(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 February 2025 (20.02.2025)

WIPO | PCT

(10) International Publication Number
WO 2025/035207 A1

(51) International Patent Classification:
A42B 3/14 (2006.01) *A42B 3/06* (2006.01)

(21) International Application Number:
PCT/CA2024/051050

(22) International Filing Date:
09 August 2024 (09.08.2024)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/518,973 11 August 2023 (11.08.2023) US

(71) Applicant: **VANQUISH HOCKEY LIMITED** [CA/CA]; 25 Royal Ridge Mount MW, Clagary, Alberta T3G 5Y9 (CA).

(72) Inventors: **WEBER, Tory**; c/o 25 Royal Ridge Mount NW, Winnipeg, Alberta T3G 5Y9 (CA). **LEMIEUX, Eric**; c/o 25 Royal Ridge Mount NW, Calgary, Alberta T3G 5Y9 (CA). **CHAMBERT, Martin**; c/o 25 Royal Ridge Mount NW, Calgary, Alberta T3G 5Y9 (CA). **CHIASSON, Michel**; c/o 25 Royal Ridge Mount NW, Calgary, Alberta T3G 5Y9 (CA). **BOISVERT-VALENCIA, Mariane**; c/o 25 Royal Ridge Mount NW, Calgary, Alberta T3G 5Y9 (CA).

(74) Agent: **ADE & COMPANY INC.**; 2157 Henderson Hwy, Winnipeg, Manitoba R2G 1P9 (CA).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) **Title:** PROTECTIVE HELMET WITH OPTIONAL CAGE

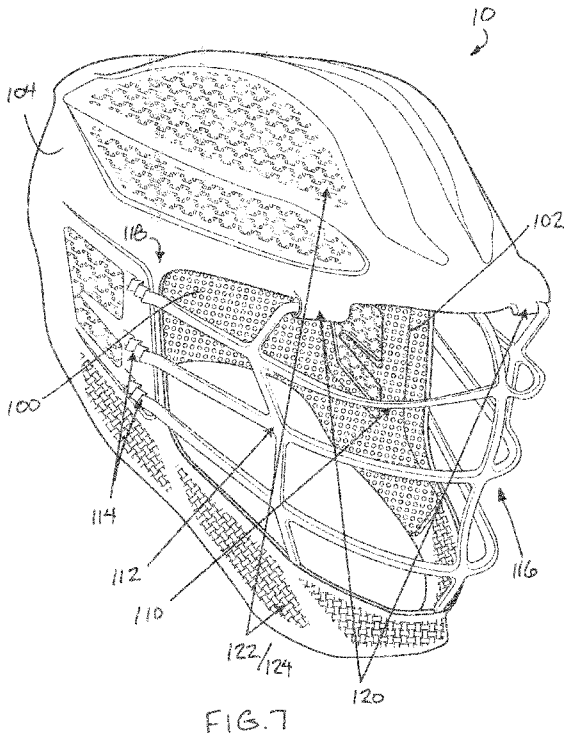


FIG.7

(57) **Abstract:** A protective article, such as a helmet, includes an inner shell with an optional liner worn on the user and an outer shell mounted overtop of the inner shell by a resilient coupling that allows resilient movement of the outer shell relative to the inner shell responsive to impacts. The resilient coupling is formed by three-dimensional printing integrally together with one or both shells. Other features including strap fasteners, protective members over ventilation openings, cage mounts, and the like can also be integrally printed with the shell(s). A cage is provided separately or integral with the outer shell in which the cage is formed by printing to define intersecting bars that can vary in shape, size or angular orientation or define a beam profile with varying directional characteristics along the length thereof. A resilient coupling between the cage and helmet can also be printed integrally with the cage or shell(s).

WO 2025/035207 A1

[Continued on next page]

Published:

— *with international search report (Art. 21(3))*

— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

PROTECTIVE HELMET WITH OPTIONAL CAGE

FIELD OF THE INVENTION

The present invention relates to protective articles, such as a helmet, of the type including an inner shell and an outer shell supported for resilient movement relative to the inner shell. The present invention further relates to a cage for a protective sports helmet to be worn while playing a sport in which the cage provides impact protection from projectiles while allowing the wearer to see through voids in the cage.

BACKGROUND

Protective helmets, for example of the type worn by goalies in the sport of hockey, typically comprises a rigid outer shell having a minimal lining of resilient material arranged to be supported directly against the head of the user. In the event of puck impacts, or other impacts during play of the game of hockey, the impacts tend to be transmitted through minimal lining of resilient material to the head of the user causing disorientation to the goalie and/or a possible concussion type injuries.

The helmets worn by goalies also typically include a cage portion which spans over the eye region to protect the face of the user while allowing visibility through the cage. Impacts the cage are also commonly transmitted through the cage to the outer shell and can also result in possible concussion type injuries.

SUMMARY OF THE INVENTION

According to one aspect of the invention there is provided a protective helmet comprising:

an inner shell arranged to be worn on a head of a user;

an outer shell arranged to be mounted overtop of the inner shell so as to cover a top, a forehead, and laterally opposing sides of the user; and

a resilient coupling supporting the outer shell on the inner shell such that the outer shell is spaced radially outward from the inner shell and supporting the outer shell for resilient movement relative to the inner shell responsive to an impact to the outer shell.

The use of an inner shell and a coupling arrangement that supports the outer shell spaced radially outward from the inner shell provides space and accommodation for impact absorbing features under the outer shell to reduce the transmission of impacts from the outer shell to the head of the user and to reduce rotational and angular forces to the brain of the user.

The resilient coupling may be formed by three-dimensional printing integrally together with at least one of the inner shell and the outer shell. In one embodiment, the inner

shell, the outer shell and the resilient coupling are formed integrally together with one another as a uniform body by three-dimensional printing.

The resilient coupling may include a plurality of first elements formed by three-dimensional printing integrally together with the inner shell and a plurality of second elements formed by three-dimensional printing integrally together with the outer shell, the first coupling elements being selectively coupled to the second coupling elements to define the resilient coupling between the inner shell and the outer shell.

In some embodiments, one of the first and second elements comprises sockets and another of the first and second elements comprises protrusions arranged to be received in the sockets respectively to define the resilient coupling. The protrusions may be selectively retained in the sockets by a resilient snap-fit arrangement.

Alternatively, each protrusion may be linearly slidable within a respective one of sockets, in which each socket further comprises a resilient element therein which is resiliently deformed by sliding movement of the protrusion within the socket in response to an impact to the outer shell. Preferably at least some of the sockets are oriented in a different direction than one of more adjacent ones of the sockets.

The resilient coupling may be arranged to provide a stepped increase in resistance to movement between the inner shell and the outer shell in response to increasing deflection between the inner shell and the outer shell. In this instance, the resilient coupling may include (i) a plurality of first resilient elements providing resistance to movement between the inner shell and the outer shell in response to a first deflection amount, and (ii) a plurality of second resilient elements providing resistance to movement between the inner shell and the outer shell only response to a second deflection amount greater than the first deflection amount.

In some instance, the outer shell may comprise a plurality of shell sections interlocked with one another so as to be movable relative to one another in a pivoting or folding manner for example. When the shell sections are interlocked for pivotal movement relative to one another, there may be provided stops on the shell sections that engage one another to limit relative pivotal movement between the shell sections to a prescribed range of angular deflection.

The resilient coupling may further comprise a lattice structure formed by three dimensional printing and occupying a cavity between the inner shell and the outer shell.

In preferred embodiments, the outer shell comprises a first rigid material, the inner shell comprises a second rigid material which is less rigid than the first rigid material, and the resilient coupling comprises a plurality of struts formed of resilient material.

The helmet may further comprise a liner supported along an interior of the inner shell to be worn against the head of the user, in which the inner shell and the liner are formed by three dimensional printing from dissimilar materials such that the inner shell is more rigid than the liner.

In this instance, integral connectors may be formed integrally by three dimensional printing together with at least one of the inner shell and the liner in which the integral connectors being arranged to releasable couple the liner to the inner shell.

The releasable connectors may comprise sockets on one of the inner shell and the liner and protrusions on another of the inner shell and the liner, wherein the protrusions are selectively retained in the sockets by a resilient snap-fit arrangement.

The liner includes may further include strap cavities formed internally therein by three dimensional printing of the liner, in which the strap cavities receive helmet straps extending therethrough.

The liner may also include electronic cavities formed internally therein by three dimensional printing of the liner in which the electronic cavities receive electronic hardware therein.

The outer shell may include a plurality of ventilation openings formed therein and a plurality of structural members spanning across the ventilation openings so as to allow air to pass between the structural members in which the structural members are formed by three-dimensional printing integrally together with the outer shell.

The outer shell may include a plurality of helmet strap connectors mounted thereon and arranged to connect helmet straps to the outer shell, in which the helmet strap connectors are formed by three-dimensional printing integrally together with the outer shell.

The outer shell preferably includes a cage supported thereon so as to be arranged to span over eyes of the user in which the cage is supported on the outer shell by cage connectors and the cage connectors are formed by three-dimensional printing integrally together with the outer shell.

The outer shell may includes at least one accessory mount arranged to mount a helmet accessory externally on the outer shell in which said at least one accessory mount is formed by three-dimensional printing integrally together with the outer shell.

The outer shell may include three dimensional indicia formed thereon in which the indicia is formed by three-dimensional printing integrally together with the outer shell.

When the outer shell includes a cage supported thereon so as to be arranged to

span over at least part of a facial area of the user in which the cage may be formed by three-dimensional printing integrally together with the outer shell.

The cage may comprise a plurality of bars mounted in an intersecting manner to define the cage in which at least one of the bars varies in shape, cross sectional size, and/or angular orientation about the longitudinal axis along a length of the bar. More particularly, when one of the bars has a profile which is elongated along a transverse axis, the transverse axis varies in orientation about a longitudinal axis of the bars along a length of the bar.

When the bars are mounted in an intersecting manner at respective intersections to define the cage, at least one of the intersections preferably includes two of the bars intersecting one another in a common plane at the intersection.

In some instances, some of the bars of the cage may be shaped to define a resilient section formed therein in which the resilient section is formed by three-dimensional printing integrally together with the cage, and in which the resilient section is resiliently deformable responsive to an impact. When the cage includes a main portion arranged to span over eyes of the user and a peripheral portion coupling the main portion to the outer shell, the resilient sections of the cage are preferably located in the peripheral portion of the cage.

In some instances, some of the bars may be shaped to define a beam profile having a greater resistance to bending in a first radial direction than a second radial direction relative to a longitudinal axis of the beam profile. Preferably the beam profile has a greater resistance to bending transversely to a plane of the cage than bending within a plane of the cage.

Some of the bars of the cage may comprise a hollow frame member.

The resilient movement between the shells preferably includes a rotational movement of the outer shell relative to the inner shell about a center of rotation located within a boundary of the inner shell, a radial movement of the outer shell relative to the inner shell, and/or a translational movement of the outer shell relative to the inner shell.

The outer shell may be a three-dimensionally printed structure comprising a unitary body of open lattice material.

The inner shell is preferably formed of a rigid material and is arranged to span at least the forehead of the user, and/or at least the temporal regions of the user.

When the helmet is a hockey goalie helmet, the outer shell and the inner shell are preferably each arranged to cover a jaw of the user and each include a central viewing portion arranged for alignment with eyes of the user which remains open for visibility.

The outer shell may be supported for translational movement along a longitudinal

axis extending between the front and an opposing rear of the helmet.

The outer shell is preferably biased forwardly to return to a neutral position relative to the inner shell in response to being deflected rearwardly relative to the inner shell by an impact.

The outer shell may be movable along the longitudinal axis relative to the inner shell from the neutral position rearwardly by a greater distance than forwardly.

The helmet may further include a plurality of tracks fixed onto a first shell among the inner shell and the outer shell, and a plurality of followers fixed onto a second shell among the inner shell and the outer shell, wherein the followers are slidably coupled to the tracks respectively to define said translational movement.

Each follower may be radially compressible transversely to the longitudinal axis such that the resilient movement includes a radial movement of the outer shell relative to the inner shell.

Each track may comprise a groove in which each follower has a head having a profile which mates with a profile of the groove to retain the head within the groove while enabling longitudinal sliding of the head along the groove.

The inner shell may be arranged to span at least part of a jaw of the user.

Preferably the inner shell also includes a central opening in alignment with the central viewing portion wherein the inner shell extends about a full perimeter of the central opening.

The resilient coupling arrangement between the outer shell and the inner shell may be located only at a top and sides of the helmet.

The resilient coupling arrangement between the outer shell and the inner shell may be located only rearward of a temporal region of the inner shell.

According to another aspect of the present invention there is provided a cage arranged for use with a helmet, the cage comprising:

a plurality of bars mounted in an intersecting manner to define a boundary of the cage arranged to span over at least part of a facial area of the user when the cage is supported on the helmet;

wherein the bars being formed integrally together with one another by three-dimensional printing.

The cage may comprise a plurality of bars mounted in an intersecting manner to define the cage in which at least one of the bars varies in shape, cross sectional size, and/or

angular orientation about the longitudinal axis along a length of the bar. More particularly, when one of the bars has a profile which is elongated along a transverse axis, the transverse axis varies in orientation about a longitudinal axis of the bars along a length of the bar.

When the bars are mounted in an intersecting manner at respective intersections to define the cage, at least one of the intersections preferably includes two of the bars intersecting one another in a common plane at the intersection.

In some instances, some of the bars of the cage may be shaped to define a resilient section formed therein in which the resilient section is formed by three-dimensional printing integrally together with the cage, and in which the resilient section is resiliently deformable responsive to an impact. When the cage includes a main portion arranged to span over eyes of the user and a peripheral portion coupling the main portion to the outer shell, the resilient sections of the cage are preferably located in the peripheral portion of the cage.

