly as a result of linear and rotational accelerations of the head-neck complex during falls, motor-vehicle crashes, and firearm assaults. Previous studies have shown that brain tissues have a poor tolerance against oblique forces or angular accelerations compared to normal forces or linear accelerations. Although a few sports helmets and motor vehicle helmets have recently employed new suspension technologies—such as multi-directional impact protection systems and Wavecel—to attenuate rotational accelerations during low velocity impacts, the majority of modern combat (e.g., military helmet) and non-combat (e.g., fire and construction helmets) helmets have not yet been modernized to provide both normal and angular head impact protections. In addition, current helmet technology do not provide suspension pads that with sufficient protection against oblique (angular) impact forces (i.e., attenuate rotational shear impact forces), even though the majority of head traumas are oblique in nature.

[0005] In modern law enforcement operations, there is increasing crossover between the traditional roles of, for example, law enforcement, and crowd control. For example, during crowd control, police, first responders, or firefighters are commonly called to situations where head trauma from gunfire and hand-thrown projectile is possible.

[0006] While the use of first responders has shifted, the technology associated with head protective gear has not kept pace. Most law enforcement officers use military helmets, such as ACH and ECH helmets, which are currently built to reduce or prevent injury from ballistic impacts, but are not well suited for prolonged wear due to heavy weight.

[0007] The current helmets do not provide thermal comfort because the suspension pads are not well-designed for heat convection underneath the helmet shell.

[0008] Also, existing helmets are not scalable. There is a need for a mission-adaptive helmet, which can be used for both crowd control and for non-violent daily operations. When needed, the additional shells can be adjusted to provide ballistic protection to the full head.

[0009] Along with these limitations, current helmet technology across a number of applications including first responder applications, fire applications, military applications, construction applications, and sports applications, have not been updated to take advantage of the increasing understanding we have of ergonomics as it relates to headwear.

[0010] As such, there is a need in the art for improved helmets as disclosed herein.

SUMMARY

[0011] The following summary is provided to facilitate an understanding of some of the innovative features unique to the embodiments disclosed and is not intended to be a full description. A full appreciation of the various aspects of the embodiments can be gained by taking the entire specification, claims, drawings, and abstract as a whole.

[0012] It is, therefore, one aspect of the disclosed embodiments to provide head protection.

[0013] It is another aspect of the disclosed embodiments to provide systems and apparatuses for helmets.

[0014] It is another aspect of the disclosed embodiments to provide methods and systems for designing helmets.

[0015] It is another aspect of the disclosed embodiments to provide methods, systems, and apparatuses for helmet shell materials.

[0016] It is another aspect of the disclosed embodiments to provide methods, systems, and apparatuses for helmet shell designs made of optimized shell materials.

[0017] It is another aspect of the disclosed embodiments to provide suspension pads for use in helmets.

[0018] It is another aspect of the disclosed embodiments to provide methods, systems, and apparatuses for the combination of suspension pads, and helmet shell designs made of optimized shell materials.

[0019] It is another aspect of the disclosed embodiments to provide ergonomic helmets configured to be heat resistant, flame retardant, and designed to mitigate ballistic impact.

[0020] It is another aspect of the disclosed embodiments to provide methods and systems for designing helmet systems.

[0021] It is another aspect of the disclosed embodiments to provide a next generation helmet.

[0022] It will be appreciated that the methods and systems can be achieved according to the embodiments disclosed herein. For example, in an embodiment, a helmet system comprises a helmet shell, at least one suspension pad configured in the helmet shell, and a suspension web. In an embodiment the helmet shell further comprises modular helmet shell segments. In an embodiment, the helmet shell further comprises an occipital lobe protection section configured to cover the occipital lobe. In an embodiment, the helmet system further comprises a retention strap system. In an embodiment, the helmet shell further comprises a rear brim. In an embodiment, the helmet shell further comprises a plurality of layers of Kevlar fabric infused with resin. In an embodiment, the helmet shell is configured with vacuum-assisted resin transfer molding. In an embodiment, the helmet shell is configured to be heat resistant, flame retardant, and bullet proof. In an embodiment of the helmet system, the at least one suspension pad further comprises a first layer of foam, a second layer of foam, and an open cell lattice sandwiched between the first layer of foam and the second layer of foam. In an embodiment, the open cell lattice comprises a triangular open cell lattice. In an embodiment, the at least one suspension pad further comprises at least one frontal pad, a top suspension pad, and at least one rear suspension pad. In an embodiment, the helmet system further comprises a face shield operably connected to the helmet shell. In an embodiment, helmet system of claim further comprises an ear and neck protector mesh.

[0023] In another embodiment, a helmet comprises a helmet shell comprising an occipital lobe protection section configured to cover the occipital lobe and a temporal lobe protection section configured to cover the temporal lobe, at least one suspension pad configured in the helmet shell comprising a first layer of foam, a second layer of foam, and an open cell lattice, and a suspension web. In an embodiment the helmet shell further comprises a plurality of layers of fabric infused with resin, the layers of fabric comprising at least one of: UHMWPE Dyneema; UHMWPE Spectra; and Kevlar 29 with carbon fiber reinforcement. In an embodiment, the open cell lattice comprises a triangular open cell lattice. In an embodiment, the at least one suspension pad further comprises: at least one frontal pad, a top suspension pad, and at least one rear suspension pad.

[0024] In an embodiment, a method for fabricating helmets comprises forming a helmet shell of layered Kevlar and resin and forming a plurality of suspension pads for installation on an inner surface of the helmet shell. In an embodiment, forming the helmet shell of layered Kevlar and resin further comprises vacuum-assisted resin transfer molding the helmet shell. In an embodiment, forming the plurality of suspension pads further comprises forming an open cell lattice and inserting the open cell lattice between a first layer of foam and a second layer of foam. In an embodiment, the method further comprises configuring the helmet shell with a center of mass selected to reduce repetitive stress injury.

BRIEF DESCRIPTION OF THE FIGURES

[0025] The accompanying figures, in which like reference numerals refer to identical or functionally similar elements throughout the separate views and which are incorporated in and form a part of the specification, further illustrate the embodiments and, together with the detailed description, serve to explain the embodiments disclosed herein.

[0026] FIG. 1A depicts aspects of a helmet, in accordance with the disclosed embodiments;

[0027] FIG. 1B depicts aspects of the helmet, in accordance with the disclosed embodiments;

[0028] FIG. 2A depicts aspects of a helmet shell, in accordance with the disclosed embodiments;

[0029] FIG. 2B depicts additional aspects of a helmet shell, in accordance with the disclosed embodiments;

[0030] FIG. 2C depicts additional aspects of a helmet shell, in accordance with the disclosed embodiments;

[0031] FIG. 2D depicts a center of gravity of a helmet shell, in accordance with the disclosed embodiments;

[0032] FIG. 2E depicts an elevation view of a helmet shell, in accordance with the disclosed embodiments;

[0033] FIG. 2F depicts of a helmet shell disposed on a user's head, in accordance with the disclosed embodiments;

[0034] FIG. 3A depicts aspects a suspension pad, in accordance with the disclosed embodiments;

[0035] FIG. 3B depicts aspects of another embodiment of a suspension pad, in accordance with the disclosed embodiments;

[0036] FIG. 3C depicts aspects of another embodiment of a suspension pad, in accordance with the disclosed embodiments;

[0037] FIG. 3D depicts aspects of another embodiment of a suspension pad, in accordance with the disclosed embodiments;

[0038] FIG. 4A depicts suspension pads in a helmet shell, in accordance with the disclosed embodiments;

[0039] FIG. 4B depicts suspension pads in relation to a user head, in accordance with the disclosed embodiments;

[0040] FIG. 4C depicts aspects of the suspension pads, in accordance with the disclosed embodiments;

[0041] FIG. 5 depicts a Vacuum-Assisted Resin Transfer Molding (VARTM) system, in accordance with the disclosed embodiments;

[0042] FIG. 6A depicts a mold for use with a Vacuum-Assisted Resin Transfer Molding (VARTM) system, in accordance with the disclosed embodiments;

[0043] FIG. 6B depicts a top plate for use with a Vacuum-Assisted Resin Transfer Molding (VARTM) system, in accordance with the disclosed embodiments;

[0044] FIG. 7 depicts a block diagram of a computer system which is implemented in accordance with the disclosed embodiments;

[0045] FIG. 8 depicts a graphical representation of a network of data-processing devices in which aspects of the present embodiments may be implemented; and

[0046] FIG. 9 depicts a computer software system for directing the operation of the data processing system depicted in FIG. 7, in accordance with an example embodiment.

DETAILED DESCRIPTION

[0047] Embodiments and aspects of the disclosed technology are presented herein. The particular embodiments and configurations discussed in the following non-limiting examples can be varied, and are provided to illustrate one or more embodiments, and are not intended to limit the scope thereof.

[0048] Reference to the accompanying drawings, in which illustrative embodiments are shown, are provided herein. The embodiments disclosed can be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the embodiments to those skilled in the art. Like numbers refer to like elements throughout.

[0049] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms “a”, “an”, and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0050] Throughout the specification and claims, terms may have nuanced meanings suggested or implied in context beyond an explicitly stated meaning. Likewise, the phrase “in one embodiment” as used herein does not necessarily refer to the same embodiment and the phrase “in another embodiment” as used herein does not necessarily refer to a different embodiment. It is intended, for example, that claimed subject matter include combinations of example embodiments in whole or in part.

[0051] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0052] It is contemplated that any embodiment discussed in this specification can be implemented with respect to any method, kit, reagent, or composition of the invention, and vice versa. Furthermore, compositions of the invention can be used to achieve methods of the invention.

[0053] It will be understood that particular embodiments described herein are shown by way of illustration and not as limitations of the invention. The principal features of this invention can be employed in various embodiments without departing from the scope of the invention. Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, numerous equivalents to the specific procedures described herein. Such equivalents are considered to be within the scope of this invention and are covered by the claims.

[0054] The use of the word “a” or “an” when used in conjunction with the term “comprising” in the claims and/or the specification may mean “one,” but it is also consistent with the meaning of “one or more,” “at least one,” and “one or more than one.” The use of the term “or” in the claims is used to mean “and/or” unless explicitly indicated to refer to alternatives only or the alternatives are mutually exclusive, although the disclosure supports a definition that refers to only alternatives and “and/or.” Throughout this application, the term “about” is used to indicate that a value includes the inherent variation of error for the device, the method being employed to determine the value, or the variation that exists among the study subjects.

[0055] As used in this specification and claim(s), the words “comprising” (and any form of comprising, such as “comprise” and “comprises”), “having” (and any form of having, such as “have” and “has”), “including” (and any form of including, such as “includes” and “include”) or “containing” (and any form of containing, such as “contains” and “contain”) are inclusive or open-ended and do not exclude additional, unrecited elements or method steps.

[0056] The term “or combinations thereof” as used herein refers to all permutations and combinations of the listed items preceding the term. For example, “A, B, C, or combinations thereof” is intended to include at least one of: A, B, C, AB, AC, BC, or ABC, and if order is important in a particular context, also BA, CA, CB, CBA, BCA, ACB, BAC, or CAB. Continuing with this example, expressly included are combinations that contain repeats of one or more item or term, such as BB, AAA, AB, BBC, AAABCCCC, CBBAAA, CABABB, and so forth. The skilled artisan will understand that typically there is no limit on the number of items or terms in any combination, unless otherwise apparent from the context.

[0057] All of the compositions and/or methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of preferred embodiments, it will be apparent to those of skill in the art that variations may be applied to the compositions and/or methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit, and scope of the invention. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

[0058] The embodiments disclosed herein are directed to helmet technologies. The helmet technology disclosed herein can include the following assembled components: a helmet shell, a scalable helmet-shell, energy-absorbing system, an adjustable retention system, fluorescent and retroreflective trim, ear covers, and a face shield or visor or both. The configuration can be configured to pass NIJ level IIA standard and PSDB standard tests, which can include helmet shell impact and penetration tests, etc. In addition, the helmet can be designed to facilitate the integration of other ancillary accessories such as communication and lighting systems. The addition of these accessories can be selected to maintain the ergonomic fit of the helmet system's weight and center of gravity (CoG), to prevent repetitive use injury to the head and neck complex.

[0059] FIG. 1A illustrates an exemplary embodiment of a helmet system 100 in accordance with the disclosed embodiments. The helmet system 100 generally includes a helmet shell 105. The helmet shell can include occipital lobe protection section 115. A rear brim 130 can be formed as a part of the helmet shell 105.

[0060] The shape of the helmet shell can be selected to provide ergonomic support to prevent repetitive stress injury as further detailed herein. The material of the shell can also be selected to be flame retardant, heat resistant, and to reduce the effect of ballistic impact as further described herein. The embodiments include methods and systems for manufacturing the shell.

[0061] A series of one or more suspension pads 110 can be configured to fit in the helmet shell 105. The suspension pads 110 can be configured to be installed on the helmet shell 105 at various points selected to prevent traumatic brain injury. The suspension pads can be configured with a sandwiched structure as further detailed herein.