In some instances, some of the bars may be shaped to define a beam profile having a greater resistance to bending in a first radial direction than a second radial direction relative to a longitudinal axis of the beam profile. Preferably the beam profile has a greater resistance to bending transversely to a plane of the cage than bending within a plane of the cage.

Some of the bars of the cage may comprise a hollow frame member.

According to a further aspect of the present invention, there is provided an article of protective equipment to be worn on a body part of a user, the article comprising:

an inner shell including a concave interior side arranged to be worn against the body part of the user and a convex exterior side;

an outer shell arranged to be mounted overtop of the inner shell so as to cover the inner shell, the outer shell including a concave interior side and a convex exterior side; and

a resilient coupling extending between the convex exterior side of the inner shell and the concave interior side of the outer shell such that the outer shell is spaced radially outward from the inner shell, the outer shell being supported by the resilient coupling for resilient movement relative to the inner shell responsive to an impact to the outer shell.

Any of the features described above in relation to the helmet may also be optionally applied individually or in any combination to the protective article.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the invention will now be described in conjunction with the accompanying drawings in which:

Figure 1 is a side elevational view of a protective sports helmet according to one

aspect of the present invention;

Figure 2 is a perspective view of the inner shell of the helmet, shown with the outer shell removed for illustrative purposes according to the helmet of Figure 1;

Figure 3 is side elevational view of the inner shell and rear cap of the helmet, shown with the outer shell removed according to the helmet of Figure 1;

Figure 4 is a front elevational view of the inner shell, shown with the outer shell removed according to the helmet of Figure 1;

Figure 5 is a sectional view of a portion of the coupling arrangement between the inner and outer shells of the helmet according to the helmet of Figure 1;

Figure 6 is a side elevational view of the helmet in which the coupling arrangement is represented schematically for illustrative purposes according to the helmet of Figure 1;

Figure 7 is a perspective view of a further embodiment of the sports helmet according to the present invention;

Figure 8 is a perspective view of yet another embodiment of the sports helmet according to the present invention;

Figure 9 are front and sectional views of one embodiment of the cage for a sports helmet on a right side of the image compared to a prior art cage on a left side of the image;

Figure 10 is a partly sectional view of one embodiment of the resilient coupling for a helmet according to the present invention;

Figure 11 is a partly sectional view of another embodiment of the resilient coupling for a helmet according to the present invention;

Figure 12 is a partly sectional view of a further embodiment of the resilient coupling for a helmet according to the present invention;

Figure 13 is a partly sectional view of yet another embodiment of the resilient coupling for a helmet according to the present invention;

Figure 14 is a sectional view of two outer shell sections coupled for relative movement according to a further embodiment of the helmet;

Figure 15 is a perspective view of various exemplary features incorporated into the bars of the cage according to various embodiments of the helmet according to the present invention;

Figure 16 is a sectional view of one embodiment of integral connectors between the liner and the inner shell of the helmet according to the present invention;

Figure 17 is a sectional view of another embodiment of integral connectors between the liner and the inner shell of the helmet according to the present invention;

Figure 18 is a sectional view of a further embodiment of integral connectors between the liner and the inner shell of the helmet according to the present invention; and

Figure 19 is a further embodiment of the helmet according to the present invention in the form of an aerodynamic bicycle helmet.

In the drawings like characters of reference indicate corresponding parts in the different figures.

DETAILED DESCRIPTION

Referring to the accompanying figures there is illustrated a protective equipment article generally indicated by reference numeral 10. In the illustrated embodiments, the protective article 10 typically comprises a helmet to be worn on the head of a user; however, the features of the protective article 10 described herein may also be applicable to a variety of other types of protective equipment that typically incorporate hard shells therein such as a protective cup or jock, elbow caps, shoulder caps and knee caps for example. The features described herein are particularly suited for use in a variety of helmets including a hockey goalie mask, a hockey player helmet, a lacrosse helmet, a baseball batting helmet, a ski helmet, a bicycle helmet with or without a chin protector, a football helmet, a cricket helmet, military helmets, safety helmets including construction helmets, and automotive type helmets used in automotive racing, motorcycling or motocross for example.

In typical embodiments of the article 10 described herein, the article generally includes a liner 100 worn against the body or head of the user in which the liner is formed of a resilient or semirigid material which may be manufactured by additive manufacturing or three-dimensional printing of a thermoplastic polyurethane material or other resilient printable plastic and foam materials for example. The article further includes an inner shell 102 that at least partially or fully covers the liner. More particularly the inner shell 102 is a rigid shell that is more rigid than the liner 100 and which is generally spherical or semi-spherical in shape so as to include a concave interior side worn against the user and a convex exterior side. The article also includes an outer shell 104 which fully covers the inner shell 102 and which is formed of a rigid material that may be similar to the inner shell, more rigid than the inner shell, or less rigid than the outer shell. Each of the inner shell and the outer shell may be formed by three-dimensional printing from suitable printable materials including thermoplastics or various metals; however, in some embodiments only one of the shells is printed and the other shell is

formed by other techniques including injection or compression molding for example. The printed features described in the following would be incorporated integrally into the printed shell when only one of the shells is printed. The outer shell 104 closely follows the shape of the inner shell so as to include a concave interior side facing towards the inner shell and a convex exterior side forming the exterior of the article. Lastly, the article includes a resilient coupling 106 coupled between the convex exterior of the inner shell 102 and the concave interior of the outer shell 104 so as to span the radial gap between the inner and outer shells. The resilient coupling is formed of a resilient or semirigid three-dimensional printed material. The resilient coupling 106 is typically printed integrally, seamlessly and continuously with one or both of the inner shell 102 and the outer shell 104.

The connecting elements between the inner and outer shells which define the resilient coupling are suitably shaped and configured to allow various relative movements between the outer shell and the inner shell in response to impacts. Specifically, the resilient coupling allows relative rotation of the outer shell relative to the inner shell about a centre of rotation typically located within the interior boundary of the inner shell. The resilient coupling 106 also allows radial compression thereof as the outer shell is compressed radially inwardly towards the inner shell. Furthermore, the resilient coupling 106 allows translational movement of the outer shell relative to the inner shell along an axis extending through the helmet, for example a longitudinal axis extending from the front to the back of the helmet, a lateral axis extending side to side across the helmet, or any other axis along which impacts may be received.

Many embodiments of the article further relate to a helmet including a cage 108. The cage 108 typically comprises a plurality of rigid bars 110 which are coupled to one another in an intersecting manner to define a boundary surface that spans over part of or the entirety of the facial area of the user when the cage is supported on the helmet. The cage 108 may be formed integrally together with the outer shell of the helmet or may be subsequently mounted onto the helmet. In preferred embodiments, all of the bars 110 of the cage 108 are manufactured together as a single body that is seamless, unitary, and continuous of the same material throughout by being three dimensionally printed as a single body by itself or together with the outer shell of the helmet.

In preferred embodiments, the individual bars of the cage 108 vary in configuration along a longitudinal axis of the bar corresponding to the length of the bar. The bars may vary in configuration in various manners to optimize the performance thereof. In some instances, the bars vary in cross-sectional size so as to be thicker where more protection is

desired and thinner where less protection is required or where improved lines of sight are desired in alignment with the eye area of the user for example. In another instance, the cross-sectional shape of the bar varies along the length for similar reasons to improve the performance or the visibility through the cage for example.

In another example, the shape and size of the cross-section of a bar may remain consistent, but the angular orientation is varied about the longitudinal axis along the length of the bar. As shown in figure 9, some of the bars in alignment with the eye area of the user may have a cross-sectional shape that is elongated along one transverse axis, for example an elliptical shape that is elongated along a major transverse axis. The transverse axis may be oriented more horizontally than vertically in the eye area to minimize the vertical thickness of the bar at the lines of sight of the user; however, the orientation of the transverse axis may vary towards the periphery of the cage for other performance benefits or to simplify mounting arrangements, or to simplify the integration of the bars with the outer shell of the helmet.

In other instances, the bars 110 of the cage 108 may be manufactured with a hollow tubular shape to reduce weight while optimizing resistance against bending. Yet further embodiments, the cross-sectional shape may be optimized to define a beam profile that is more resistant to bending in one direction than another. For example, the cross-sectional shape may define an I-beam with parallel flanges and a connecting web between the parallel flanges. When the beam profile has a greater resistance to bending in a first radial direction than a second radial direction relative to a long axis of the profile, the beam profile may be specifically oriented so that there is greater resistance to bending transversely to a plane or boundary surface of the cage than bending of the bar within the boundary or plane of the cage. The bars are thus best suited to resisting deformation from impacts directed at the cage perpendicularly to the plane or boundary of the cage while maximizing visibility through the cage where strength is less required.

As shown in figures 7 and 8, when the bars 110 intersect one another at one or more intersections 112, the bars at each intersection preferably lie in a common plane with one another at the intersection rather than the bars being separately formed and subsequently overlapping one another in the manner of construction of conventional helmet cages. Forming the bars at each intersection 112 to line a common plane is readily accomplished when the cage is manufactured by three dimensional printing.

As shown in figure 7, some of the bars 110 of the cage may include resilient sections 114 incorporated therein and which are formed integrally together with the remainder

of the cage by three-dimensional printing. In this instance the cage includes a main portion 116 generally spanning the central area and eyes of the facial area of the user, and a peripheral portion 118 at opposing sides of the main portion 116 and which serve to connect the main portion to the outer shell of the helmet. The resilient sections 114 are preferably formed in the peripheral portion 118 of the cage near the terminal ends of the bars where the bars join the outer shell. At each resilient section 114, the bar is shaped to be formed of thinner material or material which is formed into a helical or sinusoidal path to define a spring like structure where the bar of the cage is more resilient than the remaining rigid bar sections. Specifically, the resilient sections preferably function as a linear spring aligned along the longitudinal axis of the bar when the bar extends primarily in a forward and backward direction relative to the helmet at the attachment of the cage to the outer shell at opposing sides of the helmet. In this instance, impacts to the front of the cage cause the resilient sections 114 to be linearly recoiled and then resiliently spring back after the impact to absorb some of the impact.

As further shown in figure 7, the outer shell may include cage connectors 120 that are integrally formed on the outer shell of the helmet about the periphery of the viewing area that is covered by the cage. The cage connectors 120 can be formed together with the outer shell during three-dimensional printing of the outer shell so as to be formed seamlessly and of the same material with the remainder of the outer shell. In the illustrated embodiment, the cage connectors 120 are formed as a socket which receive the end portions of respective ones of the bars of the cage therein so that the cage bars each function as a hinge pin defining a lateral hinging axis extending across the top of the cage about which the cage is pivoted when recoiling in response to an impact. Hinge type cage connectors 120 at the top of the cage thus cooperate together with resilient sections 114 formed on the cage towards the sides and bottom of the cage so that the bottom of the cage recoils rearwardly with compression of the resilient sections 114 as the cage pivots about the hinge axis of the cage connectors 120 at the top of the cage.

With reference to the outer shell 104 illustrated in figures 7 and 8, the outer shell defines a goalie hockey helmet such that the outer shell fully surrounds the central viewing area aligned with the eyes and face of the user such that a portion of the outer shell provides coverage across the jaw area of the user. In each embodiment, a plurality of ventilation openings 122 are provided in the outer shell surrounded by solid and non-perforated connecting portions of the outer shell between the ventilation openings. At each ventilation opening, the material of the outer shell is formed into a plurality of structural members 124 interconnected with one another and spanning across the ventilation opening such that the ventilation opening is fully covered

by the structural members 124 which collectively form a woven type mesh or an open lattice structure that provides numerous openings therethrough through which air can still be ventilated while providing a rigid structure resistant to impacts at the ventilation opening. The structural members 124 provide a covering over each ventilation opening 122 and are formed by three-dimensional printing together with the remainder of the outer shell.

The outer shell 104 can also be formed with strap connectors 126 formed thereon which are suitable for attachment of various helmet straps mounted thereon. In one instance the strap connectors 126 comprise male snap connectors which form a snap-fit connection with corresponding female snap connectors on the helmet straps. In other instances the strap connectors comprise suitably sized slotted openings that receive straps threaded therethrough about the periphery of the outer shell. In each instance the configuration of the strap connectors 126 are formed integrally with the remainder of the outer shell together as part of the three-dimensional printing process.

As shown in figure 8, the outer shell may also be formed by three-dimensional printing to integrally include various accessory mounts 128 formed therein. The accessory mounts can include integral hooks, or various shaped openings or eyelets that enable attachment of accessories such as a neck guard suspended from the outer shell. In other instances, other types of accessory mounts 128 include openings to receive various electronic hardware including cameras and the like. The interior of the outer shell may also be configured with various cavities or pockets that serve to mount other electronic hardware therein including sensors or batteries and the like.

The helmet according to figure 8 also shows an example of three-dimensional shapes 129 representing various indicia being formed on the outer surface of the outer shell is part of the three-dimensional printed structure forming the outer shell. The three-dimensional texture 129 may include debossed indicia, embossed indicia, or internal textured shapes that can be viewed from the exterior by the thinning of the material of the outer shell produce a visible logo in the manner of a lithophane for example.

In further embodiments, the outer shell may be formed in multiple shell sections 130 which are interconnected to form the overall shape of the outer shell. As shown in figure 14, two adjacent shell sections 130 of the outer shell are joined to one another at peripheral edges such that each shell section defines a respective portion of the exterior boundary of the outer shell of the assembled helmet. The edges of the shell sections are preferably formed with cooperating shapes 132 that interlock with one another in a suitable manner to define a hinge

like structure where the shell sections can be pivoted or folded relative to one another. More particularly, in response to an external impact, the shell sections 130 can be pivoted relative to one another such that the junction between adjacent shell sections is deflected inwardly for compression of the resilient coupling or a compressible layer between the inner and outer shells. In addition to a first set of mating shapes 132 that define the pivoting or hinging movement between the shell sections, the boundary edges of the shell sections may also be provided with stops 134 that engage with one another once the shell sections have pivoted or angularly deflected relative to one another by a prescribed amount, after which further relative deflection is prevented. The stops 134 thus define a limited or prescribed range of angular deflection permitted by the interlocking shapes between the adjacent shell sections. The relative movement between shell sections interlocked with one another serves to redirect impacts from one location at the exterior of the helmet to one of the junctions between adjacent shell sections representing an area less critical to injury or an area of the helmet where greater strength is provided by the resilient coupling or the inner shell.

As described above, the resilient coupling 106 may allow a variety of relative movement between the outer shell and the inner shell or may be directional to primarily direct relative movement between the outer shell and the inner shell along a prescribed axis such as a longitudinal axis extending between front and rear of the helmet.

As shown in figure 12, according to one embodiment the resilient coupling includes a plurality of first coupling elements 136 formed integrally with the outer shell by three-dimensional printing, and a plurality of second coupling elements 138 formed integrally with the inner shell by three-dimensional printing. In this instance the first elements 136 comprise protrusions or fingers which are elongated and flexible and which are formed at the distal ends to mate with the second elements which represent sockets receiving the protrusions or fingers therein. The sockets may be sized and shaped to retain the distal ends of the protrusions therein by friction fit, or snap-fit arrangement, or with an arrangement of catches retained on respective shoulders or undercut surfaces on the protrusions and sockets respectively.

The protrusions or fingers defining the first elements 136 are shown generally aligned in a common direction with one another in the illustrated embodiment, however in other embodiments the elements may be oriented at various transverse directions relative to one another in which the direction that the fingers are sloped relative to one or both of the inner and outer shell can be used to dictate the direction of relative movement of the outer shell relative to the inner shell in response to an impact. When the sockets have a semispherical shape receiving

the distal ends of the protrusions therein, providing sockets at opposing sides of the helmet which are oriented in opposing directions may be sufficient to retain the protrusions within the sockets to couple the outer shell relative to the inner shell. Alternatively, the resilient coupling 106 as shown may be combined with other types of couplings of different configuration which serve to align the outer shell with the inner shell to suitably align the first elements 136 in mating and interlocking cooperation with the second elements 138.

Turning now to figure 11, the coupling elements may comprise a plurality of three-dimensional printed resilient elements 140 interconnected between the inner shell in the outer shell. Although various embodiments of the resilient elements 140 are shown, the resilient elements may be integrally formed with only one of the inner or outer shell while simply abutting the opposing shell, or may be formed integrally with both the inner and outer shell when the inner and outer shell and the resilient coupling are collectively three dimensionally printed as a single unitary structure. In some instances, the resilient elements may be formed as arches 140A which can flex and collapse in response to an impact. In another instance, the resilient elements may comprise sinusoidal or helical springs 140B which are similarly resiliently deformed in response to an impact. In yet another configuration, the resilient elements may comprise posts 140C with a line of weakness formed therein defining a fold line or hinge point about which the resilient element is resiliently folded to deflect and return to shape responsive to an impact.

According to a further embodiment shown in figure 13, the resilient coupling may again be defined by a plurality of first coupling elements 136 integrally formed with the outer shell and second elements 138 integrally formed with the inner shell. In this instance, the second elements again comprise sockets which receive the distal ends of the first elements formed as protrusions or fingers received in the sockets; however, the coupling elements in figure 13 are distinguished in that the first elements are rigid non-compressible elements which are instead coupled to the sockets of the second elements 138 to define a relative linear movement therebetween similar to a piston received within a cylinder. The first and second elements thus define a relative linear motion which may be oriented in the radial direction normal to the inner and outer shells or in a transverse direction that is sloped relative to the shells and the normal direction.

The coupling element 106 in this instance further includes a resilient element 142 located in the chamber of the socket between the terminal end of the socket and the protrusion of the first element 136 such that an impact causes the first elements to be slidable into the sockets in a manner that compresses the resilient element 142 at each coupling. The resilient

element may be a compressible material such as a gel or fluid or a flowable fluid that is redirected into an expandable chamber. The resilient element 142 may yet further comprise a resilient member such as a three-dimensional spring or deformable structure that is three dimensionally printed together with the socket. As shown, some of the first and second coupling elements 136 and 138 may be oriented such that the linear sliding direction thereof is oriented transversely to other coupling elements. In this instance, each protruding piston or first coupling element 136 may be joined to the respective shell to allow for some relative pivotal movement, for example by a line of weakness defining a fold line or other suitable structures for forming a hinge.

In a further embodiment of the resilient coupling 106 shown in figure 10, the resilient coupling in this instance may be arranged to provide a stepped increase in resistance to a deflected movement of the outer shell relative to the inner shell in response to an increasing deflection of the outer shell relative to the inner shell. More particularly, the resilient coupling is arranged to provide a first resistance to the deflection until a first deflection amount is achieved at which point a second larger resistive force to the deflection is initiated. As deflection continues past a second deflection amount greater than the first deflection amount, a third larger resistive force to the deflection can be initiated. In the illustrated embodiment, the resilient coupling includes a plurality of first resilient elements 144, a plurality of second resilient elements 146 and a plurality of third resilient elements 148. Each set of resilient elements, 144, 146 and 148 are actuated to provide resistive force against deflection at different amounts of deflection while also providing different resistive forces to the deflection. The first resilient elements 144 in this instance span the greatest distance across the gap between the inner and outer shells such that the first elements 144 will immediately undergo resilient deformation and provide resistive force to the deflection as the outer shell is deflected up to a first deflection amount relative to the inner shell. The remaining elements are shorter than the first elements 144 and do not engage the inner shell such that they do not undergo any deflection or provide any resistive force to the deflection until the first deflection amount is reached.

After the first deflection amount is reached and the deflection continues up to a second deflection amount, the shorter second elements 146 begin to engage the inner shell and undergo resilient deformation so as to provide much greater resistance to the deformation than the first elements alone. The second elements may also be thicker than the first elements so that each individual second element divides greater resistance to deformation than the first elements.

Lastly, after the second deflection amount is reached and the deflection continues up to a third deflection amount, the shortest third elements 148 that are shorter than both the first

and second elements begin to engage the inner shell and undergo resilient deformation so as to provide an even greater resistance to the deformation than the first and second elements. The third elements may also be thicker than both the first elements and the second element such that each individual third element provides greater resistance to the deformation than the first elements or the second elements individually. In further embodiments, yet further stages to resist deformation may be provided by further resilient elements engaging at a further deflection amount.

As described herein, the liner 100 is preferably formed as a three-dimensional printed structure together with the shells or as a separate component to be coupled to the shells after manufacture. When manufactured separately, the liner 100 and the inner shell 102 are preferably provided with releasable connectors as shown in figures 16 through 18 for example to releasably mount the liner 100 fixedly relative to the inner shell without additional mounting hardware or adhesives and the like being required. In each of the illustrated examples, a protruding connector 150 is provided on the inner shell to protrude into the interior for mating with a corresponding socket 152 formed integrally on the liner. In further embodiments, the protrusion 150 may instead be formed on the liner while the sockets may be formed on the inner shell.

In each of the illustrated embodiments, the protrusion mates with the corresponding socket using a resilient catch 154 retained on a corresponding retaining surface in the socket. In the embodiment of figure 16, the catches are provided on a pair of sprung arms 156 which are biased outwardly to engage the catches on the respective retaining surfaces. Pulling the releasable connectors apart with sufficient force causes the arms 156 to be resiliently deflected inwardly relative to one another to release the catches from the corresponding retaining surfaces.

In the embodiment of figure 17, the catches may be formed on diametrically opposed barbs extending outward from the protrusion for selective mating with retaining surfaces formed in the opposing boundary walls of the socket 152. Pulling the connectors apart causes the material of the protrusion or the socket to be resiliently compressed to sufficiently release the catches from the retaining surfaces.

As shown in figure 18, the protrusion in this instance may comprise a mushroom head type connector with undercut surfaces at opposing sides thereof. The catches in this instance are formed on resilient arms 158 so that the catches are biased to extend inwardly towards one another to be retained on the opposing undercut surfaces of the mushroom head.

In yet further embodiments, the releasable connectors integrally formed on the liner 100 and the inner shell 102 may cooperate by friction fit or using hook and loop type fasteners integrally formed on the liner and the inner shell as part of the three-dimensional printing process.

As shown in figure 20, the liner 100 received within the shells may be provided with one or more cavities formed integrally therein as part of the three-dimensional printing process such that the cavities may be recessed fully into the interior of the liner in spaced relation to either the interior or exterior boundaries of the liner. The cavities may include strap cavities 160 in the form of elongate passages extending fully through the liner to receive respective helmet straps threaded therethrough which serve to strap the helmet onto the head of the user. In another instance the cavities comprise hardware cavities 162 that are suitably arranged to receive various electronic hardware therein including camera components, impact sensors of various types for monitoring impacts, or batteries associated with any of the electronics for example.

The liner 100 may also be formed integrally by three-dimensional printing together with one or more lattice structures 164 which occupy any irregular shaped voids between the liner and the shell layers.

Turning now to figure 19, an aerodynamic bicycle helmet is illustrated in longitudinal cross-section in which the bike helmet is shown to include an inner shell 102 formed of a rigid foam material to be mounted against the head of the user possibly without an additional liner being required, and an outer shell 104 forming a smooth and continuous exterior boundary of the helmet which defines the aerodynamic shape of the helmet. A large void defined between the inner protective shell 102 and the outer aerodynamic shell 104 in this instance is occupied by a three-dimensional printed lattice structure 166. The lattice structure can be formed integrally of the same material and as a single manufacturing step together with either one of the inner shell 102 or the outer shell 104. The lattice structure provides a resiliently deformable crumple zone about the inner shell 102 so as to again allow some resilient movement of the outer shell relative to the inner shell.

Turning now more particularly to figures 1 through 6, another embodiment of the protective article 10 will now be described in further detail in which the article is again a sports helmet that is particularly suited for being worn by a goalie in the sport of hockey.

The helmet 10 in this instance again includes an inner shell 12 arranged to be worn against the head of the user, an outer shell 14 arranged to at least partly surround the inner

shell on the head of the user, and a coupling arrangement between the inner shell 12 and the outer shell 14 which allows some resilient relative movement between the shells such that the outer shell can be deflected relative to the inner shell from a neutral position to a deflected position while being biased to return to the neutral position. The coupling arrangement further allows one or more movements of the outer shell relative to the inner shell including translational movements, rotational movements having a centre of rotation inside the inner shell, and radial movements inward and outward relative to a centre of the generally spherical shape of the helmet.

The inner shell 12 is a rigid unitary body. An additional layer of a resilient or compressible lining material may be mounted as a liner on an inner surface of the rigid body forming the inner shell. The inner shell 12 is intended to be worn in a tightfitting manner about the face and part of the head of the user such that it may be desirable for the inner shell 12 to be manufactured in a plurality of different sizes and shapes to best fit the head of the user. In some instances, the inner shell may be custom fit or custom manufactured to match the shape of the head of the user. In further instances the inner shell may be manufactured and subsequently moulded to the head of the user for example using thermoforming techniques to make the inner shell malleable under application of heat to take the shape of the head of the user followed by allowing the inner shell to cool to form a rigid moulded shape that closely fits the head of the user. In another instance, the inner shell may be custom manufactured using three-dimensional printing techniques according to printing instructions which have been modified to take into consideration custom measurements taken from the head of the user to ensure the printed structure of the inner shell closely fits the head of the user.

The inner shell 12 has a shape which approximately forms part of a sphere in shape while being sized to cover various parts of the head of the user. More particularly, the inner shell includes (i) a top section 16 for spanning the top of the head of the user, (ii) a pair of side sections 18 extending downwardly from opposing sides of the top section while remaining substantially above the ears of the user, (iii) temporal sections 20 extending forwardly from the side sections 18 to extend over temporal regions of the user and to extend downwardly in front of the ears below the bottom edges of the side sections 18, (iv) a forehead section 22 extending downwardly and forwardly from the front edge of the top section so as to be connected across the forehead of the user between the temporal sections 20, (v) two jaw sections 24 extending downwardly from the temporal regions 20 respectively along respective portions of the jaw of the user, and (vi) a central chin section 26 connected between the jaw sections 24 for partly

engaging the chin of the user.

In this manner, the forehead section 22, the temporal sections 20, the jaw sections 24, and the chin section 26 collectively extend about a full perimeter of a central opening 28 in the inner shell that aligns with the mouth, nose and eyes of the user. The inner shell is otherwise continuous and uninterrupted across the width and height of the inner shell between opposing perimeter edges. The inner shell 12 remains open at the rear and bottom by a rear bottom opening 30 receiving the head and the neck of the user inserted therethrough when mounting the inner shell onto the head of the user.

The helmet 10 further includes a rear shell 32 which is also formed as a rigid unitary body. The rear shell 32 forms part of a sphere in shape and is sized to closely fit perimeter edges of the inner shell about the rear opening 30 at the rear of the top section 16 and the rear of the side sections 18. The rear shell 32 may also be provided with a resilient or compressible lining on the inner surface thereof to comfortably fit the rear shell to the rear of the head of the user.