[0062] The helmet system 100 can include a web suspension system 120, which is configured to connect to the interior of the helmet shell 105 and serves as the interface between the helmet system 100 and the user's head. The helmet system 100 likewise includes a retention strap system 125 that engages with the helmet shell 105, and is configured to buckle below the user's chin to hold the helmet system 100 on the user's head.

[0063] FIG. 1B illustrates another embodiment of a helmet system 150 in accordance with the disclosed embodiments. Like aspects of helmet system 100 and helmet system 150 are identified with like reference numerals. Aspects of the helmet system 100 and helmet system 150 can be implemented in either embodiment.

[0064] The helmet system 150 comprises a helmet shell 105. The helmet shell 105 can include ribs 155. The helmet shell 105 can further include a built in flashlight 160, and hook and loop attachment 165 where an identifier or other label can be affixed to the shell 105. The helmet shell 105 can include a front brim 170 as well as occipital lobe protection 115. In this embodiment, the rear brim 130 can include a hinge 175 such that the brim is adjustable.

[0065] The helmet system 150 can further include a face shield 180 and ear and neck protector 185. The helmet system 150 includes a chin strap 190. In certain embodiments, the chin strap can be replaced with the retention strap system 125, or can comprise a chin strap 190 as illustrated.

[0066] The helmet system 100 is configured to protect the head against low-velocity impacts. The helmet system 100 is configured to protect the head from fire and high-temperature environments. The helmet system 100 is configured to provide occipital and parietal skull coverage. The helmet system 100 is configured to provide ballistic impact protection. The shape and configuration of the helmet system 100 is selected so that it does not inhibit hearing and visibility. The helmet design and material is selected to be lighter than traditional helmets, with better retention. The helmet system 100 is configured to improve head and neck range of motion. The helmet system is further configured to house other supporting accessories.

[0067] Outer Helmet Shell Design

[0068] The outer helmet shell design is configured to provide at least the minimum shell thickness that withstands NIJ 0101.06 level ballistic impacts, in addition to protecting the head and brain from (sub) traumatic ballistic impacts. The shape and/or profile of the helmet shell 105 provides the required skull coverage, including the occipital bone and temporal bone, to a wide range of users, including both males and females. The outer helmet shell 105 shape and/or profile is further configured to keep the center of gravity within the safe weight and center of gravity limit. The placements (or positions) of ancillary accessories that do not offset the center of gravity from the safe envelope of weight and center of gravity of the helmet.

[0069] Design aspects of the helmet shell include the safe envelope of helmet weight and center of gravity for a wide range of users. Cervical spinal loads and neck muscle activations under various head-neck movements and loading conditions can be considered in selecting the helmet shell design. Weight ranges that yield minimal amounts of flexor and extensor moments are preferrable. Similarly, the CoG envelope can be selected based on minimal lateral bending, flexor, and extensor moments.

[0070] This disclosed helmet shell is configured to be scalable to provide protection to the occipital and temporal bones. The scalable design lets the helmet be used for various mission scenarios. When the temporal and occipital shells are needed, they can be added to the original (baseline) helmet shell.

[0071] The modular concept of the helmet shell design lets the user flexibly switch between mid-cut to full-cut helmets. It provides light weight benefits during prolonged use by switching from full-cut to mid-cut option. It provides full head protection during riot or aggressive missions by attaching temporal and occipital armor segments to the baseline helmet shell, i.e., switching from mid-cut to full-cut option.

[0072] A finite element platform implemented using the computer systems illustrated in FIGs. 7-9, can be used to design helmet shell thickness and profile that reduce traumatic head injuries during ballistic and low-velocity impacts. As the skull thickness varies across the head, the injury mechanism (i.e., stress and deformation relationship) is also different at different head locations. For example, the skull thickness is comparatively lesser in the temporal and occipital regions than in the frontal head. So, the minimal helmet shell thickness should be maintained to provide head impact protection across all areas of the head. In another embodiment, the shell design can be selected to have a comparatively thicker shell in the temporal and occipital regions compared to the frontal region. As such, the thickness and material properties of both helmet shell can be selected according to the expected impact risk.

[0073] In certain embodiments a least square approximation method, implemented with the computer systems illustrated in FIGs. 7-9, can be used to determine the shape of the helmet profile. Parametric and non-parametric statistics can be used to assess different sizes of helmet profiles. The helmet shell can provide the required skull coverage (including the occipital lobe).

[0074] An aspect of the helmet shell design can take account of head-neck range of movement, range of peripheral vision, neck muscle activation, muscle fatigue, balance, and endurance for various head-neck movements and user activities. Neck muscle loading, functional head-neck range of movement, dynamic helmet stability, and eye-tracking data are necessary to understand the peripheral vision limit for helmet shell designs.

[0075] Software including but not limited to Solidworks, MATLAB, OpenSim, and Geomagic can be used to custom design the helmet shell design, using the computer systems illustrated in FIGs. 7-9. The software can be used to process 3D helmet scan data and calculate the weight and center of gravity of the helmet system. During this process, material properties, weight, and center of gravity of individual helmet components can be considered. In certain embodiments, the head and head-helmet 3D CAD model data can be preprocessed with, for example, Geomagic software. The processed scan data are then inputted into aforementioned software platforms to measure the head-helmet dynamic fit. Furthermore, the influences of the various ancillary accessories on the weight and center of gravity can be accounted for as a part of the whole helmet system.

[0076] FIG. 2A illustrates a perspective view of a helmet shell 105 in accordance with the disclosed embodiments. The helmet shell 105 shape can be selected as described *supra*. The shape includes a rounded upper portion 205, and occipital lobe cover 210.

[0077] FIG. 2B illustrates aspects of the helmet shell 105. As illustrated, the interior surface 215 of the helmet shell 105 can be configured to accept suspension pads 110. Pads 110 can be configured in the forward rim 220 of the interior surface 215, along the rear cover 225 of the interior surface, and at other strategic locations as necessary. For example, as illustrated in FIG. 2C additional suspension pads 110 can be configured on the roof 230 of the interior surface 215. FIG. 2D illustrates an aspect of the disclosed embodiments, which includes selecting the shape of the helmet shell 105 to provide an ergonomic center of gravity 235.

[0078] FIG. 2E illustrates a side elevation view of the helmet shell 105, which includes a more hemispherical (i.e., domed) shape 240 with occipital lobe covers 210. FIG. 2F further illustrates a rear elevation view of the helmet shell 105 as it sits on a user's head.

[0079] Suspension Pads

[0080] The suspension pads 110 can be specially configured to improve performance. FIGs. 3A-3D illustrate exemplary embodiments of the suspension pads 110. The suspension pad 110 system can comprise a truss sandwich structure 305, which includes a combination of both open-cell lattice 310 and closed-cell structures 315. The truss sandwich structure 315 provides an increased level of energy absorption in the shear direction. Likewise, the truss sandwich structure 315 can provide greater rotational impact protection by allowing the helmet shell to displace some extents in relation to the skull 320, i.e., releasing a certain amount of energy in the shear direction.

[0081] The rigidity and energy absorption characteristics of the truss sandwich structure 305 depend on the choice of truss structural shape 325 and materials used. Therefore, in certain embodiments the truss structural shape can be selected to provide linear and angular impact attenuation characteristics as well as the greatest rigidity and energy absorption characteristics in the shear direction. In certain embodiments, the truss structural shape can be selected to be triangular, ortho-triangular, and/or honeycomb.

[0082] In certain embodiments, a finite element model of the helmet shell panel, suspension padding system created using software and the computer systems illustrated in FIGs. 7-9, can be used to select the truss sandwich structure 315. In FIG. 3A the structural shape 325 is selected to be triangular. In other embodiments, other structural shapes can be used. For example, FIG. 3B illustrates an ortho-triangular structural shape 330. FIG. 3C illustrates a honeycomb structural shape 335. FIG. 3D illustrates an embodiment, with closed-cell structure 315, as the only component of the truss sandwich structure.

[0083] The energy absorption characteristics of the truss sandwich structure of the suspension pad depends on the materials being chosen. The closed-cell structures 315 can comprise expanded polystyrene for the foams. The open-cell lattice 310 structures can be comprised of thermoplastic polyurethane. It should be appreciated that, in other embodiments, other materials (such as, rubber-based foams or Kevlar-reinforced polyurethane foams) can be used.

[0084] Mechanical properties, such as rigidity and flexibility, and ergonomics, such as anthropometric fit, thermal comfort, and concussion protection, of the suspension pads depend on the thickness of individual layers of open-cell and closed-cell structure as well as the total thickness of the layers and the total thickness of the joined embodiment. An optimization algorithm, implemented using the computer systems illustrated in FIGs. 7-9, can be used to determine the individual thickness and the total thickness of the suspension pads, providing desired mechanical properties and ergonomic benefits.

[0085] In addition to the structure of the suspension pads 110, the shape and location of the suspension pads 110 can be selected to optimize impact resistance. FIG. 4A illustrates a selection of suspension pads 110 and their relative locations in the helmet shell 105. In an embodiment, a plurality of frontal pads 405 can comprise generally rectangular pads configured to fit, side by side in the helmet shell. In addition, a top suspension pad 410 can be configured to fit in the top portion of the helmet shell 105. The top suspension pad 410 can be configured to be substantially circular to match the general shape of the top of a user's head. Finally, a series of rear suspension pads 415 can be configured along the rear of the helmet shell 105. FIG. 4B illustrates the relative interface of the suspension pads 110 on a user's skull 320.

[0086] FIG. 4C further illustrates aspects of the suspension pads 110, including the frontal pads 405, top suspension pad 410, and the rear suspension pads 415. As illustrated the frontal pads can be sized and shaped differently to account for impact minimization and the shape of the internal surface of the helmet shell 105 and/or to improve fit for a specific user.

[0087] The design of the suspension pad is selected to provide the highest oblique (shear force) impact protection. The materials can be selected to provide both rigidity and flexibility. The thickness of each layer can also be selected to optimize and the total layer that facilitate the greatest impact attenuation.

[0088] Helmet Shell Material

[0089] The helmet shell 105 can be configured as a single sheet with a plurality of layers. In an embodiment, a ballistic Kevlar shell can be fabricated by infusing layers of Kevlar fabrics. For example, the shell design can be made by infusing Kevlar 29 fabrics (or other such materials) with the polymeric resin to make the shell. Depending on the infusion process, the layering of the shell can be made up of 10 - 24 layers. The individual layers can be cut to account for the flat aspect of the fabric so that it can conform and drape to the shape of the helmet shell as required. In order to provide the required thermal properties, Kevlar fabrics are infused as opposed to the use of one solid Kevlar layer. It should be appreciated that the fibers can be weaved into a fabric. This lamination procedure offers superior properties because the "rope-like" fibers are stabilized by the polymeric resin. Various resins can be used to infuse the Kevlar fabrics.

[0090] The helmet shell 105 can be formed using plaques with various thicknesses using the selected thermosetting resins and Kevlar® 29 fabrics. The purpose of fabricating such a ballistic plaque is to ensure that the selected materials can meet the NIJ 0101.06 ballistic standards, as well as estimating the required thickness of the fabricated composite helmet shell to endure the ballistic impact. Thickness of the plaques is an important parameter. Thickness can be selected based on ballistic tests and numerical simulations.

[0091] The embodiments disclosed herein are configured such that the material can offers both ballistic protection and thermal protection. By choosing the correct composite material, both the resin and the fabric parts can contribute to the desired properties. The ballistic protection is provided mainly from the Kevlar® (poly-paraphenylene terephthalamide, also known as para-aramid) fabrics, specifically Kevlar® 29 which is a high toughness commercial ballistic grade material. Kevlar® KM2+ can also be selected for its enhanced ballistic resistance.

[0092] Ultra-high molecular weight polyurethane (UHMWPE) Dyneema and UHMWPE Spectra and Kevlar 29 with carbon fiber are also considered to make the helmet light weight and improve ballistic protection.

[0093] Some level of thermal protection is mainly provided by the thermosetting resins. Thermosetting resins are polymers that form a rigid 3D network of covalent bonds by crosslinking the polymer chains upon curing. By using a thermosetting resin, the helmet shell can sustain higher temperatures without deforming or warping significantly. The thermosetting resins can be selected to have a high glass transition temperature (T) upon post-curing of approximately 200 $°C$ and above. Note, it may not be necessary to use an extremely high glass transition temperature. The reason for the selection of such a resin is that the thermosetting nature of the resin ensures the high temperature integrity for short time exposures (which is what is required for the disclosed application). Thus, in other embodiments, other resins can be used (e.g., a lower Tg resin) provided that the glasses do not melt.

[0094] The resins can have low viscosity before curing which ensures that they can be processed by vacuum infusion methods as disclosed herein. In the disclosed embodiments, the resins can comprise epoxy resins, PVB-phenolic resins, cyanate ester resins and “Grubbs-catalyst” type dicyclopentadiene (DCPD) resin for consideration.

[0095] The raw materials can also be selected to make the helmets affordable. For the above reasons, the thermosetting resins are selected including a commercial epoxy resin PT5760 from PTM&W Industries, Inc. and a commercial DCPD resin Proxima®.