The rear shell 32 is coupled to the inner shell 12 by a set of straps of resilient or elastic material that are connected under tension between the rear shell and respective portions of the inner shell 12. The straps include a plurality of upper straps 34 connected between the rear shell and respective mounting locations on the top section 16 and the side sections 18 of the inner shell at circumferentially spaced locations about the top and sides of the inner shell. A set of lower straps 36 are connected at laterally opposing sides of the rear shell adjacent the bottom thereof to respective mounting locations on the jaw sections 24 of the inner shell respectively. In this manner, the lower straps 36 extend longitudinally forward from the rear shell to the inner shell at a location below the ears of the user.

The outer shell 14 is also provided as a single unitary body of rigid material. The outer shell is generally sized and configured relative to the inner shell such that the outer shell can be mounted to fully cover and conceal the inner shell while remaining spaced radially outward from a centre of the helmet relative to the inner shell.

The outer shell 14 is formed to include (i) a top section 38 for covering the top section 16 of the inner shell, (ii) a forehead section 40 for covering the forehead section 22 of the inner shell, (iii) two side sections 42 extending downwardly from opposing sides of the top section 38 to fully cover the side sections 18 of the inner shell as well as extending further downward to fully span the ears and upper neck of the user at opposing sides of the head, and (vi) a lower section 44 which extends across the front of the helmet between the two side sections

42 of the outer shell to fully span over and conceal the jaw sections 24 and the chin section 26 of the inner shell. The lower section 44 may also be tapered downwardly in front of the neck of the user in the same manner as a conventional hockey goalie mask.

A central area at a front of the mask includes a viewing portion 46 formed in the outer shell in the form of a central opening which is fully surrounded by the forehead section 40 above, the side sections 42 at laterally opposing sides thereof and the lower section 44 therebelow. A set of bars 48 extend across the central opening and are interconnected with one another to define a cage extending across the central opening 46 to divide the central opening into smaller apertures of suitable dimension to prevent pucks penetrating through the apertures into the interior of the helmet. The viewing portion 46 is aligned with the central opening 28 formed in the inner shell to provide full visibility to the user of the helmet. The overall area of the viewing portion 46 is typically larger than the central opening 28 in the inner shell to maximize visibility through the outer shell despite the outer shell being positioned forwardly and outwardly from the inner shell 12 against the head of the user.

The rear edge of the top section 38 and the rear edges of the side section 42 are arranged to be positioned near or rearward from the rearmost portion of the rear shell 32 in a mounted position on the head of the user. More particularly, the top section 38 and the side sections 42 each protrude rearwardly farther than corresponding rear edges of the side sections 18 and top section 16 of the inner shell that form the strapped connection to the rear shell 32. In this manner, the upper and lower straps are concealed beneath the outer shell at the sides and top of the helmet.

The outer shell is oversized relative to the inner shell with a gap being provided between the inner shell and the outer shell in all directions to provide a clearance gap between the inner shell and outer shell that allows the outer shell to be deflected from a neutral position suspended over the inner shell in many different directions including the relative translational, rotational, and radial directions described above.

The coupling arrangement provides a connection between the top section 16 of the inner shell and the top section 38 of the outer shell as well as between the side sections 18 of the inner shell and the corresponding side sections 42 of the outer shell such that all of the connections of the coupling arrangement are located substantially above the level of the ears of the user and generally rearward of the temporal regions of the user. The outer shell remains spaced radially outward from the inner shell along the forehead section 40, and along the entirety of the lower section 44 relative to the corresponding forehead section, jaw sections and chin

section of the inner shell. Accordingly at the front side of the helmet, the outer shell is supported fully spaced outward from and separated by a clearance gap from the inner shell against the face or head of the user.

More particularly, the coupling arrangement generally includes a plurality of tracks 50 which are mounted on an inner surface of the outer shell 14 and a plurality of corresponding followers 52 which are mounted to protrude from the outer surface of the inner shell 12. One or more of the followers 52 is coupled in a mating connection with each track 50 such that the followers 52 are slidably movable along the respective tracks 50. In the illustrated embodiment, the tracks 50 all extend in a common longitudinal direction of a longitudinal axis extending from a central location at the rear of the helmet to a central location at the front of the helmet. The longitudinal axis in which the tracks extend defines the translating movement of the outer shell relative to the inner shell as the followers are displaced longitudinally within the respective tracks 50 forwardly and rearwardly.

Each follower 52 is a pin having an enlarged head 54 which is reduced in diameter at the inner end forming a stem 56. Beneath laterally opposing sides of the enlarged head 54 where the dimension of the pin is stepped inwardly at opposing sides, two shoulder surfaces 58 are defined so that the follower is generally T-shaped.

Each track 50 includes a groove formed within protruding channel mounted on the inner surface of the outer shell. The grooves of the tracks 50 generally T-shaped in profile to match the shape of the followers 52 received therein. The internal groove defining each track thus includes a central main guideway 60 sized to receive the enlarged head 54 of each follower longitudinally slidable therein and two undercut surfaces 62 beneath laterally opposed flanges at the mouth of the groove. The undercut surfaces 62 align with and engage the shoulder surfaces 58 of the followers received therein such that when the followers are mated within the respective tracks, the followers are restricted from removal in a radial direction while remaining freely slidable longitudinally along the length of the track.

Each follower 52 is radially compressible from a neutral position when the outer shell is spaced outwardly in a balanced manner form the inner shell, to a retracted position corresponding to the follower being radially compressed in length. Each follower 52 is biased to return to the neutral position when deflected inwardly into the retracted position. In the illustrated embodiment, the follower 52 is retractable by forming the head 54 of each follower as a telescoping member with an internal spring mounted therein biasing the head to expand radially in dimension. In the neutral position, the head occupies the full depth of the groove in

the corresponding track 50; however, a radially inward impact in the area of the follower causes the head 54 to be radially compressed which in turn allows the outer shell 14 to be deflected radially inwardly towards the inner shell 12. The internal spring within the head 54 immediately biases the follower to return to the extended and neutral position, which in turn returns the outer shell to a neutral position relative to the inner shell 12.

In further embodiments, the stem 54 of each follower may be radially compressible or telescoping in nature to allow the outer shell to be similarly radially deflected inwardly relative to the inner shell followed by outward biasing to return the outer shell to the neutral position.

Each track 50 is also provided with a plurality of longitudinal springs 64 biasing each follower in the longitudinal direction to return to an intermediate neutral position corresponding to the neutral position of the outer shell relative to the inner shell. In the neutral position, the followers are generally located closer to the forward end of the tracks such that the outer shell can be deflected rearward relative to the inner shell from the neutral position by a greater distance than the outer shell can be deflected forwardly relative to the inner shell from the neutral position. In each instance, the longitudinal springs bias the followers back to their respective neutral positions which in turn re-positions the outer shell in the neutral position relative to the inner shell.

The overall combination of the longitudinal tracks extending generally rearward together with the ability of each follower to be compressed radially allows a combination of translational and radial movements to occur between the outer shell and the inner shell such that the resulting movement may be a rotational movement of the outer shell relative to the inner shell within a controlled range. Controlling the force required to compress the followers in the radial direction as well as controlling the force required to deflect the outer shell rearwardly relative to the inner shell by translating movement of any of the followers within the tracks allows different degrees of absorption of forces to occur between the outer shell in the inner shell.

The general location of the coupling arrangement being at the top and sides of the helmet towards the rear of the helmet provides support for the front of the mask to be suspended freely at a location forward and detached from the front of the inner shell. This detachment between the front of the outer shell and the front of the inner shell minimizes the transmission of concussive vibrations from impacts at the front of the outer shell to be transmitted to the front of the inner shell on the face and skull of the user.

In the illustrated embodiment of figures 1 through 6, the outer shell 14 is fully formed as a single unitary body manufactured as a three-dimensional printed structure. The single three-dimensional printed structure is formed of uniform material throughout which includes the top section 38, the forehead section 40, the side sections 42, the lower section 44, and the bars 48 extending across the viewing portion 46. The singular body formed by the three-dimensional printed structure may also include the channels forming the tracks 50 integrally formed on the inner surface of the outer shell. The majority of the outer shell forming the top section 38, the forehead section 40, the side sections 42 and the lower section 44 may be manufactured as a three-dimensional lattice of individual struts connected at respective nodes so as to be oriented relative to one another in three dimensions. The three-dimensional printed structure is preferably formed of metal which is printed as an open framed lattice that remains open and porous to allow ventilation through the shell. The printed lattice structure is strong and lightweight, while the lattice can be printed in different densities at different regions of the helmet to ensure the outer shell is either fully rigid or has a controlled degree of resilience and shock absorption at specific regions.

In further embodiments, the outer shell can be formed of various composite materials, fiberglass, plastic materials, or any combination thereof while still be supported for resilient movement relative to the inner shell as described above.

Since various modifications can be made in the invention as herein above described, and many apparently widely different embodiments of same made, it is intended that all matter contained in the accompanying specification shall be interpreted as illustrative only and not in a limiting sense.

CLAIMS:

1. A protective helmet comprising:

an inner shell arranged to be worn on a head of a user;

an outer shell arranged to be mounted overtop of the inner shell so as to cover a top, a forehead, and laterally opposing sides of the user; and

a resilient coupling supporting the outer shell on the inner shell such that the outer shell is spaced radially outward from the inner shell and supporting the outer shell for resilient movement relative to the inner shell responsive to an impact to the outer shell.

2. The helmet according to claim 1 wherein the resilient coupling is formed by three-dimensional printing integrally together with at least one of the inner shell and the outer shell.

3. The helmet according to claim 1 wherein the inner shell, the outer shell and the resilient coupling are formed integrally together with one another as a uniform body by three-dimensional printing.

4. The helmet according to claim 1 wherein the resilient coupling includes a plurality of first elements formed by three-dimensional printing integrally together with the inner shell and a plurality of second elements formed by three-dimensional printing integrally together with the outer shell, the first coupling elements being selectively coupled to the second coupling elements to define the resilient coupling between the inner shell and the outer shell.

5. The helmet according to claim 4 wherein one of the first and second elements comprises sockets and another of the first and second elements comprises protrusions arranged to be received in the sockets respectively to define the resilient coupling.

6. The helmet according to claim 5 wherein the protrusions are selectively retained in the sockets by a resilient snap-fit arrangement.

7. The helmet according to claim 5 wherein each protrusion is linearly slidable within a respective one of sockets, each socket further comprising a resilient element therein which is resiliently deformed by sliding movement of the protrusion within the socket in response to an impact to the outer shell.

8. The helmet according to claim 7 wherein at least some of the sockets are oriented in a different direction than one of more adjacent ones of the sockets.

9. The helmet according to any one of claims 1 through 8 wherein the resilient coupling is arranged to provide a stepped increase in resistance to movement between the inner shell and the outer shell in response to increasing deflection between the inner shell

and the outer shell.

10. The helmet according to claim 9 wherein the resilient coupling includes (i) a plurality of first resilient elements providing resistance to movement between the inner shell and the outer shell in response to a first deflection amount, and (ii) a plurality of second resilient elements providing resistance to movement between the inner shell and the outer shell only response to a second deflection amount greater than the first deflection amount.

11. The helmet according to any one of claims 1 through 10 wherein the outer shell comprises a plurality of shell sections interlocked with one another so as to be movable relative to one another.

12. The helmet according to claim 11 wherein the shell sections are interlocked for pivotal movement relative to one another, and wherein stops on the shell sections engage one another to limit relative pivotal movement between the shell sections to a prescribed range of angular deflection.

13. The helmet according to any one of claims 1 through 12 wherein the resilient coupling comprise a lattice structure formed by three dimensional printing and occupying a cavity between the inner shell and the outer shell.

14. The helmet according to any one of claims 1 through 13 wherein the outer shell comprises a first rigid material, the inner shell comprises a second rigid material which is less rigid than the first rigid material, and wherein the resilient coupling comprises a plurality of struts formed of resilient material.

15. The helmet according to any one of claims 1 through 14 further comprising a liner supported along an interior of the inner shell to be worn against the head of the user, the inner shell and the liner are formed by three dimensional printing from dissimilar materials such that the inner shell is more rigid than the liner.

16. The helmet according to claim 15 further comprising integral connectors formed integrally by three dimensional printing together with at least one of the inner shell and the liner, the integral connectors being arranged to releasable couple the liner to the inner shell.

17. The helmet according to claim 16 wherein the releasable connectors comprise sockets on one of the inner shell and the liner and protrusions on another of the inner shell and the liner, wherein the protrusions are selectively retained in the sockets by a resilient snap-fit arrangement.

18. The helmet according to any one of claims 15 through 17 wherein the liner includes strap cavities formed internally therein by three dimensional printing of the liner,

the strap cavities receiving helmet straps extending therethrough.

19. The helmet according to any one of claims 15 through 17 wherein the liner includes electronic cavities formed internally therein by three dimensional printing of the liner, the electronic cavities receiving electronic hardware therein.

20. The helmet according to any one of claims 1 through 19 wherein the outer shell includes a plurality of ventilation openings formed therein and a plurality of structural members spanning across the ventilation openings so as to allow air to pass between the structural members, the structural members being formed by three-dimensional printing integrally together with the outer shell.

21. The helmet according to any one of claims 1 through 20 wherein the outer shell includes a plurality of helmet strap connectors mounted thereon and arranged to connect helmet straps to the outer shell, the helmet strap connectors being formed by three-dimensional printing integrally together with the outer shell.

22. The helmet according to any one of claims 1 through 21 wherein the outer shell includes a cage supported thereon so as to be arranged to span over eyes of the user, the cage being supported on the outer shell by cage connectors, the cage connectors being formed by three-dimensional printing integrally together with the outer shell.

23. The helmet according to any one of claims 1 through 22 wherein the outer shell includes at least one accessory mount arranged to mount a helmet accessory externally on the outer shell, said at least one accessory mount being formed by three-dimensional printing integrally together with the outer shell.

24. The helmet according to any one of claims 1 through 23 wherein the outer shell includes three dimensional indicia formed thereon, the indicia being formed by three-dimensional printing integrally together with the outer shell.

25. The helmet according to any one of claims 1 through 24 wherein the outer shell includes a cage supported thereon so as to be arranged to span over at least part of a facial area of the user, the cage being formed by three-dimensional printing integrally together with the outer shell.

26. The helmet according to claim 25 wherein the cage comprises a plurality of bars mounted in an intersecting manner to define the cage, at least one of the bars varying in shape along a length of the bar.

27. The helmet according to claim 25 or claim 26 wherein the cage comprises a plurality of bars mounted in an intersecting manner to define the cage, at least one of the bars

varying in cross-sectional size along a length of the bar.

28. The helmet according to any one of claims 25 through 27 wherein the cage comprises a plurality of bars mounted in an intersecting manner to define the cage, at least one of the bar having a profile which is elongated along a transverse axis in which the transverse axis varies in orientation about a longitudinal axis of the bars along a length of the bar.

29. The helmet according to any one of claims 25 through 28 wherein the cage comprises a plurality of bars mounted in an intersecting manner at respective intersections to define the cage, at least one of the intersections comprises two of the bars intersecting one another in a common plane at the intersection.

30. The helmet according to any one of claims 25 through 29 wherein the cage comprises a plurality of bars mounted in an intersecting manner at respective intersections to define the cage, at least some of the bars being shaped to define a resilient section formed therein, the resilient section being formed by three-dimensional printing integrally together with the cage, and the resilient section being resiliently deformable responsive to an impact.

31. The helmet according to claim 30 wherein the cage includes a main portion arranged to span over eyes of the user and a peripheral portion coupling the main portion to the outer shell, the resilient sections of the cage being located in the peripheral portion of the cage.

32. The helmet according to any one of claims 25 through 31 wherein the cage comprises a plurality of bars mounted in an intersecting manner at respective intersections to define the cage, at least some of the bars being shaped to define a beam profile having a greater resistance to bending in a first radial direction than a second radial direction relative to a longitudinal axis of the beam profile.

33. The helmet according to claim 32 wherein the beam profile has a greater resistance to bending transversely to a plane of the cage than bending within a plane of the cage.

34. The helmet according to any one of claims 25 through 33 wherein the cage comprises a plurality of bars mounted in an intersecting manner at respective intersections to define the cage, at least some of the bars comprising a hollow frame member.

35. The helmet according to any one of claims 1 through 34 wherein the resilient movement includes a rotational movement of the outer shell relative to the inner shell about a center of rotation located within a boundary of the inner shell.

36. The helmet according to any one of claims 1 through 35 wherein the resilient movement includes a radial movement of the outer shell relative to the inner shell.

37. The helmet according to any one of claims 1 through 36 wherein the resilient movement includes a translational movement of the outer shell relative to the inner shell.

38. The helmet according to any one of claims 1 through 37 wherein the inner shell and the outer shell are rigid.

39. The helmet according to any one of claims 1 through 38 wherein the inner shell is arranged to span at least the forehead of the user.

40. The helmet according to any one of claims 1 through 39 wherein the inner shell is arranged to span at least the temporal regions of the user.

41. The helmet according to any one of claims 1 through 40 wherein the outer shell is a three-dimensionally printed structure comprising a unitary body of open lattice material.

42. The helmet according to any one of claims 1 through 41 wherein the helmet is a hockey goalie helmet in which the outer shell is arranged to cover a jaw of the user and includes a central viewing portion arranged for alignment with eyes of the user which remains open for visibility.

43. The helmet according to claim 42 wherein the outer shell is supported for translational movement along a longitudinal axis extending between the front and an opposing rear of the helmet.

44. The helmet according to claim 43 wherein the outer shell is biased forwardly to return to a neutral position relative to the inner shell in response to being deflected rearwardly relative to the inner shell by an impact.

45. The helmet according to claim 44 wherein the outer shell is movable along the longitudinal axis relative to the inner shell from the neutral position rearwardly by a greater distance than forwardly.

46. The helmet according to any one of claims 43 through 45 further comprising a plurality of tracks fixed onto a first shell among the inner shell and the outer shell, and a plurality of followers fixed onto a second shell among the inner shell and the outer shell, wherein the followers are slidably coupled to the tracks respectively to define said translational movement.

47. The helmet according to claim 46 wherein each follower is radially compressible transversely to the longitudinal axis such that the resilient movement includes a radial movement of the outer shell relative to the inner shell.

48. The helmet according to claim 46 or claim 47 wherein each track comprises a groove and wherein each follower has a head having a profile which mates with a profile of the groove to retain the head within the groove while enabling longitudinal sliding of the head along the groove.

49. The helmet according to any one of claims 42 through 48 wherein the inner shell is arranged to span at least part of a jaw of the user.

50. The helmet according to any one of claims 42 through 49 wherein the inner shell includes a central opening in alignment with the central viewing portion and wherein the inner shell extends about a full perimeter of the central opening.

51. The helmet according to any one of claims 42 through 50 wherein the coupling arrangement between the outer shell and the inner shell is located only at a top and sides of the helmet.

52. The helmet according to any one of claims 42 through 51 wherein the coupling arrangement between the outer shell and the inner shell is located only rearward of a temporal region of the inner shell.

53. A cage arranged for use with a helmet, the cage comprising:

a plurality of bars mounted in an intersecting manner to define a boundary of the cage arranged to span over at least part of a facial area of the user when the cage is supported on the helmet;

wherein the bars being formed integrally together with one another by three-dimensional printing.

54. The cage according to claim 53 wherein at least one of the bars varies in shape along a length of the bar.

55. The cage according to claim 53 or claim 54 wherein at least one of the bars varies in cross-sectional size along a length of the bar.

56. The cage according to any one of claims 53 through 55 wherein at least one of the bars has a profile which is elongated along a transverse axis in which the transverse axis varies in orientation about a longitudinal axis of the bar along a length of the bar.

57. The cage according to any one of claims 53 through 56 wherein at least one of the intersections comprises two of the bars intersecting one another in a common plane at the intersection.

58. The cage according to any one of claims 53 through 57 wherein at least some of the bars are shaped to define a resilient section formed therein, the resilient section

being formed by three-dimensional printing integrally together with the cage, and the resilient section being resiliently deformable responsive to an impact.

59. The cage according to any one of claims 53 through 58 wherein the cage includes a main portion arranged to span over eyes of the user and a peripheral portion coupling the main portion to the outer shell, the resilient sections of the cage being located in the peripheral portion of the cage.

60. The cage according to any one of claims 53 through 59 wherein at least some of the bars are shaped to define a beam profile having a greater resistance to bending in a first radial direction of the bar transversely to a plane of the cage than a second radial direction of the bar within a plane of the cage.

61. The cage according to any one of claims 53 through 60 wherein at least some of the bars comprise a hollow frame member.

62. An article of protective equipment to be worn on a body part of a user, the article comprising:

an inner shell including a concave interior side arranged to be worn against the body part of the user and a convex exterior side;

an outer shell arranged to be mounted overtop of the inner shell so as to cover the inner shell, the outer shell including a concave interior side and a convex exterior side; and

a resilient coupling extending between the convex exterior side of the inner shell and the concave interior side of the outer shell such that the outer shell is spaced radially outward from the inner shell, the outer shell being supported by the resilient coupling for resilient movement relative to the inner shell responsive to an impact to the outer shell.

63. The article according to claim 62 wherein the resilient coupling is formed by three-dimensional printing integrally together with at least one of the inner shell and the outer shell.

64. The article according to claim 62 wherein the inner shell, the outer shell and the resilient coupling are formed integrally together with one another as a uniform body by three-dimensional printing.

65. The article according to claim 62 wherein the resilient coupling includes a plurality of first elements formed by three-dimensional printing integrally together with the inner shell and a plurality of second elements formed by three-dimensional printing integrally together with the outer shell, the first coupling elements being selectively coupled to the second coupling elements to define the resilient coupling between the inner shell and the outer shell.

66. The article according to claim 65 wherein one of the first and second elements comprises sockets and another of the first and second elements comprises protrusions arranged to be received in the sockets respectively to define the resilient coupling.

67. The article according to claim 66 wherein the protrusions are selectively retained in the sockets by a resilient snap-fit arrangement.

68. The article according to claim 66 wherein each protrusion is linearly slidable within a respective one of sockets, each socket further comprising a resilient element therein which is resiliently deformed by sliding movement of the protrusion within the socket in response to an impact to the outer shell.

69. The article according to claim 68 wherein at least some of the sockets are oriented in a different direction than one of more adjacent ones of the sockets.

70. The article according to any one of claims 62 through 69 wherein the resilient coupling is arranged to provide a stepped increase in resistance to movement between the inner shell and the outer shell in response to increasing deflection between the inner shell and the outer shell.

71. The article according to claim 70 wherein the resilient coupling includes (i) a plurality of first resilient elements providing resistance to movement between the inner shell and the outer shell in response to a first deflection amount, and (ii) a plurality of second resilient elements providing resistance to movement between the inner shell and the outer shell only response to a second deflection amount greater than the first deflection amount.

72. The article according to any one of claims 62 through 71 wherein the outer shell comprises a plurality of shell sections interlocked with one another so as to be movable relative to one another.

73. The article according to claim 72 wherein the shell sections are interlocked for pivotal movement relative to one another, and wherein stops on the shell sections engage one another to limit relative pivotal movement between the shell sections to a prescribed range of angular deflection.

74. The article according to any one of claims 62 through 73 wherein the resilient coupling comprise a lattice structure formed by three dimensional printing and occupying a cavity between the inner shell and the outer shell.

75. The article according to any one of claims 62 through 74 wherein the outer shell comprises a first rigid material, the inner shell comprises a second rigid material which is less rigid than the first rigid material, and wherein the resilient coupling comprises a

plurality of struts formed of resilient material.

76. The article according to any one of claims 62 through 75 further comprising a liner supported along an interior of the inner shell to be worn against the head of the user, the inner shell and the liner are formed by three dimensional printing from dissimilar materials such that the inner shell is more rigid than the liner.