[0096] Kevlar® 29 3000 denier and Kevlar® KM2+ 850 denier fabrics can have density of 1.44 $g/cm3$. The Kevlar® 29 fabrics can be plain weaved with 17 warp count and 17 fill count. Tensile strength of Kevlar® 29 is 2.9 GPa and tensile modulus is 75 GPa. The Kevlar® KM2+ 850D fabrics are plain weaved with 23 warp count and 23 fill count. Tensile strength of Kevlar® KM2+ is 3.4 GPa and tensile modulus is 81 GPa. The decomposition temperature for both Kevlar® 29 and Kevlar® KM2+ is 450 $°C$.

[0097] The thermal property of a cured resin is dependent on the details of the curing cycle. Specifically, the relationship between the conversion and the glass transition temperature as well as the cure time and the glass transition temperature can be obtained to determine the optimal cycle for the resin cure to achieve the desired glass transition temperature for the performance requirements.

[0098] Manufacturing Process

[0099] The helmet shell 105 can be configured of ballistic plaques as detailed herein. In certain embodiments, the ballistic plaque can be fabricated using a Vacuum-Assisted Resin Transfer Molding (VARTM) process in a custom designed mold, as illustrated in system 500 of FIG. 5. FIG. 6A illustrates the custom designed mold 600.

[00100] The system 500 comprises a vacuum pump 510 connected to a vacuum bag 515. The vacuum pump includes a flexible vacuum hose 520 regulated with a vacuum control valve 525, and vacuum throttle valve 530. The connection can include a trap 535, and port 540. The vacuum can be monitored with a vacuum gauge 545.

[00101] In the VARTM process, fabrics can be layered up in a one-sided mold 550 as illustrated in FIG. 5, and the vacuum bag 515 is placed over the top of the mold 550 to form a vacuum-tight seal. One or several inlet hoses 520 are placed through vacuum bag 515 at various locations to infuse the resin into the mold 550, and an outlet hose is connected to the vacuum trap 535, which is used to contain any resin flowing out of the mold 550. The vacuum trap 535 is then connected to the vacuum pump 510 to create a vacuum for the resin to be drawn by vacuum through the fabric layers to facilitate wet out of the fabrics. The reactive mixture is fed into the mold 550 inside a convection oven or other type of heating system. Both resin and mold are preheated to elevated temperature to reduce viscosity and facilitate the infusion. Once infusion is complete, the resin feed is removed and the temperature inside the oven is increased to the desired curing temperature for reaction.

[00102] In certain embodiments, the fabric layers can include a breather material 555, an optional perforated film 560, a release fabric 565, plies of laminate 570, and a mastic sealant 575.

[00103] During the fabrication of the composite plaque, warpage due to residual stress is possible. This can be addressed by employing a ply orientation of [0°/– 45°/90°] initially, but if the number of plies increases in the laminate, other stacking sequences can be chosen. to obtain a quasi-isotropic laminate, and by making a top plate to the present mold to compress the fabric during cure and post cure process to help reduce/remove the warpage. The design for the top plate 650 is illustrated in FIG. 6B.

[00104] Aspects of the design methods illustrated herein can be completed and/or controlled by a computer system. FIGS. 7-9 are provided as exemplary diagrams of data-processing environments in which embodiments may be implemented. It should be appreciated that FIGS. 7-9 are only exemplary and are not intended to assert or imply any limitation with regard to the environments in which aspects or embodiments of the disclosed embodiments may be implemented. Many modifications to the depicted environments may be made without departing from the spirit and scope of the disclosed embodiments.

[00105] A block diagram of a computer system 700 that executes programming for implementing parts of the methods and systems disclosed herein is provided in FIG. 7. A computing device in the form of a computer 710 configured to interface with controllers, peripheral devices, and other elements disclosed herein may include one or more processing units 702, memory 704, removable storage 712, and non-removable storage 714. Memory 704 may include volatile memory 706 and non-volatile memory 708. Computer 710 may include or have access to a computing environment that includes a variety of transitory and non-transitory computer-readable media such as volatile memory 706 and non-volatile memory 708, removable storage 712 and non-removable storage 714. Computer storage includes, for example, random access memory (RAM), read only memory (ROM), erasable programmable read-only memory (EPROM) and electrically erasable programmable read-only memory (EEPROM), flash memory or other memory technologies, compact disc read-only memory (CD ROM), Digital Versatile Disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage, or other magnetic storage devices, or any other medium capable of storing computer-readable instructions, as well as data including image data.

[00106] Computer 710 may include, or have access to, a computing environment that includes input 716, output 718, and a communication connection 720. The computer may operate in a networked environment using a communication connection 720 to connect to one or more remote computers, remote sensors and/or controllers, detection devices, hand-held devices, multi-function devices (MFDs), speakers, mobile devices, tablet devices, mobile phones, Smartphone, or other such devices. The remote computer may also include a personal computer (PC), server, router, network PC, RFID enabled device, a peer device or other common network node, or the like. The communication connection may include a Local Area Network (LAN), a Wide Area Network (WAN), Bluetooth connection, or other networks. This functionality is described more fully in the description associated with FIG. 8 below.

[00107] Output 718 is most commonly provided as a computer monitor, but may include any output device. Output 718 and/or input 716 may include a data collection apparatus associated with computer system 700. In addition, input 716, which commonly includes a computer keyboard and/or pointing device such as a computer mouse, computer track pad, or the like, allows a user to input instructions to computer system 700. A user interface can be provided using output 718 and input 716. Output 718 may function as a display for displaying data and information for a user, and for interactively displaying a graphical user interface (GUI) 730.

[00108] Note that the term “GUI” generally refers to a type of environment that represents programs, files, options, and so forth by means of graphically displayed icons, menus, and dialog boxes on a computer monitor screen. A user can interact with the GUI to select and activate such options by directly touching the screen and/or pointing and clicking with a user input device 716 such as, for example, a pointing device such as a mouse, and/or with a keyboard. A particular item can function in the same manner to the user in all applications because the GUI provides standard software routines (e.g., module 725) to handle these elements and report the user’s actions. The GUI can further be used to display the electronic service image frames as discussed below.

[00109] Computer-readable instructions, for example, program module or node 725, which can be representative of other modules or nodes described herein, are stored on a computer-readable medium and are executable by the processing unit 702 of computer 710. Program module or node 725 may include a computer application. A hard drive, CD-ROM, RAM, Flash Memory, and a USB drive are just some examples of articles including a computer-readable medium.

[00110] FIG. 8 depicts a graphical representation of a network of data-processing systems 800 in which aspects of the present invention may be implemented. Network data-processing system 800 can be a network of computers or other such devices, such as mobile phones, smart phones, sensors, controllers, actuators, speakers, “internet of things” devices, and the like, in which embodiments of the present invention may be implemented. Note that the system 800 can be implemented in the context of a software module such as program module 725. The system 800 includes a network 802 in communication with one or more clients 810, 812, and 814. Network 802 may also be in communication with one or more devices 804, servers 806, and storage 808. Network 802 is a medium that can be used to provide communications links between various devices and computers connected together within a networked data processing system such as computer system 700. Network 802 may include connections such as wired communication links, wireless communication links of various types, and fiber optic cables. Network 802 can communicate with one or more servers 806, one or more external devices such as device 804, and a memory storage unit such as, for example, memory or database 808. It should be understood that device 804 may be embodied as a detector device, controller, receiver, transmitter, transceiver, transducer, driver, signal generator, testing apparatus, control system for an autonomous vehicle or other such device.

[00111] In the depicted example, device 804, server 806, and clients 810, 812, and 814 connect to network 802 along with storage unit 808. Clients 810, 812, and 814 may be, for example, personal computers or network computers, handheld devices, mobile devices, tablet devices, smart phones, personal digital assistants, controllers, recording devices, speakers, MFDs, etc. Computer system 700 depicted in FIG. 7 can be, for example, a client such as client 810 and/or 812 and/or 814.

[00112] Computer system 700 can also be implemented as a server such as server 806, depending upon design considerations. In the depicted example, server 806 provides data such as boot files, operating system images, applications, and application updates to clients 810, 812, and/or 814. Clients 810, 812, and 814 and device 804 are clients to server 806 in this example. Network data-processing system 800 may include additional servers, clients, and other devices not shown. Specifically, clients may connect to any member of a network of servers, which provide equivalent content.

[00113] In the depicted example, network data-processing system 800 is the Internet, with network 802 representing a worldwide collection of networks and gateways that use the Transmission Control Protocol/Internet Protocol (TCP/IP) suite of protocols to communicate with one another. At the heart of the Internet is a backbone of high-speed data communication lines between major nodes or host computers consisting of thousands of commercial, government, educational, and other computer systems that route data and messages. Of course, network data-processing system 800 may also be implemented as a number of different types of networks such as, for example, an intranet, a local area network (LAN), or a wide area network (WAN). FIGS. 7 and 8 are intended as examples and not as architectural limitations for different embodiments of the present invention.

[00114] FIG. 9 illustrates a software system 900, which may be employed for directing the operation of the data-processing systems such as computer system 700 depicted in FIG. 7. Software application 905, may be stored in memory 704, on removable storage 712, or on non-removable storage 714 shown in FIG. 7, and generally includes and/or is associated with a kernel or operating system 910 and a shell or interface 915. One or more application programs, such as module(s) or node(s) 725, may be “loaded” (i.e., transferred from removable storage 714 into the memory 704) for execution by the data-processing system 700. The data-processing system 700 can receive user commands and data through user interface 915, which can include input 716 and output 718, accessible by a user 920. These inputs may then be acted upon by the computer system 700 in accordance with instructions from operating system 910 and/or software application 905 and any software module(s) 725 thereof.

[00115] Generally, program modules (e.g., module 725) can include, but are not limited to, routines, subroutines, software applications, programs, objects, components, data structures, etc., that perform particular tasks or implement particular abstract data types and instructions. Moreover, those skilled in the art will appreciate that elements of the disclosed methods and systems may be practiced with other computer system configurations such as, for example, hand-held devices, mobile phones, smart phones, tablet devices multi-processor systems, microcontrollers, printers, copiers, fax machines, multi-function devices, data networks, microprocessor-based or programmable consumer electronics, networked personal computers, minicomputers, mainframe computers, servers, medical equipment, medical devices, and the like.

[00116] Note that the term “module” or “node” as utilized herein may refer to a collection of routines and data structures that perform a particular task or implements a particular abstract data type. Modules may be composed of two parts: an interface, which lists the constants, data types, variables, and routines that can be accessed by other modules or routines; and an implementation, which is typically private (accessible only to that module), and which includes source code that actually implements the routines in the module. The term module may also simply refer to an application such as a computer program designed to assist in the performance of a specific task such as word processing, accounting, inventory management, etc., or a hardware component designed to equivalently assist in the performance of a task.

[00117] The interface 915 (e.g., a graphical user interface 730) can serve to display results, whereupon a user 920 may supply additional inputs or terminate a particular session. In some embodiments, operating system 910 and GUI 730 can be implemented in the context of a “windows” system. It can be appreciated, of course, that other types of systems are possible. For example, rather than a traditional “windows” system, other operation systems such as, for example, a real-time operating system (RTOS) more commonly employed in wireless systems may also be employed with respect to operating system 910 and interface 915. The software application 905 can include, for example, module(s) 725, which can include instructions for carrying out steps or logical operations such as those shown and described herein.

[00118] The description is presented with respect to embodiments of the present invention, which can be embodied in the context of, or require the use of, a data-processing system such as computer system 700, in conjunction with program module 725, and data-processing system 800 and network 802 depicted in FIGS. 7-9. The present invention, however, is not limited to any particular application or any particular environment. Instead, those skilled in the art will find that the system and method of the present invention may be advantageously applied to a variety of system and application software including database management systems, word processors, and the like. Moreover, the present invention may be embodied on a variety of different platforms including Windows, Macintosh, UNIX, LINUX, Android, Arduino, LabView and the like. Therefore, the descriptions of the exemplary embodiments, which follow, are for purposes of illustration and not considered a limitation.

Based on the foregoing, it can be appreciated that a number of embodiments, preferred and alternative, are disclosed herein. In an embodiment, a helmet system comprises a helmet shell, at least one suspension pad configured in the helmet shell, and a suspension web.

[00119] In an embodiment the helmet shell further comprises modular helmet shell segments. In an embodiment, the helmet shell further comprises an occipital lobe protection section configured to cover the occipital lobe.

[00120] In an embodiment, the helmet system further comprises a retention strap system.

[00121] In an embodiment, the helmet shell further comprises a rear brim. In an embodiment, the helmet shell further comprises a plurality of layers of Kevlar fabric infused with resin.

[00122] In an embodiment, the helmet shell is configured with vacuum-assisted resin transfer molding.

[00123] In an embodiment, the helmet shell is configured to be heat resistant, flame retardant, and bullet proof.

[00124] In an embodiment of the helmet system, the at least one suspension pad further comprises a first layer of foam, a second layer of foam, and an open cell lattice sandwiched between the first layer of foam and the second layer of foam. In an embodiment, the open cell lattice comprises a triangular open cell lattice. In an embodiment, the at least one suspension pad further comprises at least one frontal pad, a top suspension pad, and at least one rear suspension pad.