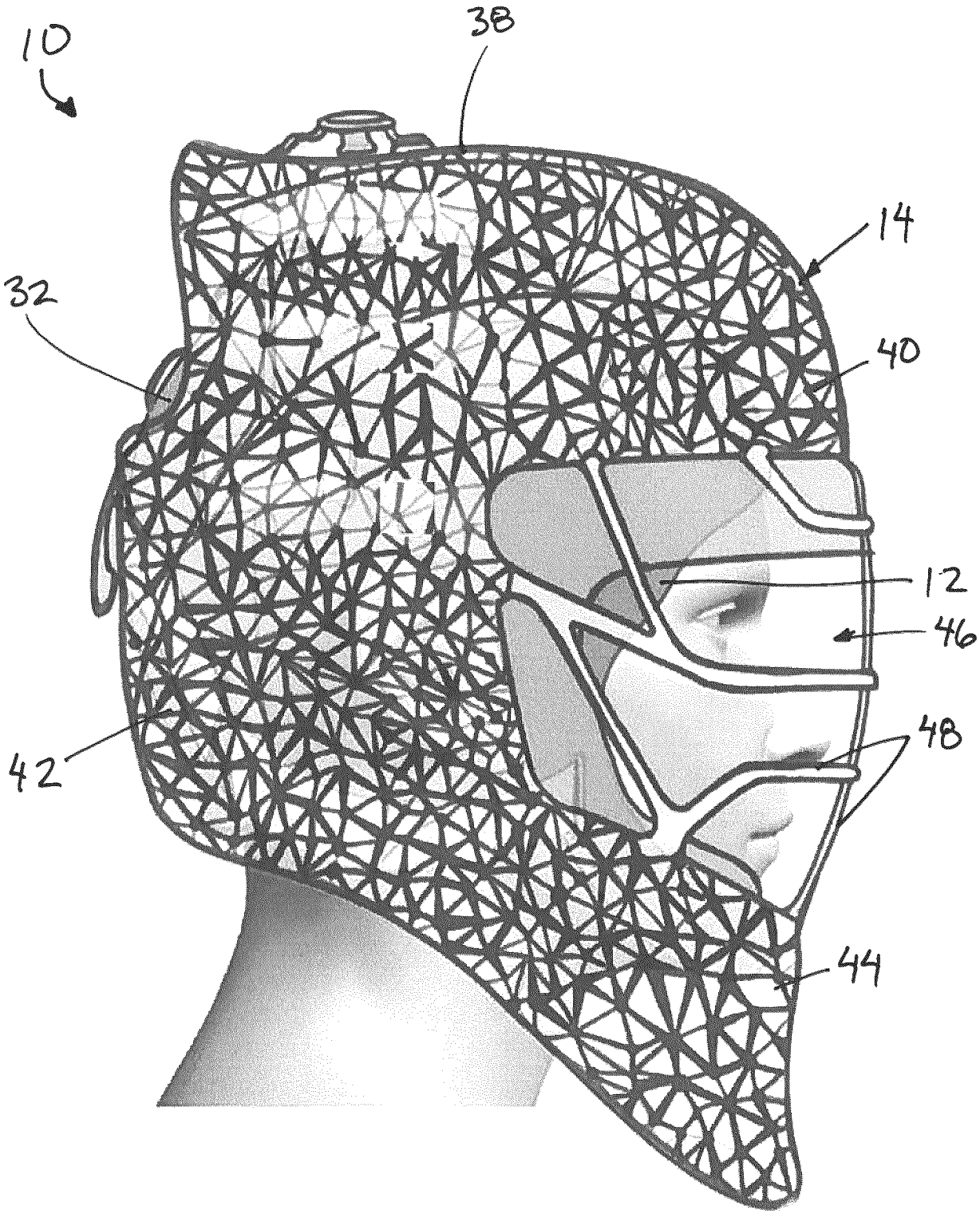


FIG. 1

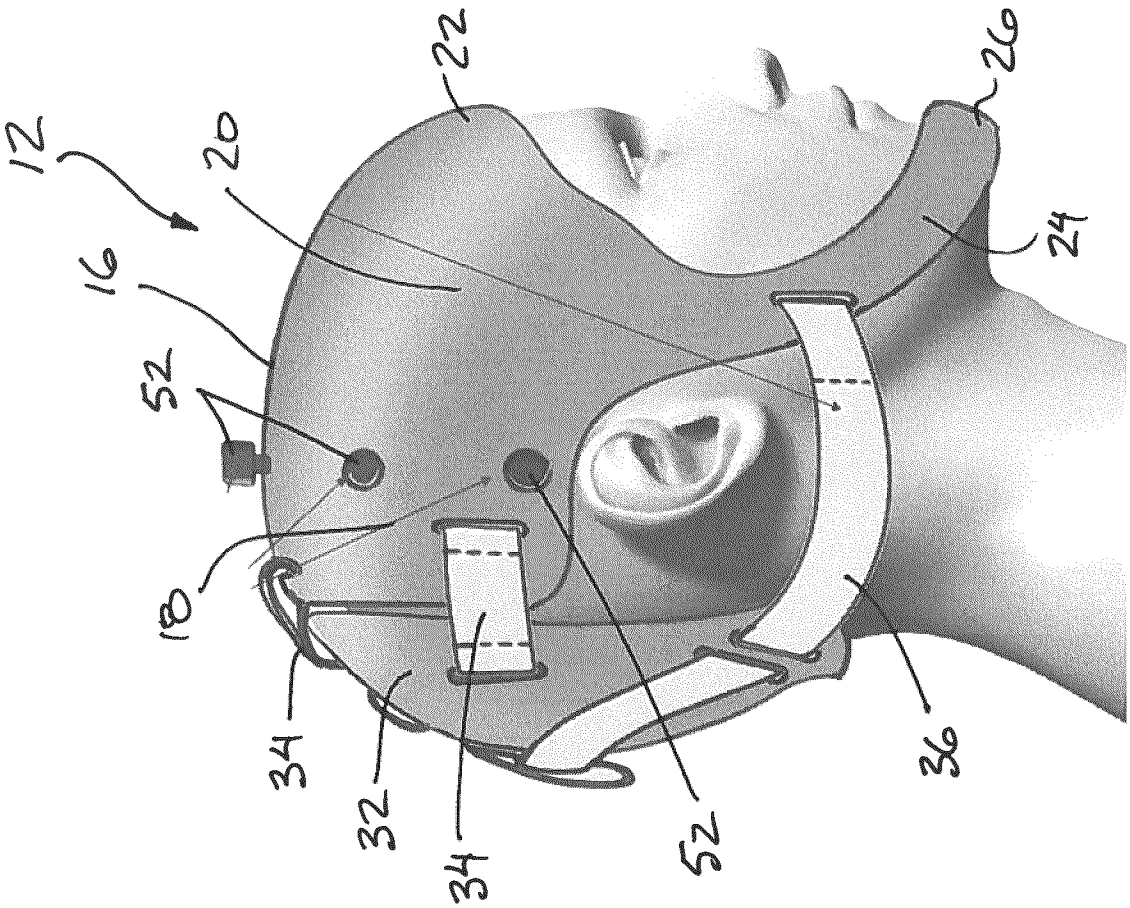

12
20
22
26
16
24
52
18
34
32
34
52
36

FIG. 3

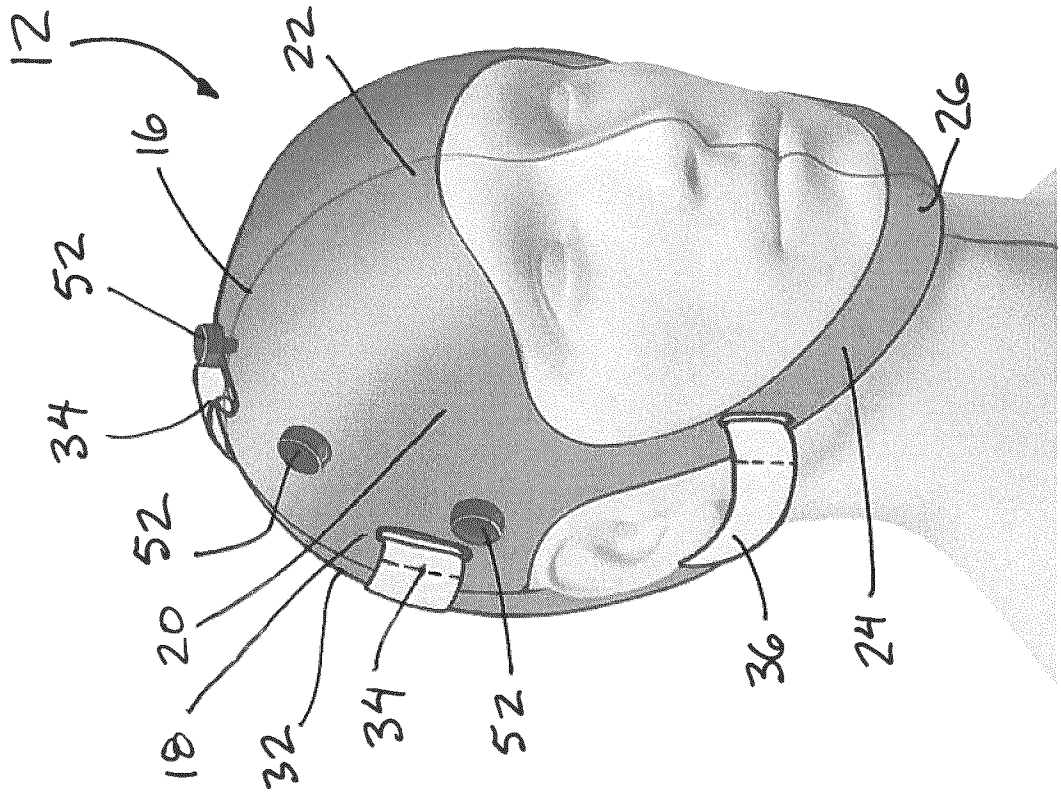

12
22
16
26
52
34
52
20
18
32
34
52
36
24

FIG. 2

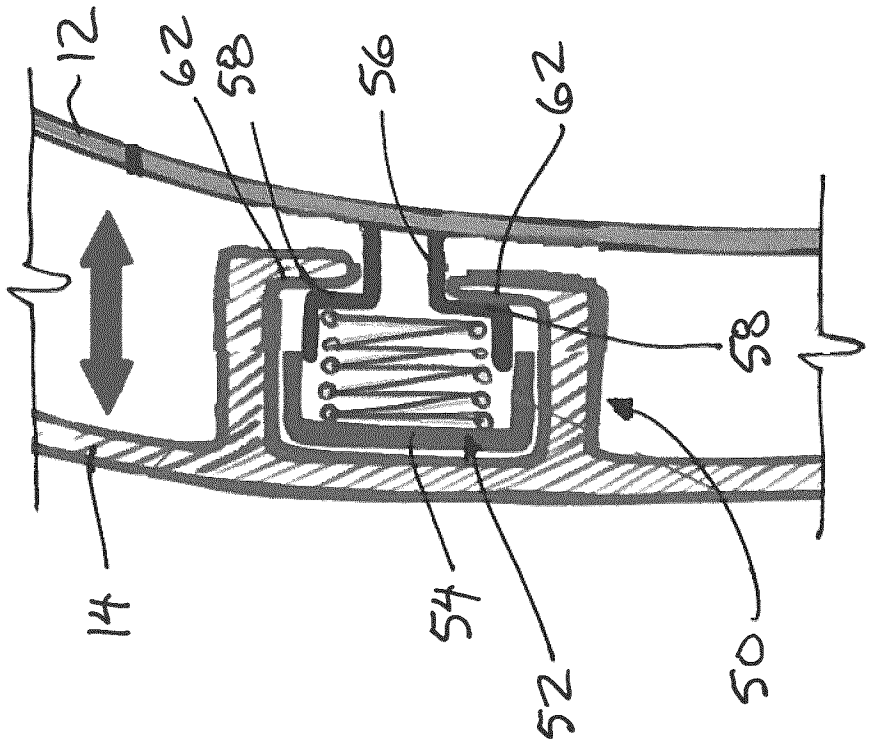


FIG. 5

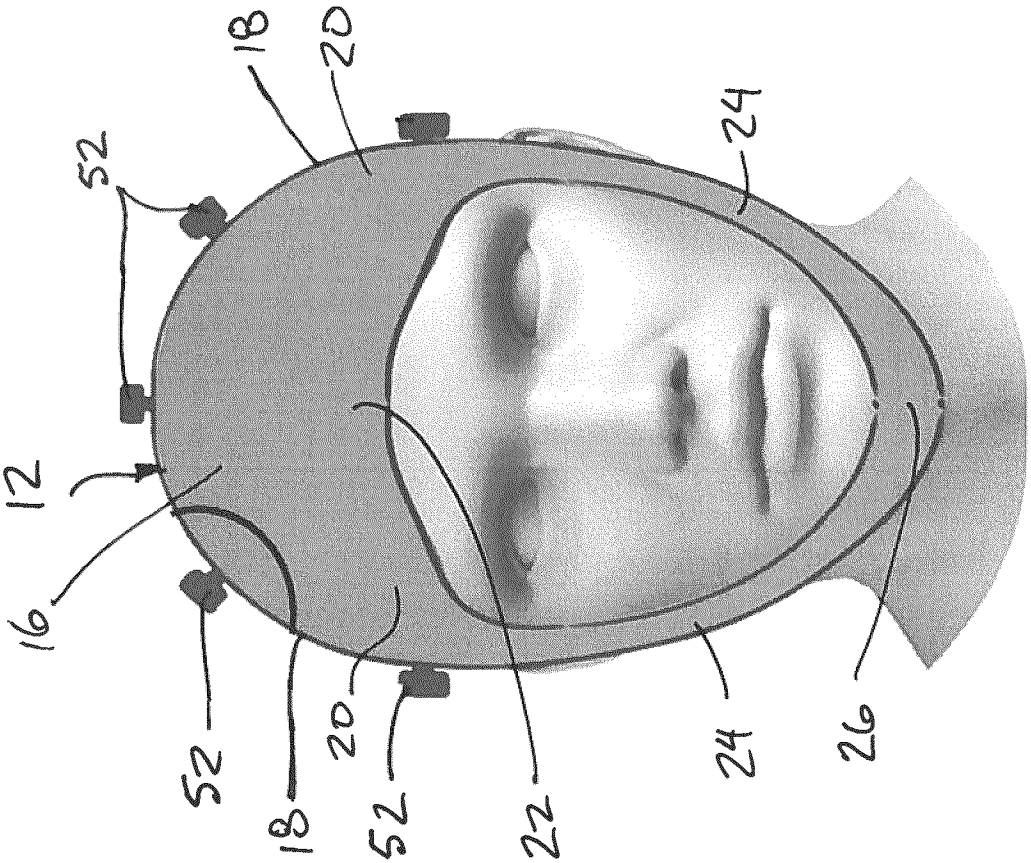


FIG. 4

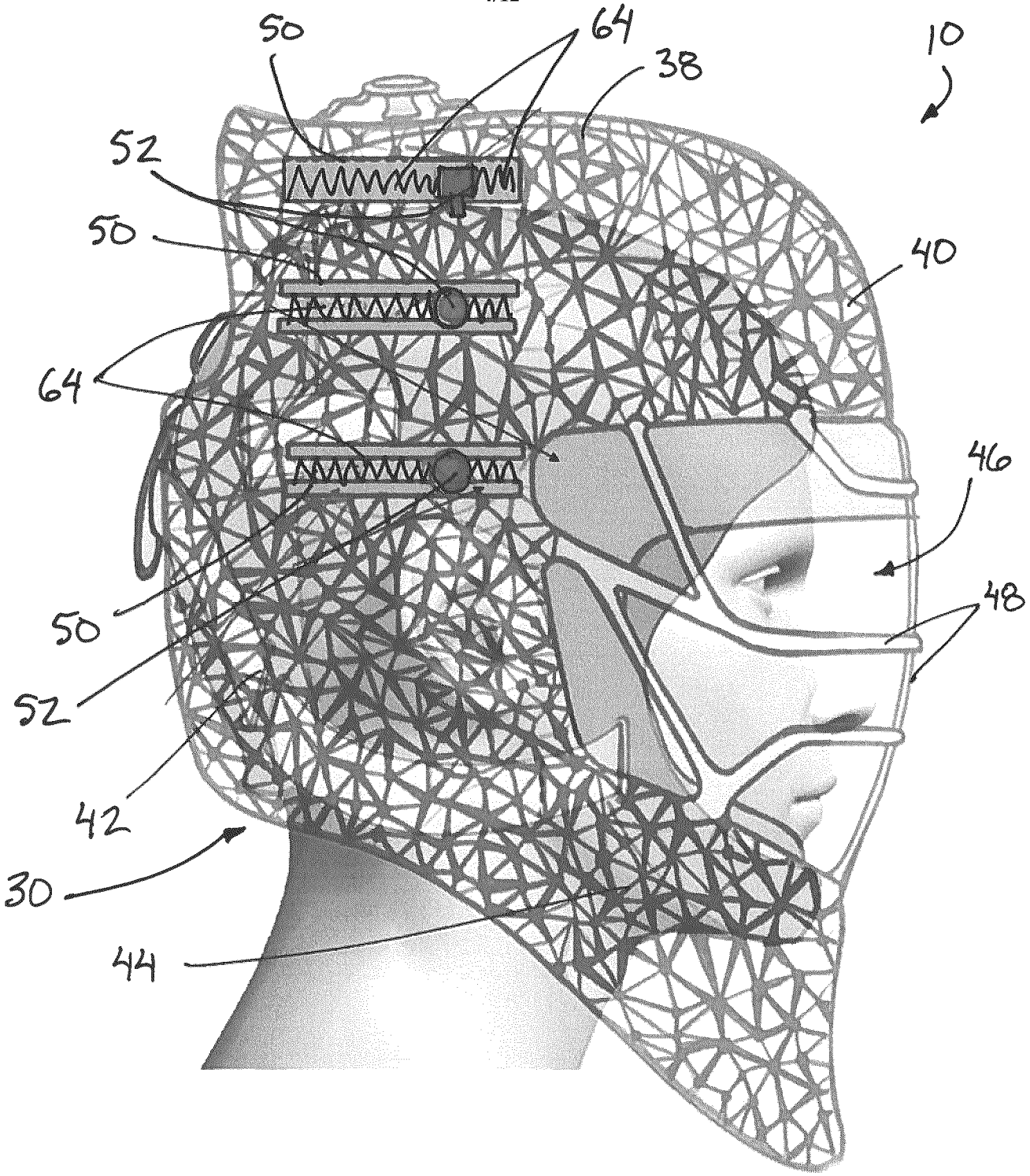


FIG. 6

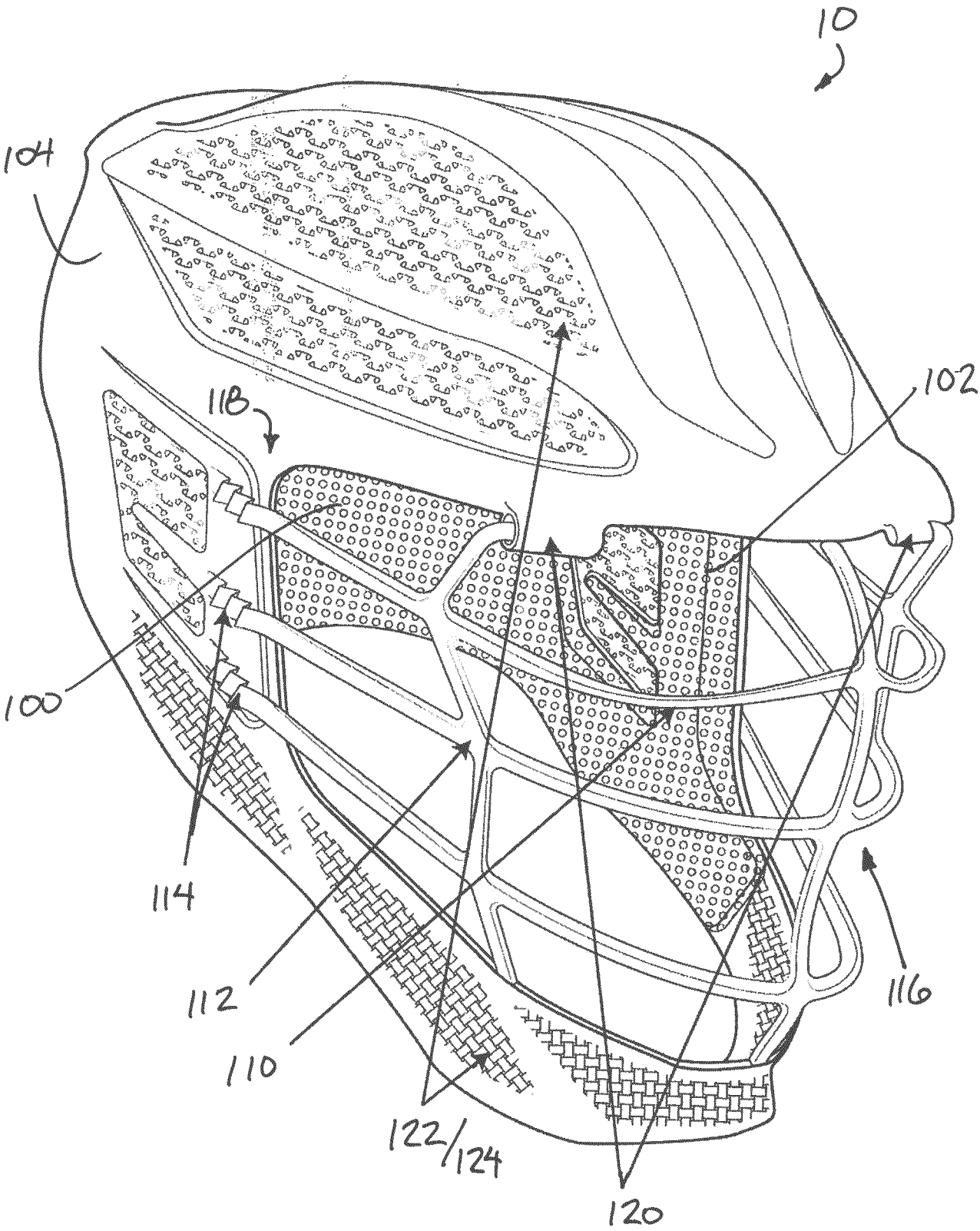


FIG.7

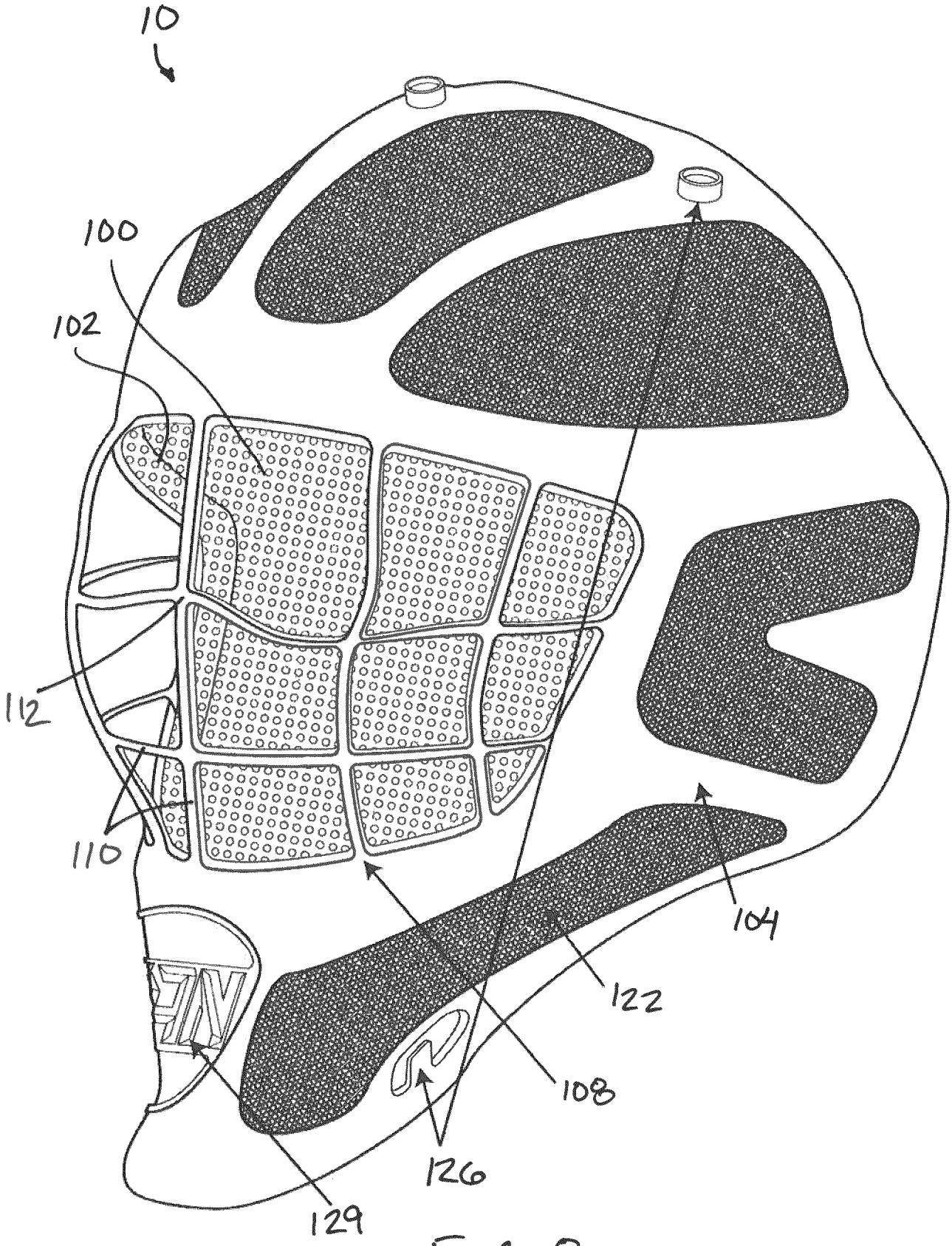


FIG. 8

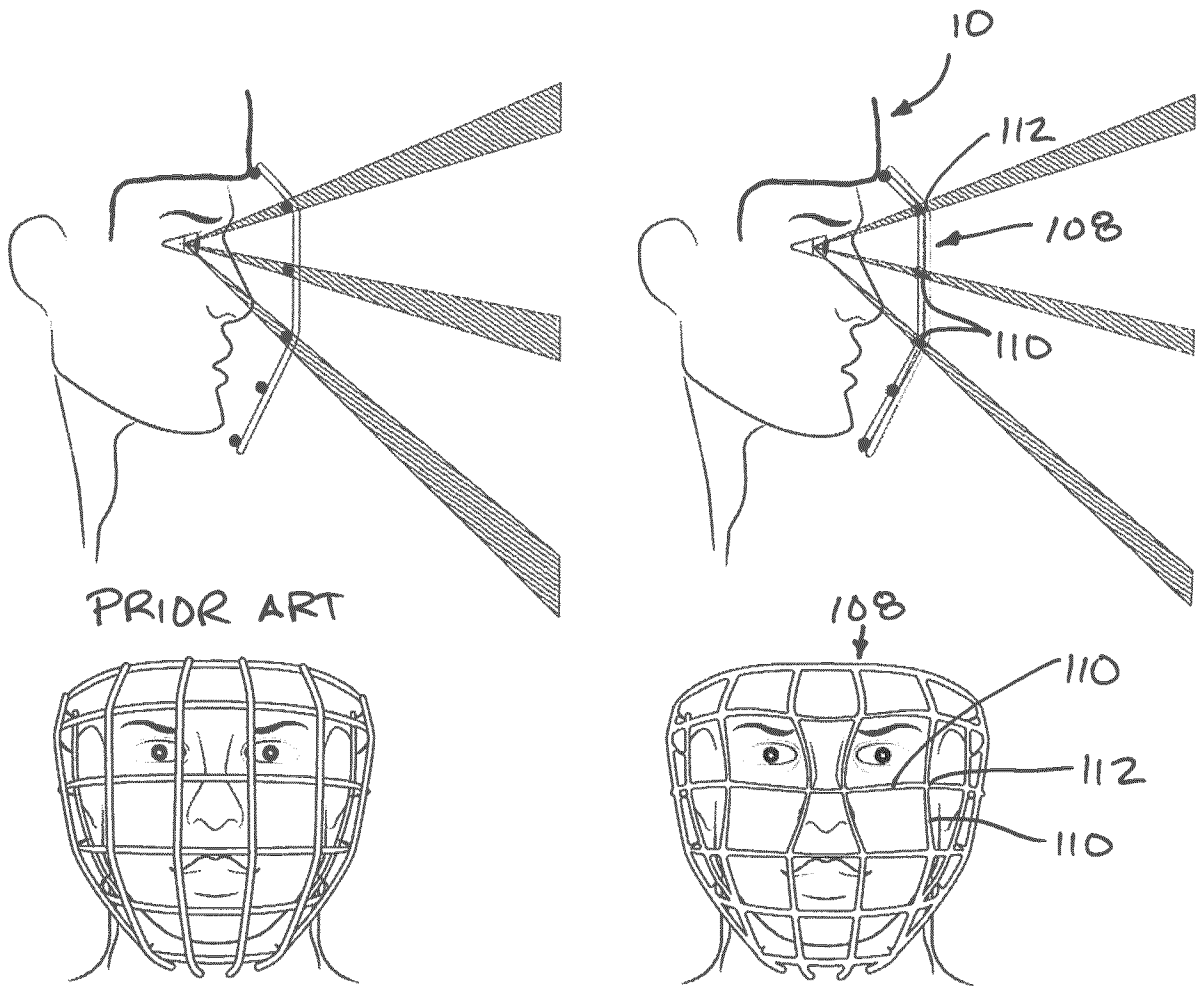


FIG. 9

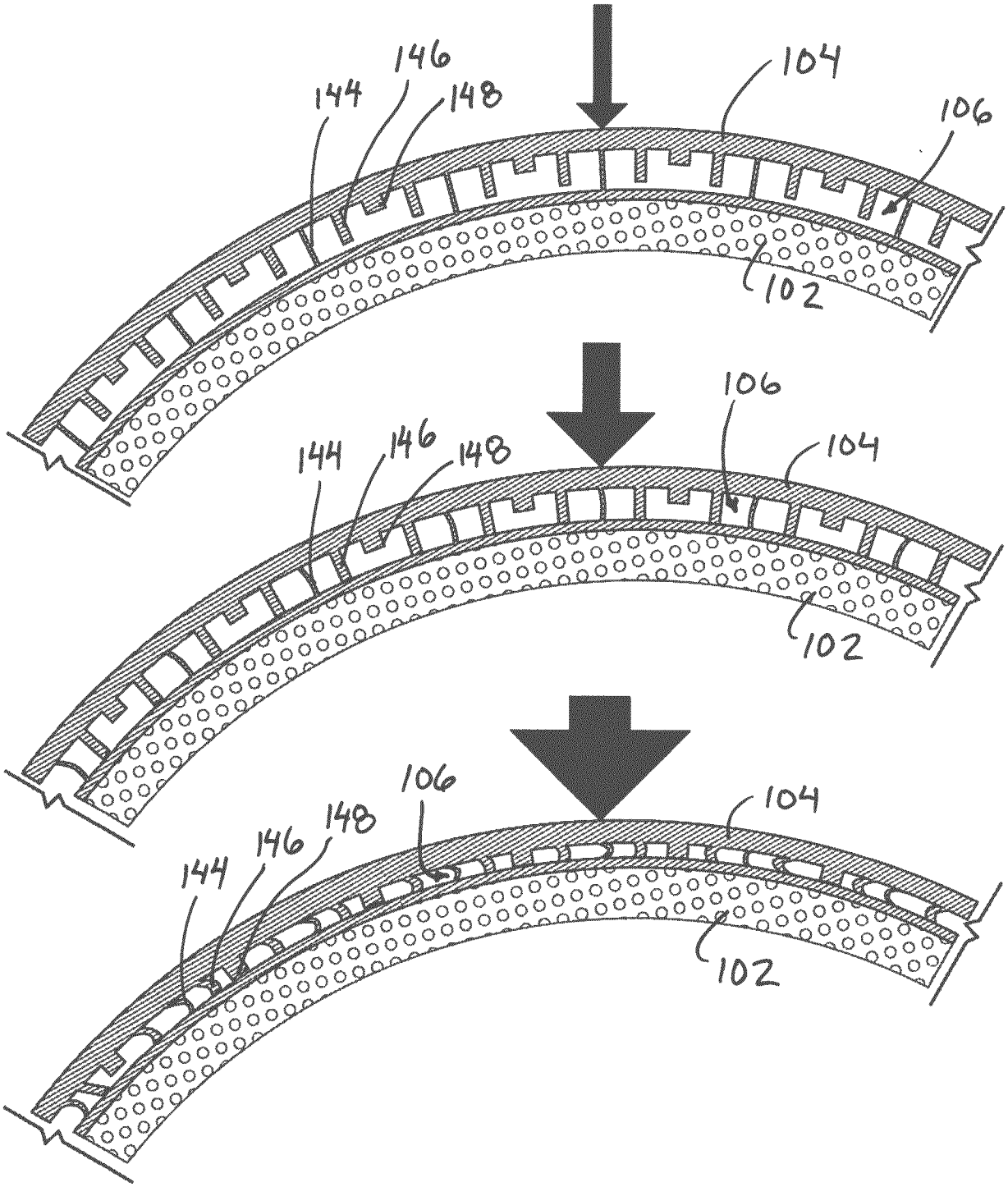