[00125] In an embodiment, the helmet system further comprises a face shield operably connected to the helmet shell.

[00126] In an embodiment, helmet system of claim further comprises an ear and neck protector mesh.

[00127] In another embodiment, a helmet comprises a helmet shell comprising an occipital lobe protection section configured to cover the occipital lobe and a temporal lobe protection section configured to cover the temporal lobe, at least one suspension pad configured in the helmet shell comprising a first layer of foam, a second layer of foam, and an open cell lattice, and a suspension web.

[00128] In an embodiment the helmet shell further comprises a plurality of layers of fabric infused with resin, the layers of fabric comprising at least one of: UHMWPE Dyneema; UHMWPE Spectra; and Kevlar 29 with carbon fiber reinforcement. In an embodiment, the open cell lattice comprises a triangular open cell lattice. In an embodiment, the at least one suspension pad further comprises: at least one frontal pad, a top suspension pad, and at least one rear suspension pad.

[00129] In an embodiment, a method for fabricating helmets comprises forming a helmet shell of layered Kevlar and resin and forming a plurality of suspension pads for installation on an inner surface of the helmet shell. In an embodiment, forming the helmet shell of layered Kevlar and resin further comprises vacuum-assisted resin transfer molding the helmet shell. In an embodiment, forming the plurality of suspension pads further comprises forming an open cell lattice and inserting the open cell lattice between a first layer of foam and a second layer of foam. In an embodiment, the method further comprises configuring the helmet shell with a center of mass selected to reduce repetitive stress injury.

[00130] It will be appreciated that variations of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also, it should be appreciated that various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

CLAIMS

What is claimed is:

1. A helmet system comprising:
   a helmet shell;
   at least one suspension pad configured in the helmet shell; and
   a suspension web.

2. The helmet system of claim 1 wherein the helmet shell further comprises:
   modular helmet shell segments.

3. The helmet system of claim 1 further comprising:
   a retention strap system.

4. The helmet system of claim 1 wherein the helmet shell further comprises:
   an occipital lobe protection section configured to cover the occipital lobe; and
   a rear brim.

5. The helmet system of claim 1 wherein the helmet shell further comprises:
   a plurality of layers of Kevlar fabric infused with resin.

6. The helmet system of claim 1 wherein the helmet shell is configured with vacuum-assisted resin transfer molding.

7. The helmet system of claim 1 wherein the helmet shell is configured to be heat resistant, flame retardant, and bullet proof.

8. The helmet system of claim 1 wherein the at least one suspension pad further comprises:
   a first layer of foam;
   a second layer of foam; and
   an open cell lattice sandwiched between the first layer of foam and the second layer of foam.

9. The helmet system of claim 8 wherein the open cell lattice comprises:

a triangular open cell lattice.

10. The helmet system of claim 1 wherein the at least one suspension pad further comprises:

at least one frontal pad;

a top suspension pad; and

at least one rear suspension pad.

11. The helmet system of claim 1 further comprising:

a face shield operably connected to the helmet shell.

12. The helmet system of claim 1 further comprising:

an ear and neck protector mesh.

13. A helmet comprising:

a helmet shell comprising an occipital lobe protection section configured to cover the occipital lobe and a temporal lobe protection section configured to cover the temporal lobe;

at least one suspension pad configured in the helmet shell comprising a first layer of foam, a second layer of foam, and an open cell lattice; and

a suspension web.

14. The helmet of claim 13 wherein the helmet shell further comprises:

a plurality of layers of fabric infused with resin, the layers of fabric comprising at least one of:

UHMWPE Dyneema;

UHMWPE Spectra; and

Kevlar 29 with carbon fiber reinforcement.

15. The helmet of claim 13 wherein the open cell lattice comprises:

a triangular open cell lattice.

16. The helmet system of claim 13 wherein the at least one suspension pad further comprises:

at least one frontal pad;

a top suspension pad; and

at least one rear suspension pad.

17. A method for fabricating helmets comprising:

forming a helmet shell of layered Kevlar and resin; and

forming a plurality of suspension pads for installation on an inner surface of the helmet shell.

18. The method of claim 17 wherein forming the helmet shell of layered Kevlar and resin further comprises:

vacuum-assisted resin transfer molding the helmet shell.

19. The method of claim 17 wherein forming the plurality of suspension pads further comprises:

forming an open cell lattice; and

inserting the open cell lattice between a first layer of foam and a second layer of foam.

20. The method of claim 19 further comprising:

configuring the helmet shell with a center of mass selected to reduce repetitive stress injury.

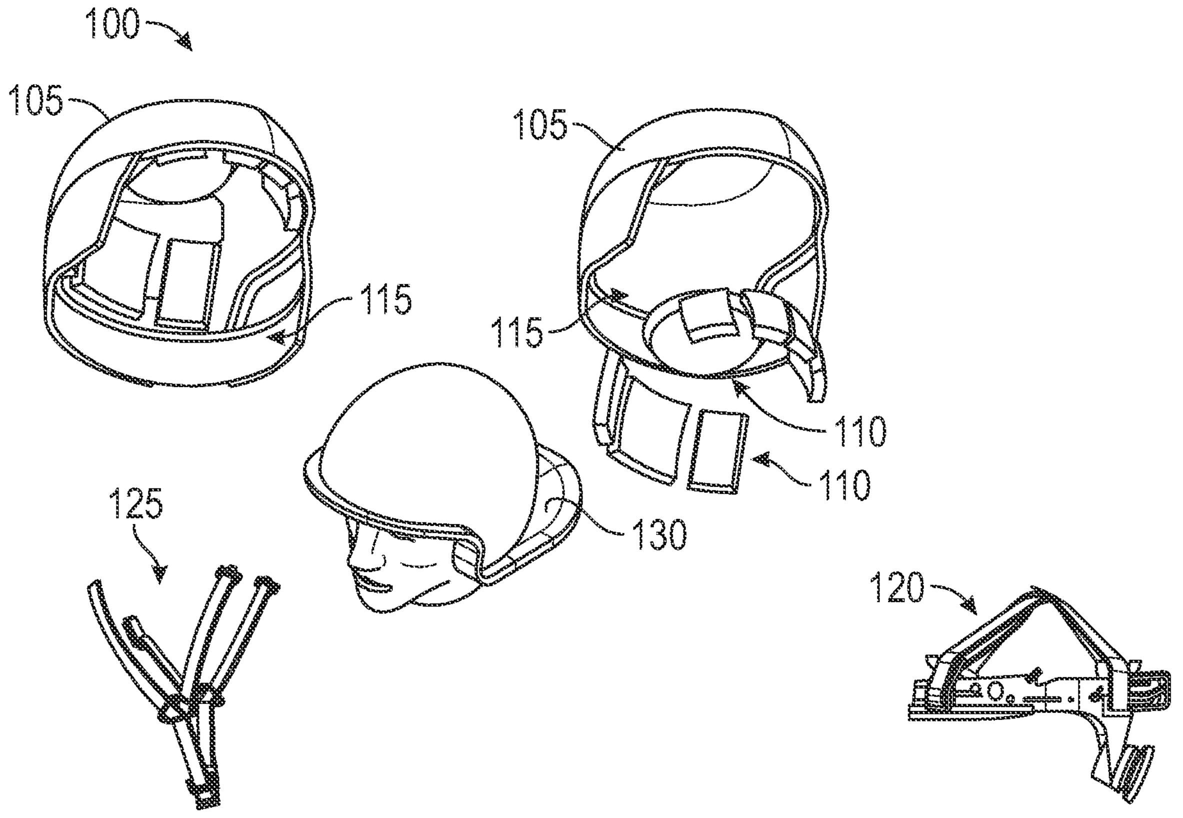
100
105
115
105
115
110
110
130
125
120

FIG. 1A

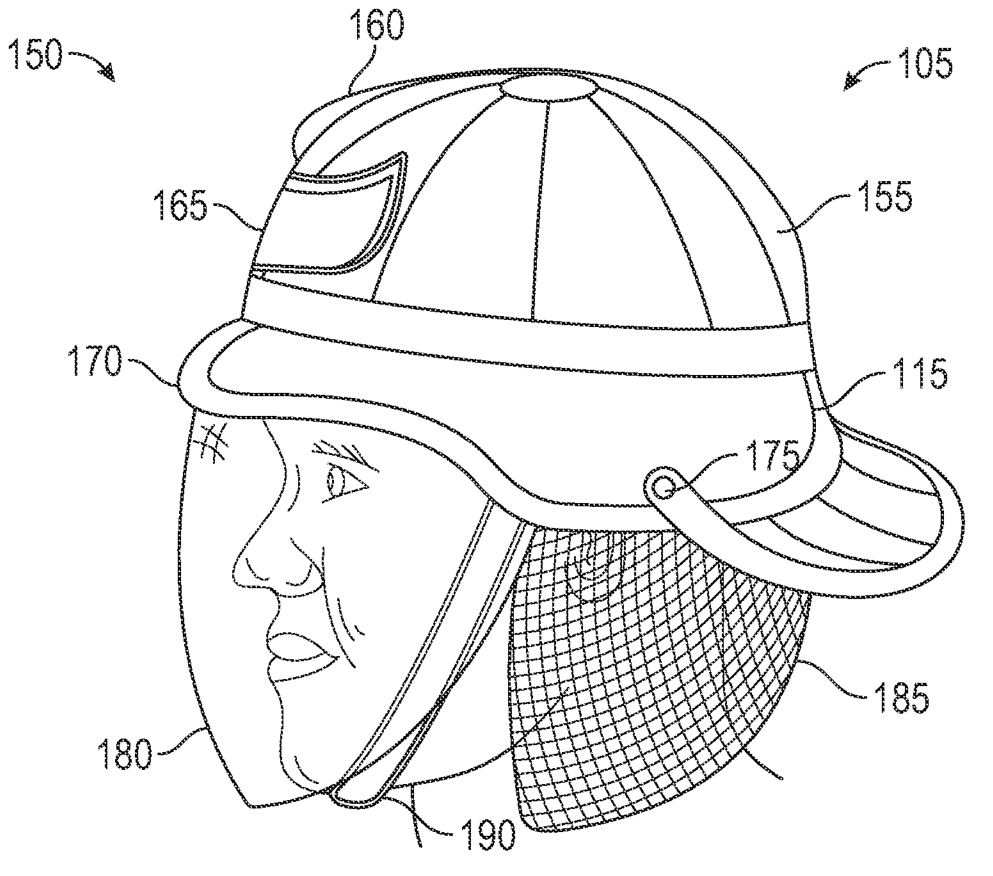
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FIG. 1B

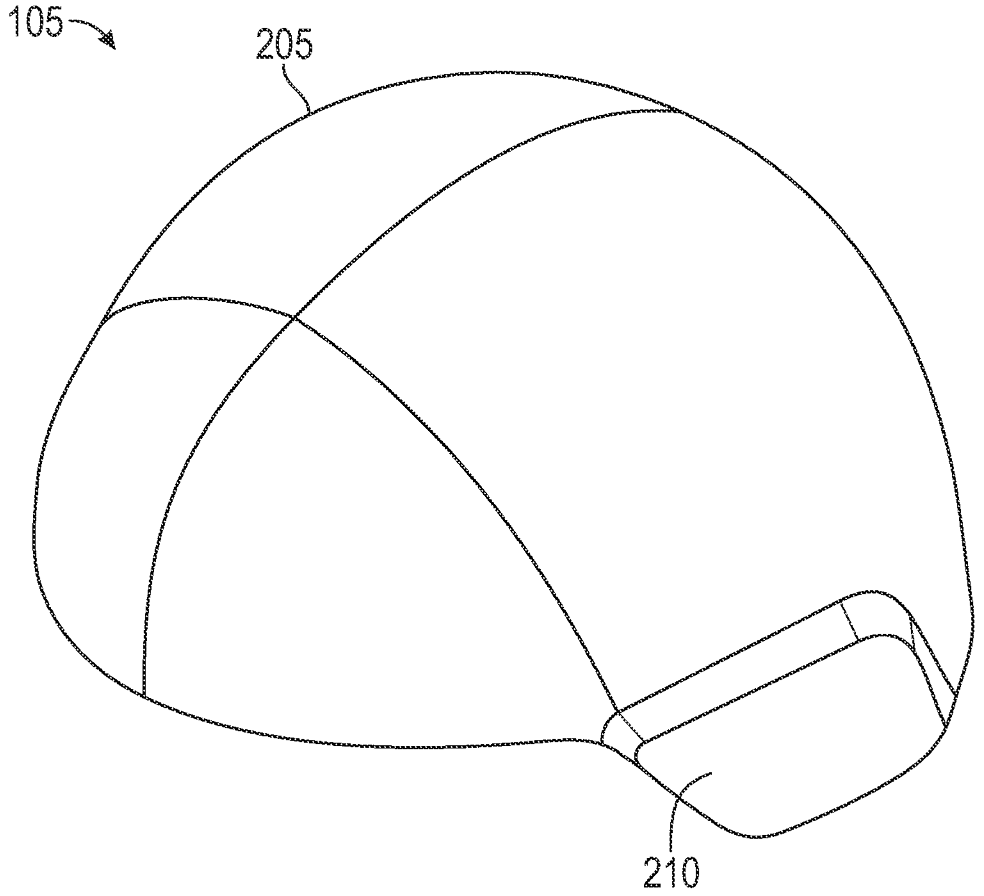

FIG. 2A

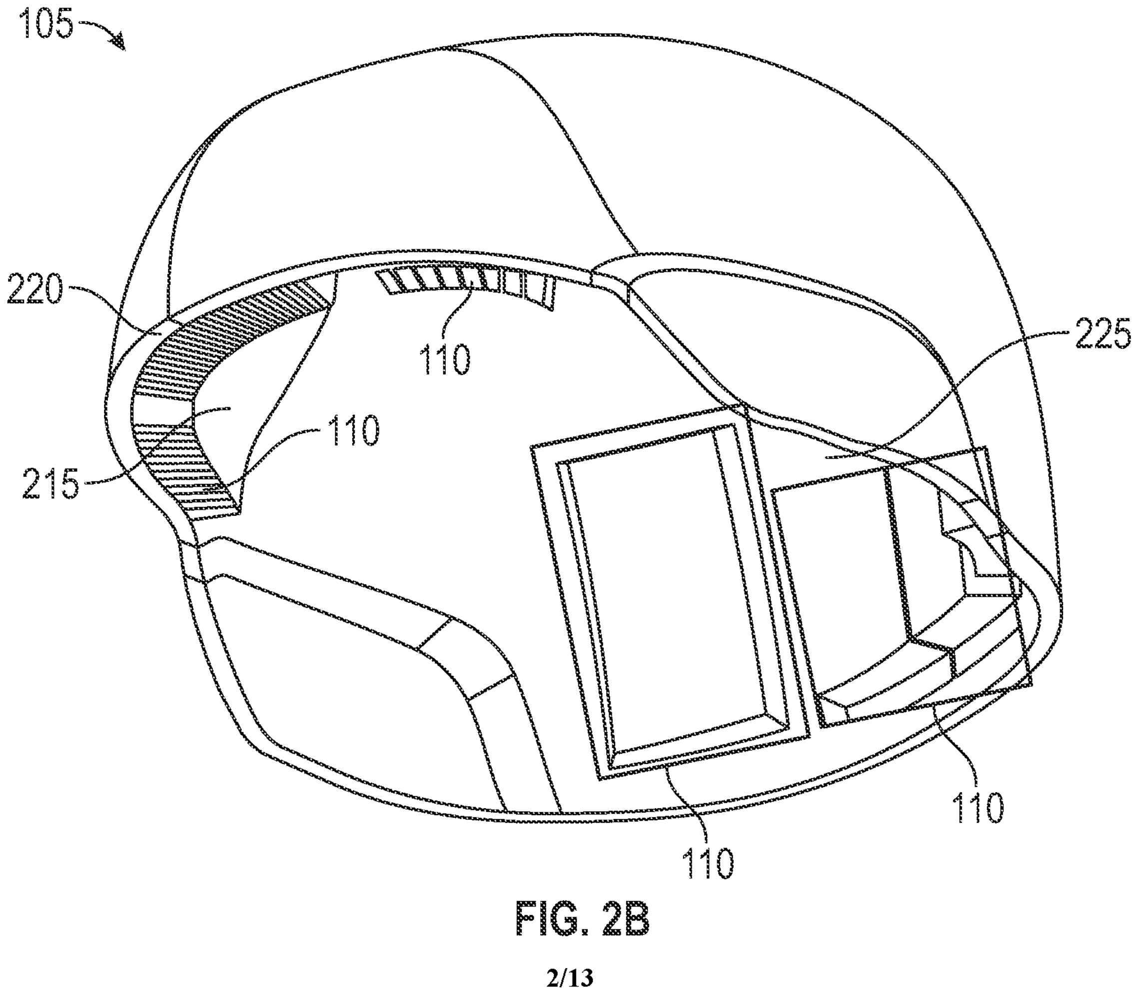

FIG. 2B

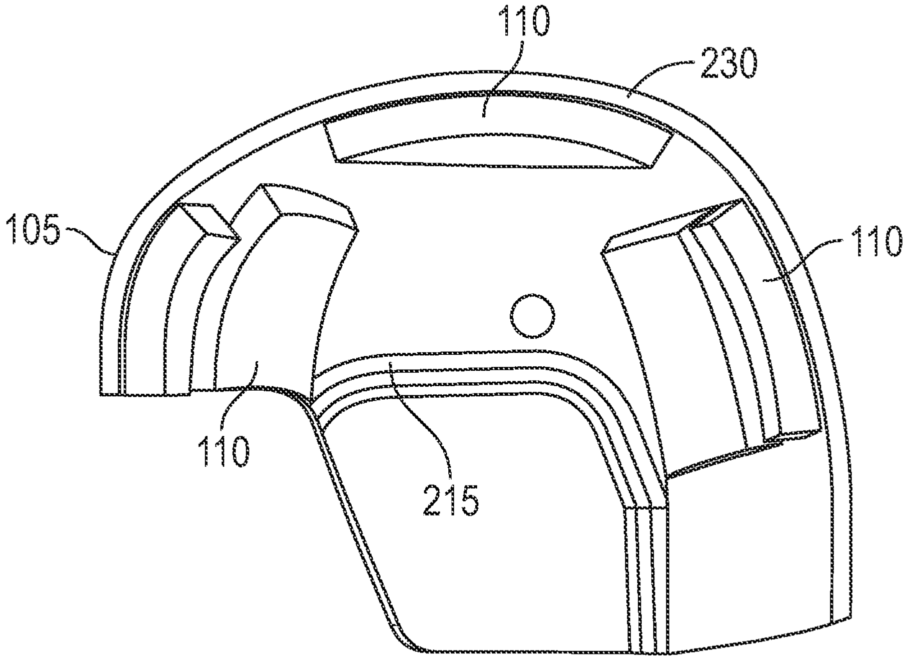

FIG. 2C

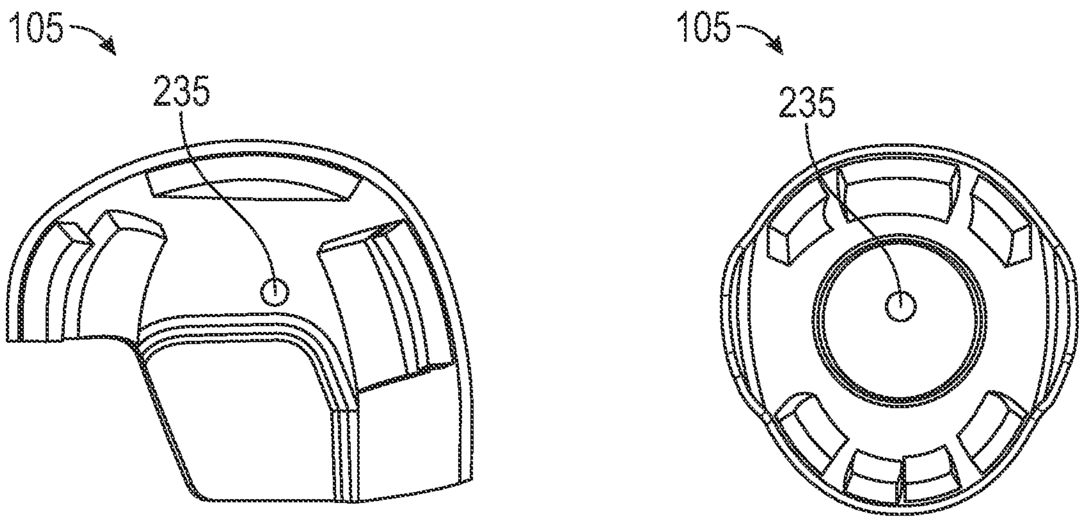

FIG. 2D

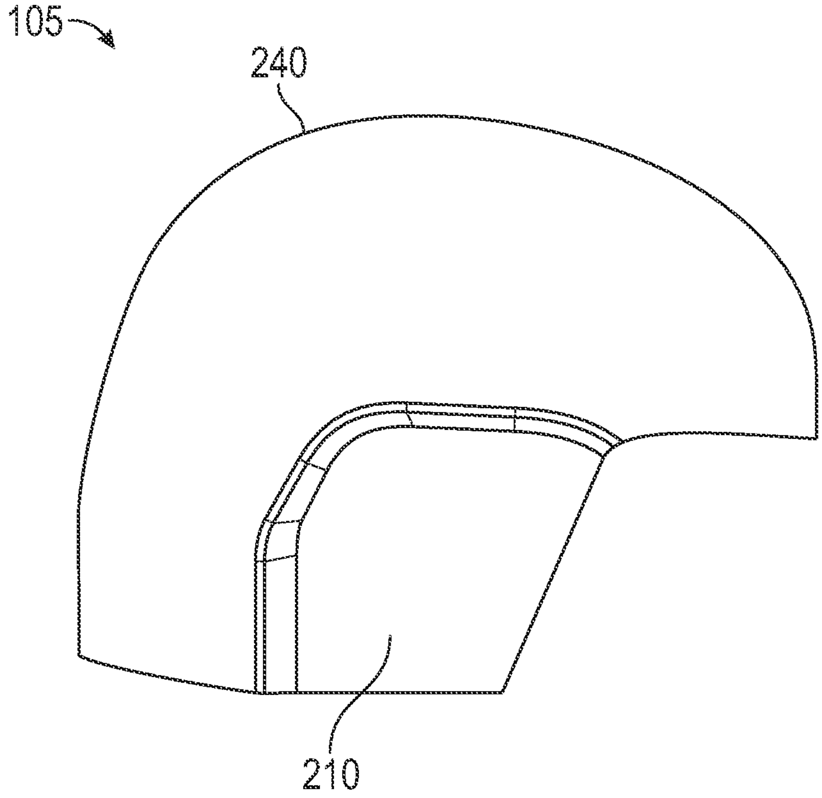

FIG. 2E

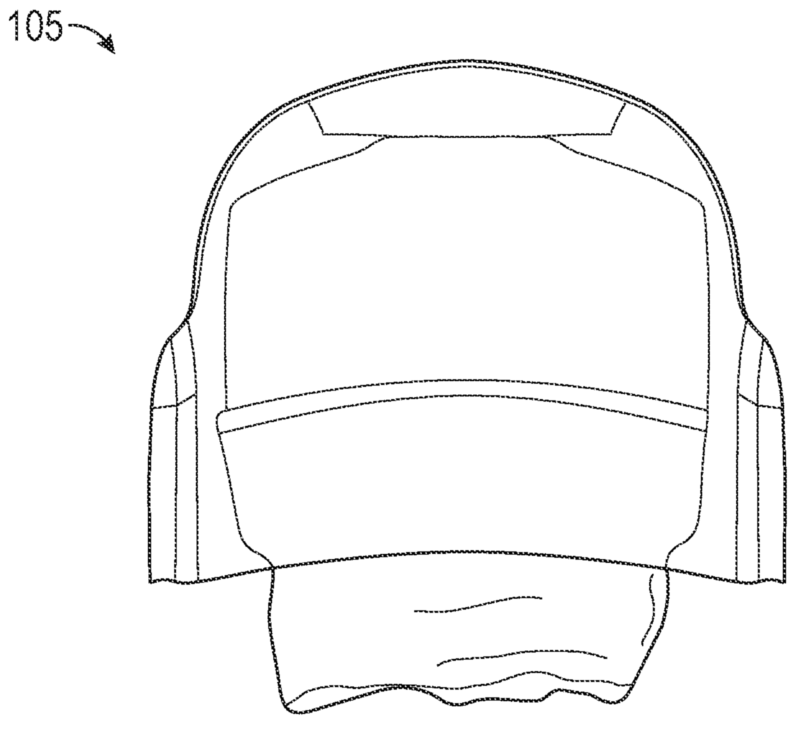

FIG. 2F

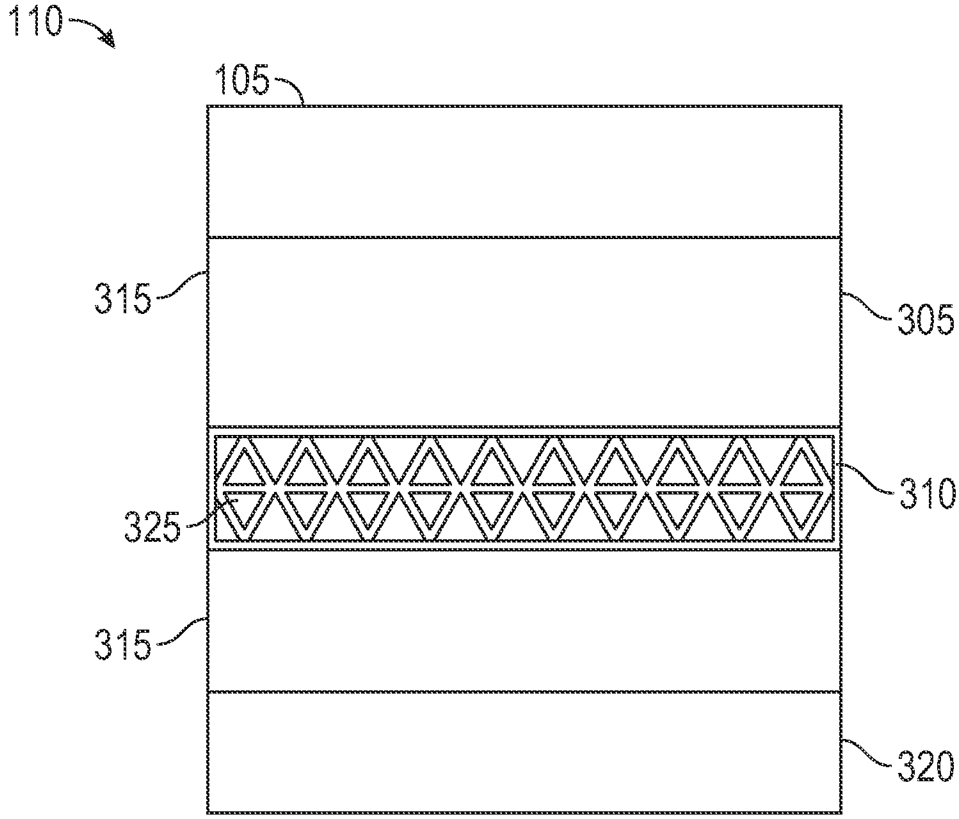

FIG. 3A

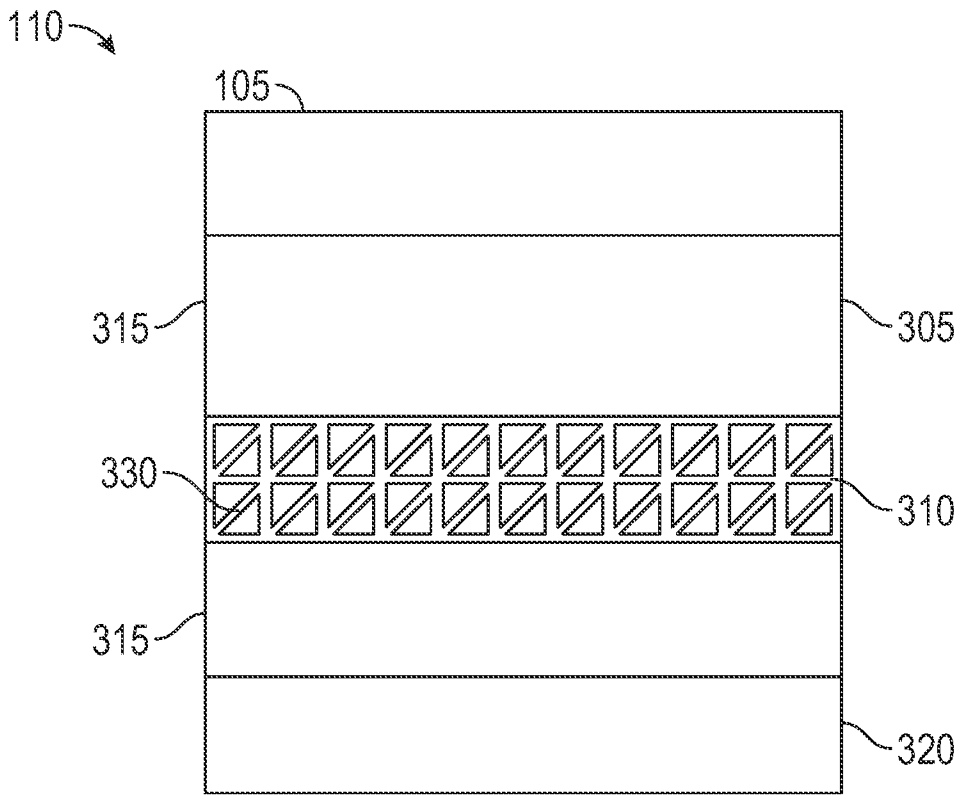

FIG. 3B

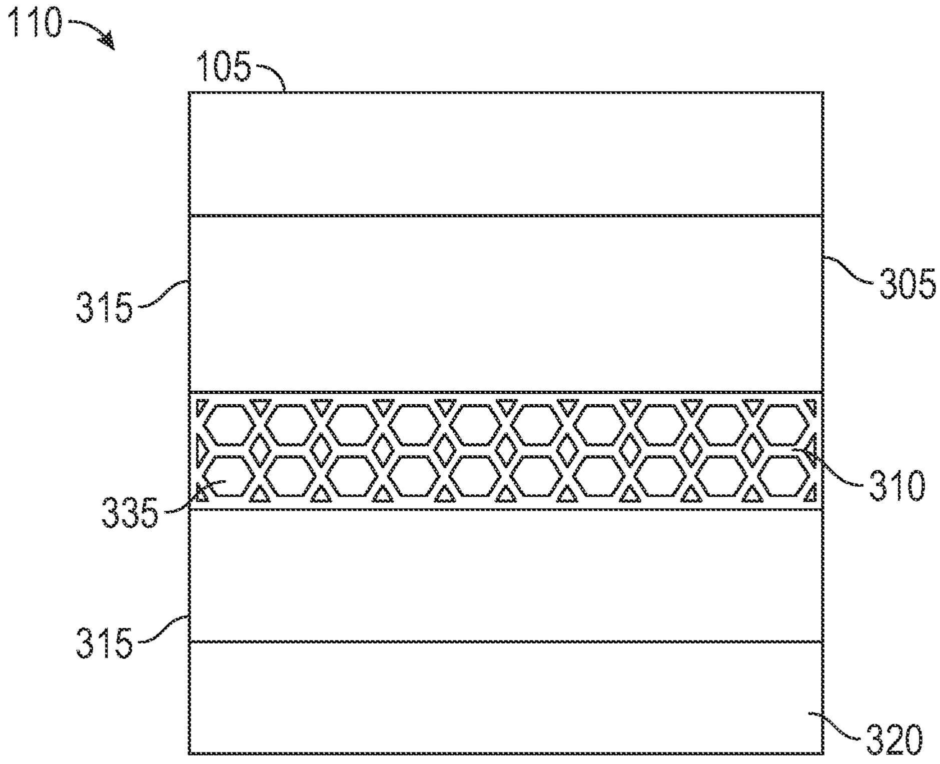

FIG. 3C

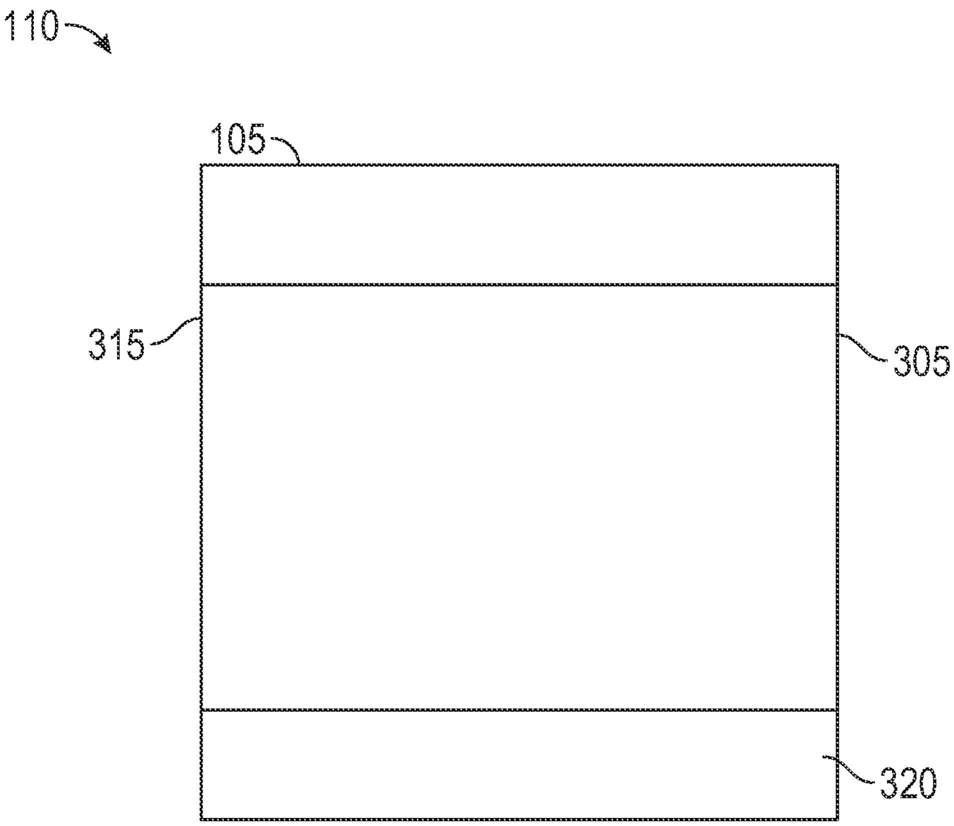

FIG. 3D

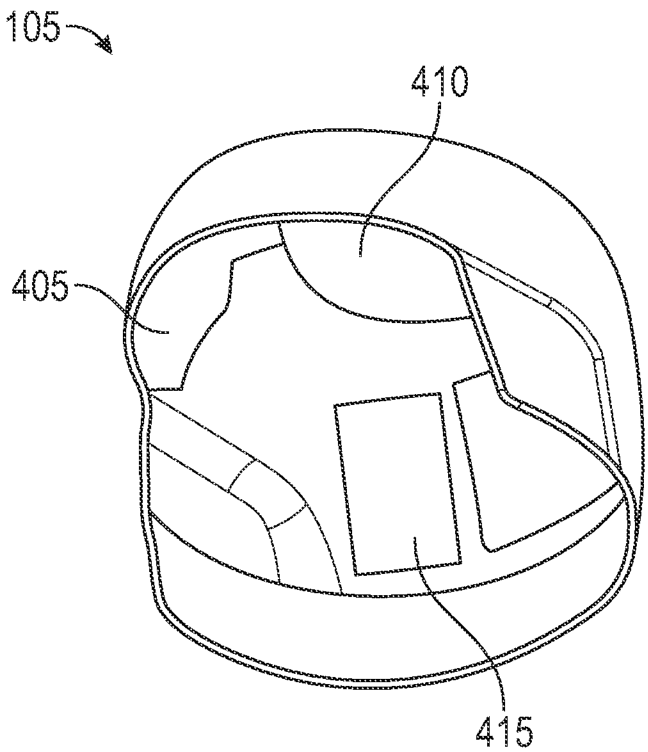

FIG. 4A

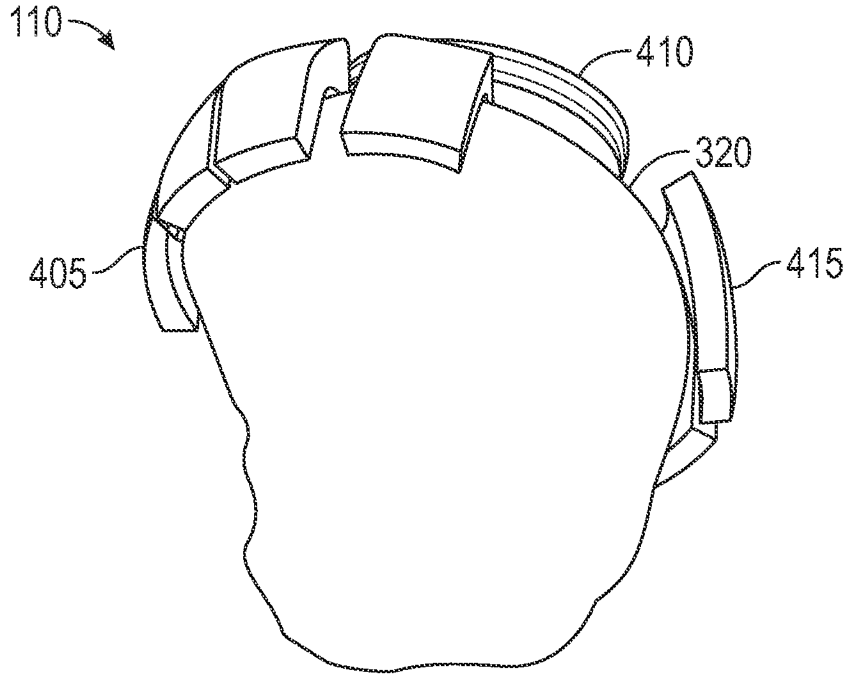

FIG. 4B

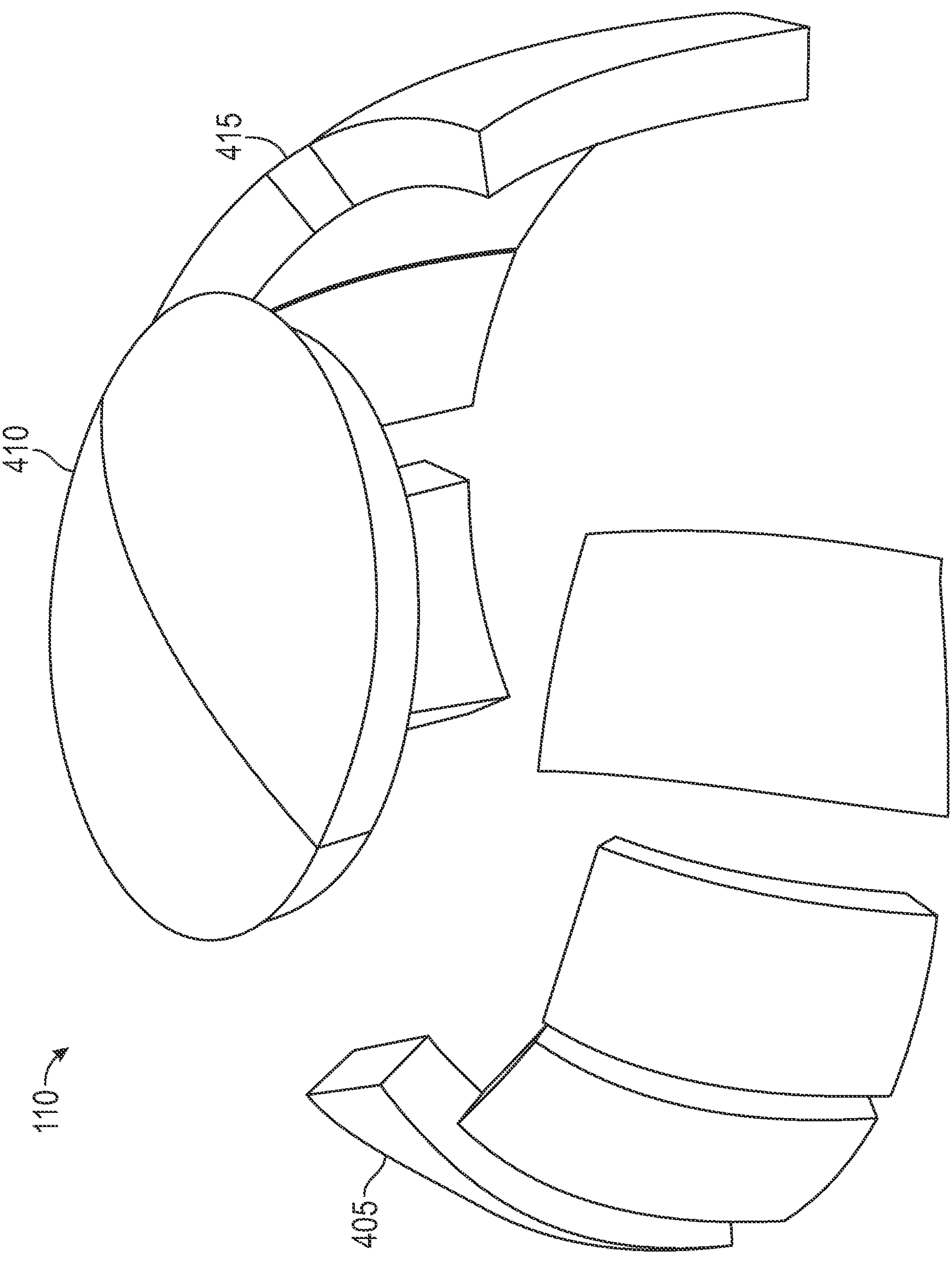

FIG. 4C

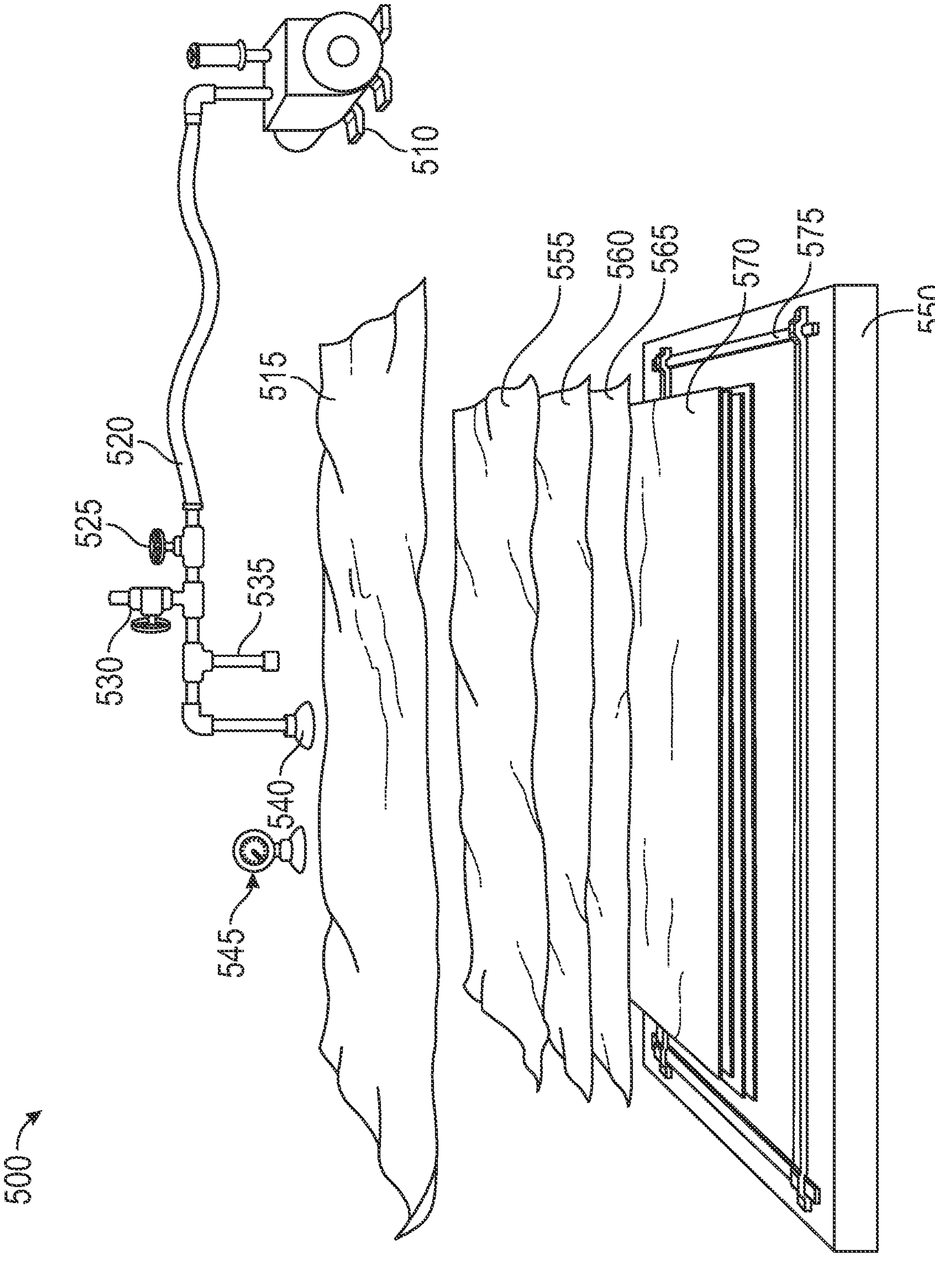

FIG. 5

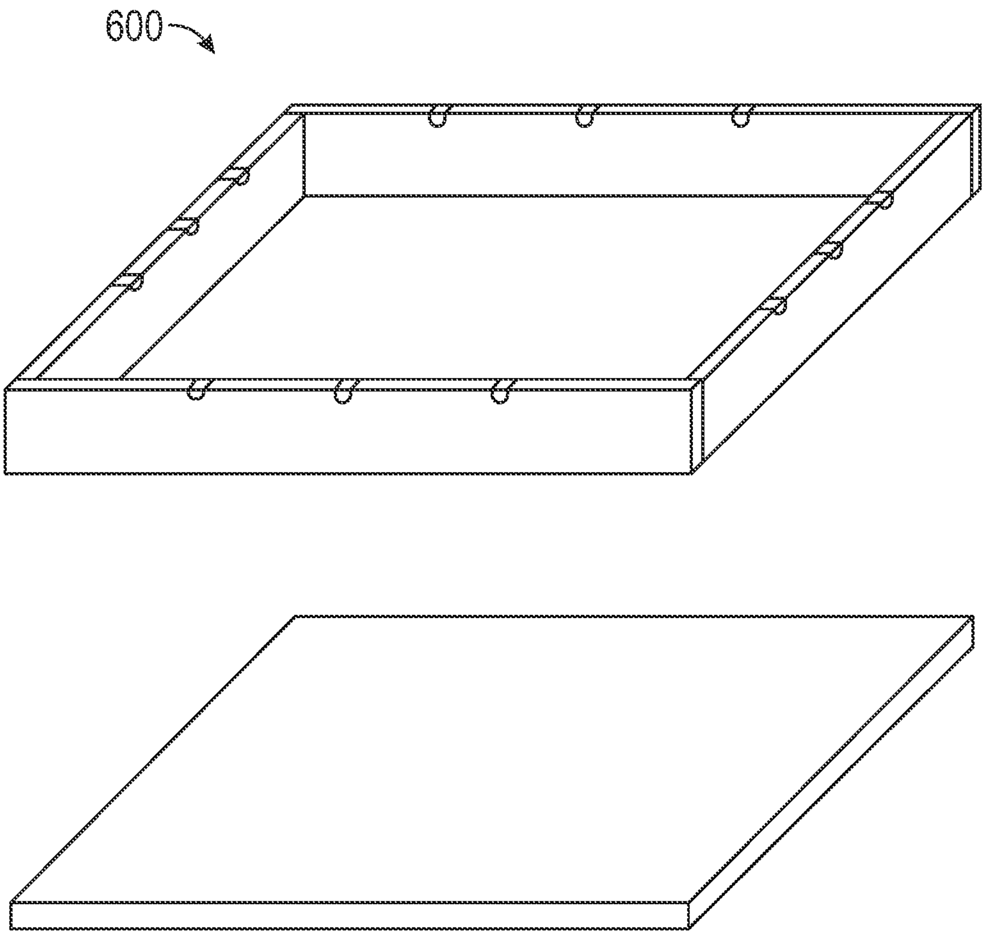

FIG. 6A

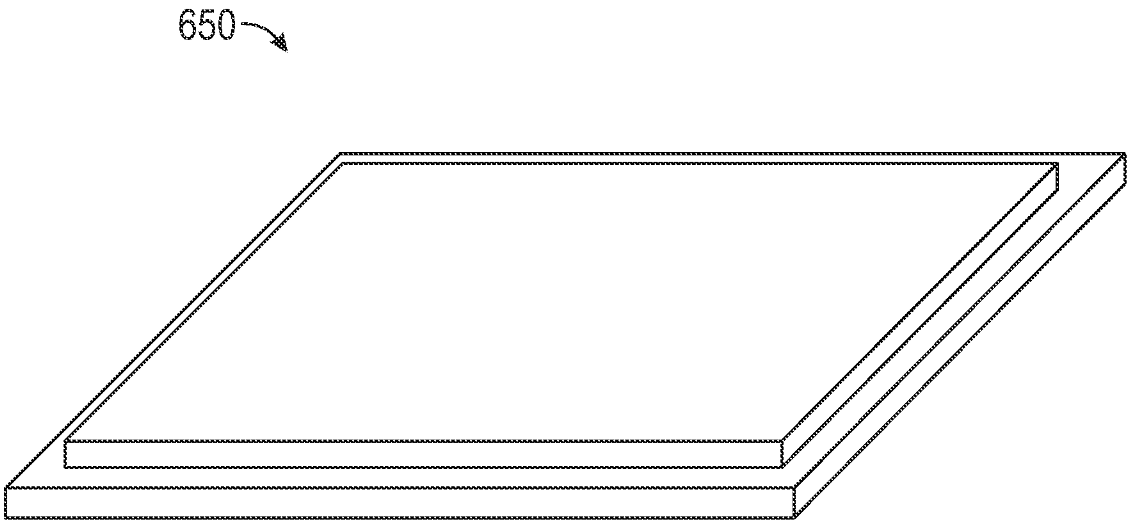

FIG. 6B

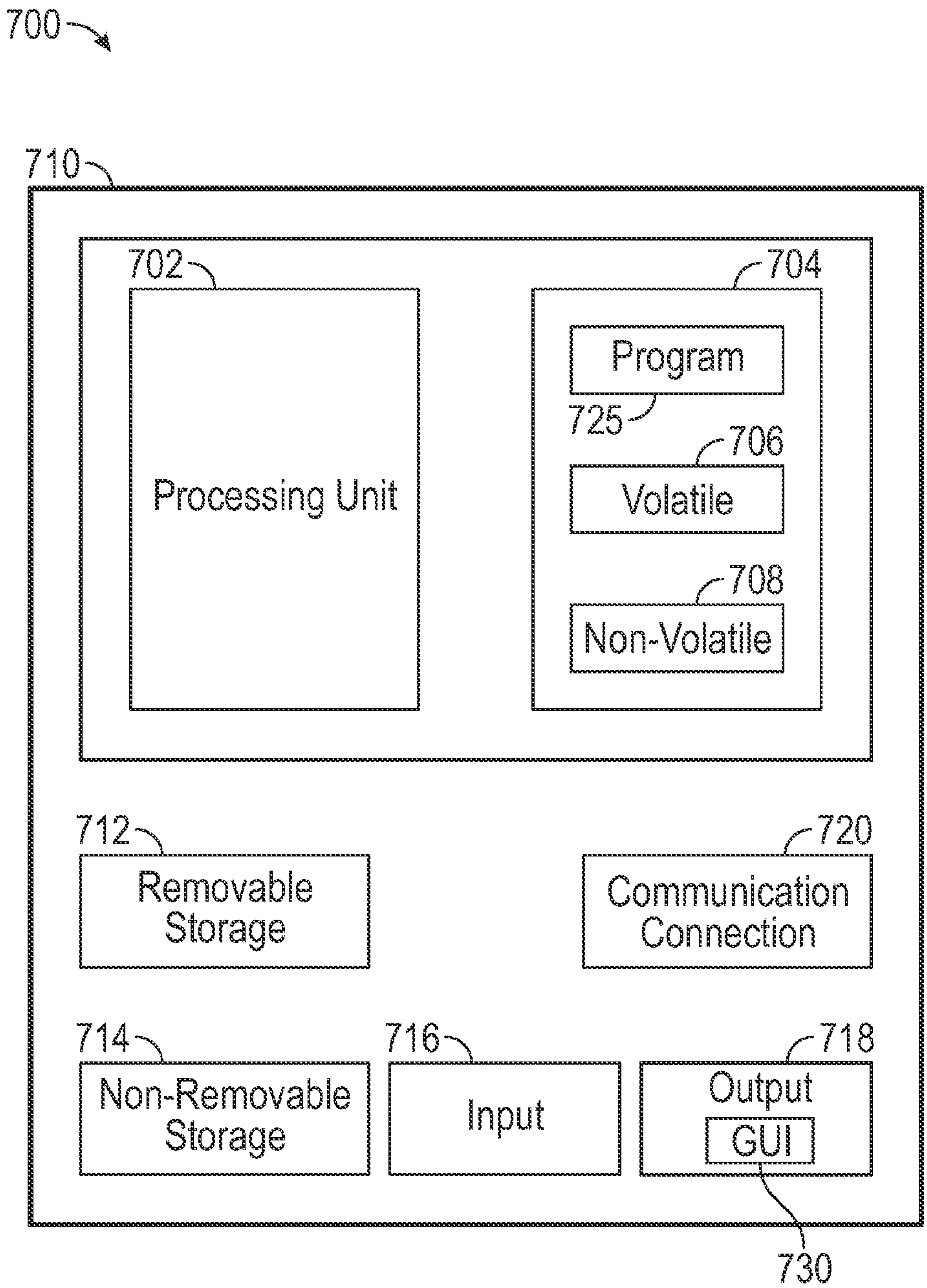
700
710
702
Processing Unit
704
Program
725
706
Volatile
708
Non-Volatile
712
Removable Storage
720
Communication Connection
714
Non-Removable Storage
716
Input
718
Output
GUI
730

FIG. 7

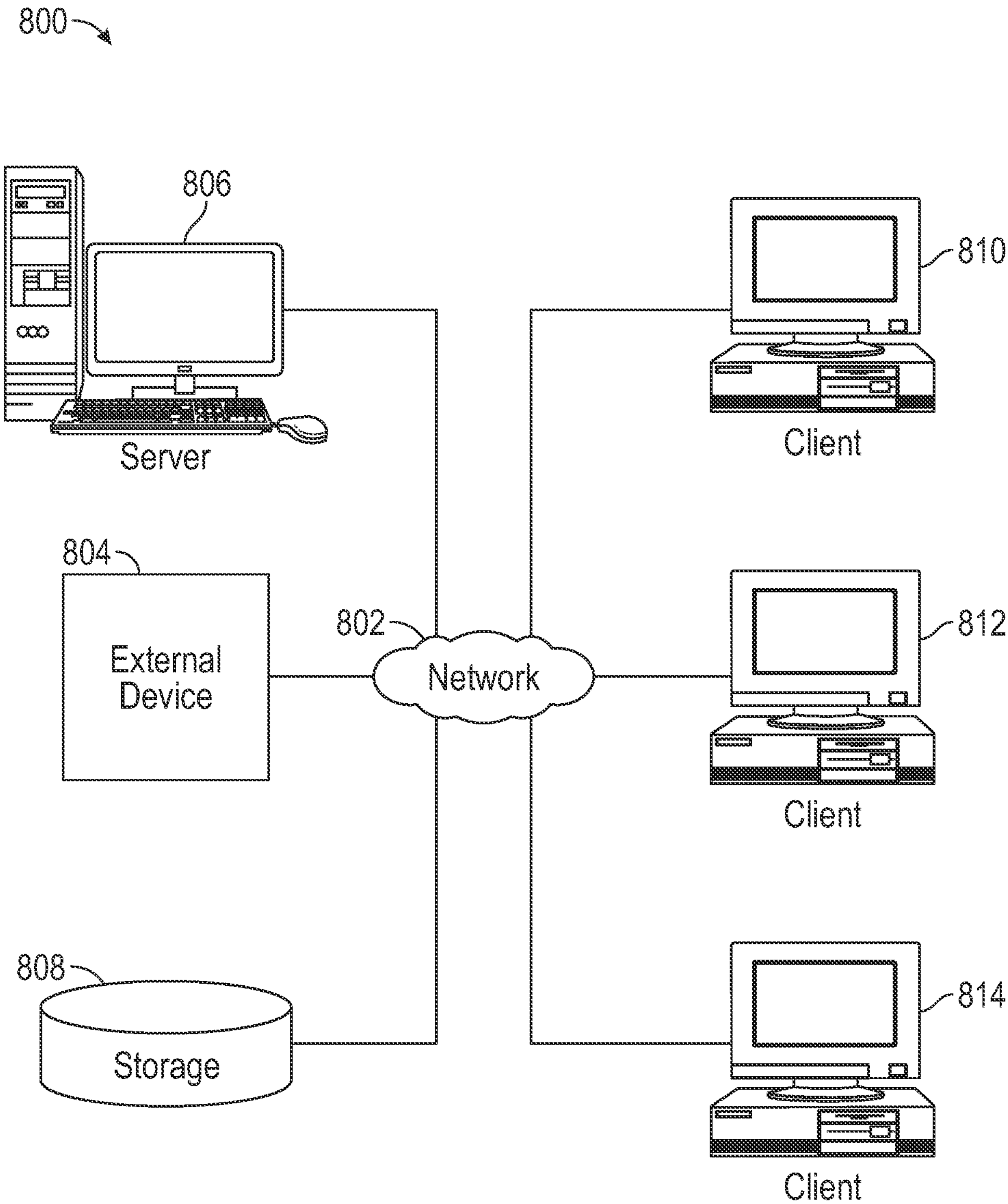
800
806
Server
804
External Device
802
Network
808
Storage
810
Client
812
Client
814
Client

FIG. 8

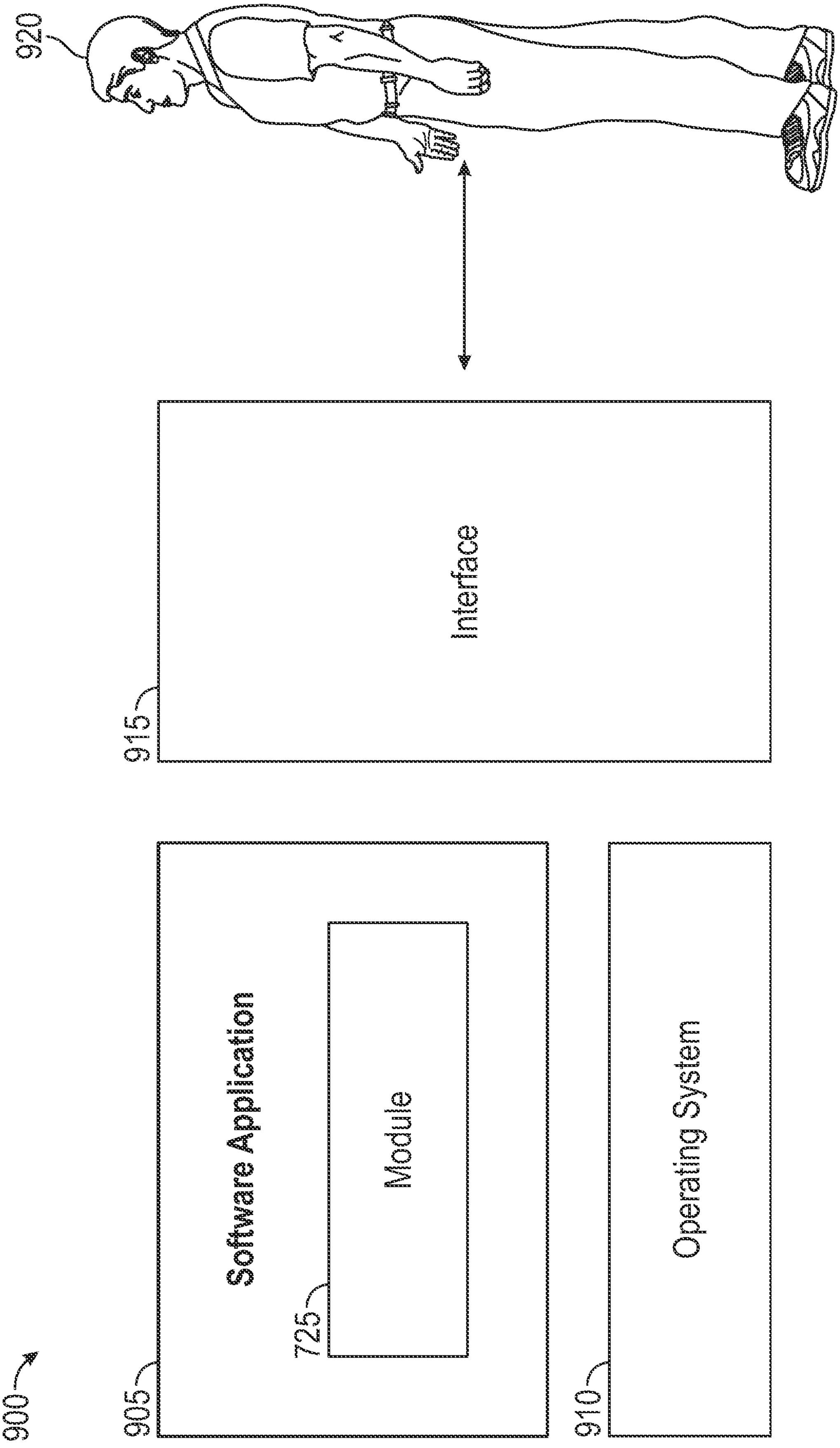
900
905
Software Application
725
Module
910
Operating System
915
Interface
920

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 23/34819

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. A42B 3/10, A42B 3/12, A42B 3/06, A42B 3/32 (2023.01)
ADD. A42B 3/00, A41D 13/00, A42B 3/04, F41H 1/04 (2023.01)

CPC - INV. A42B 3/10, A42B 3/12, A42B 3/062, A42B 3/06, A42B 3/32, A42B 3/063

ADD. A42B 3/00, A41D 13/00, A42B 3/04, F41H 1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/0056071 A1 (Smith) 15 March 2007 (15.03.2007), entire document, especially Fig. 1A-5; para[0025]; para[0029]; para[0006]; para[0031];	1-4, 11-12
Y	US 2012/0278963 A1 (Hersick et al.) 08 November 2012 (08.11.2012), entire document, especially Fig. 1-7D; para[0038]; para[0043]; para[0036];	1, 5-10, 13-16
Y	US 2021/0187897 A1 (VICIS, Inc.) 24 June 2021 (24.06.2021), entire document, especially Fig. 8A-8C, 13-14, 23A-23B; para[0049]; para[0109]; para[0145]; para[0146]; para[0013]; para[0060]; para[0141]; para[0118];	1, 5-10, 13-20
Y	US 2018/0304598 A1 (Board of Trustees of Michigan State University) 25 October 2018 (25.10.2018), entire document, especially Fig. 1-7; para[0040]; para[0041]; para[0042]; para[0049]; para[0052]; para[0075]; para[0081];	5-6, 17-20
A	WO 2022/051873 A1 (SPORT MASKA INC.) 17 March 2022 (17.03.2022), entire document	1-20
A	US 2020/0215415 A1 (Riddell, Inc.) 09 July 2020 (09.07.2020), entire document	1-20
A	US 2022/0079280 A1 (Bauer Hockey Ltd.) 17 March 2022 (17.03.2022), entire document	1-20
A	US 6,032,297 A (Barthold et al.) 07 March 2000 (07.03.2000), entire document	1-20
A	US 4,286,339 A (Coombs) 01 September 1981 (01.09.1981), entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 December 2023	JAN 22 2024

Name and mailing address of the ISA/US	Authorized officer
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