144
146
148
104
106
102
106
144
146
148
104
102
106
144
146
148
104
102

FIG. 10

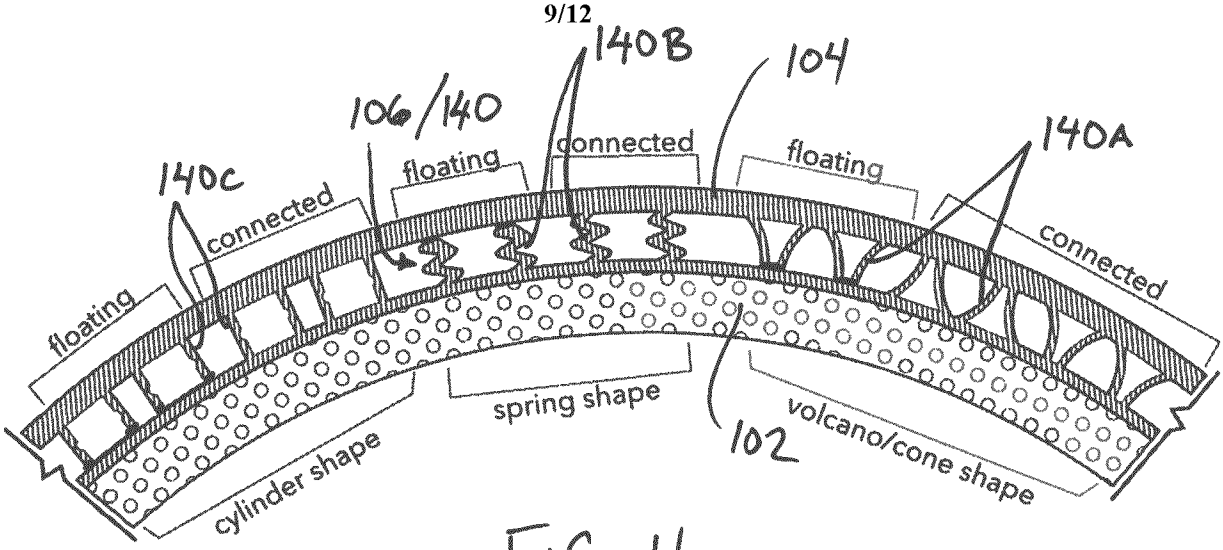


FIG. 11

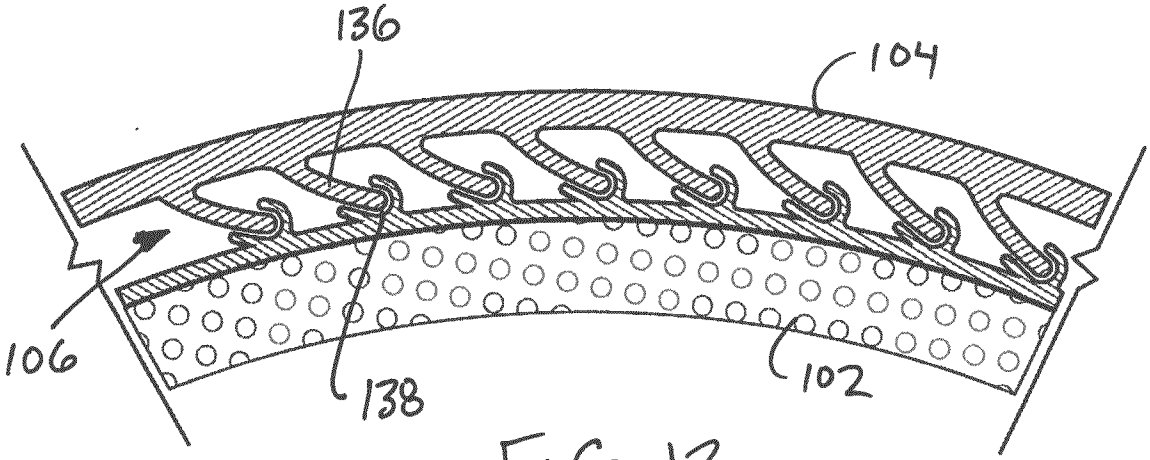


FIG. 12

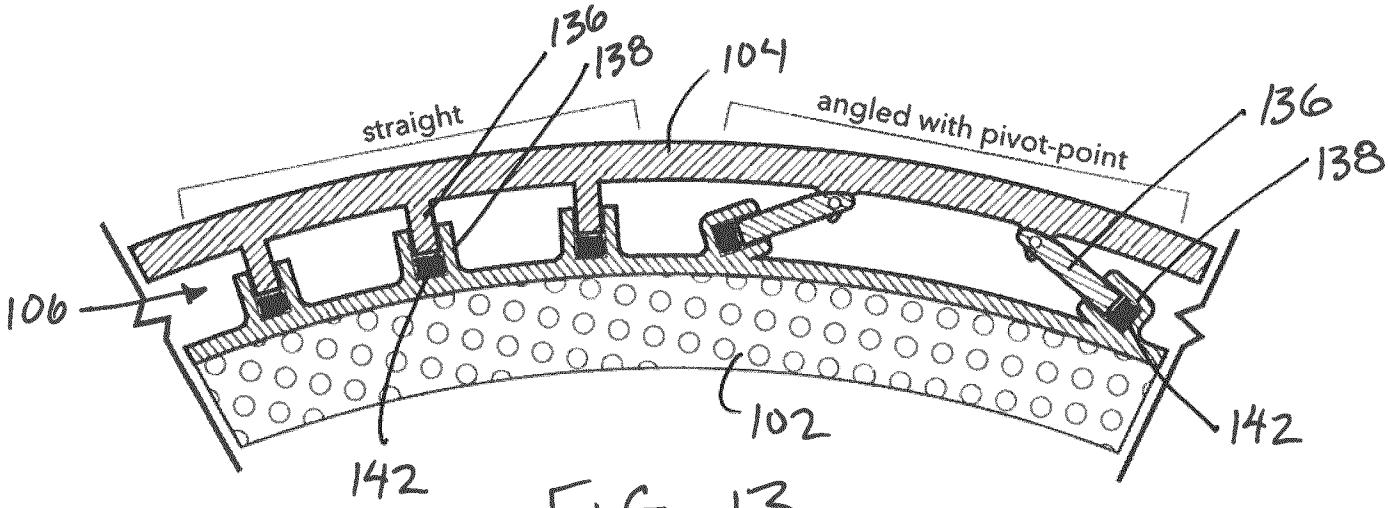


FIG. 13

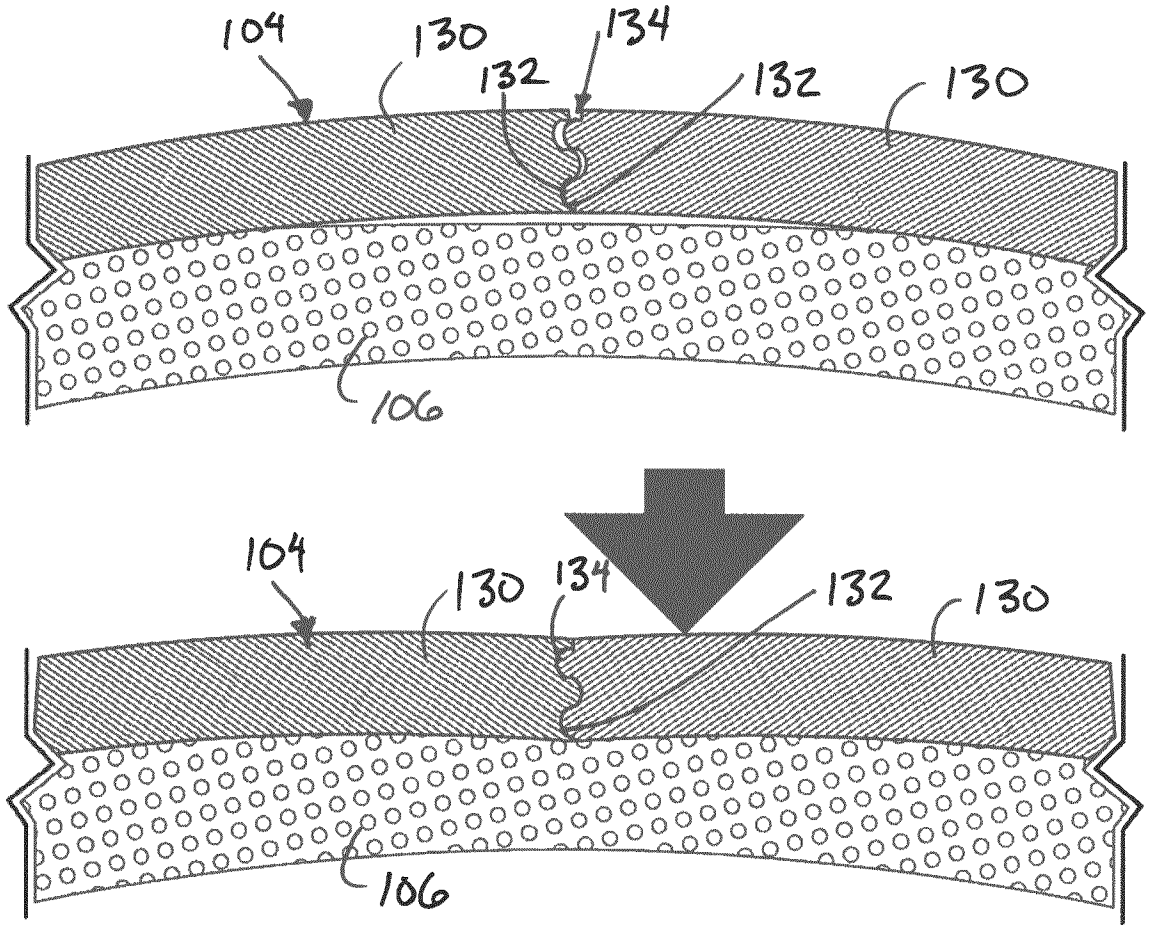


FIG. 14

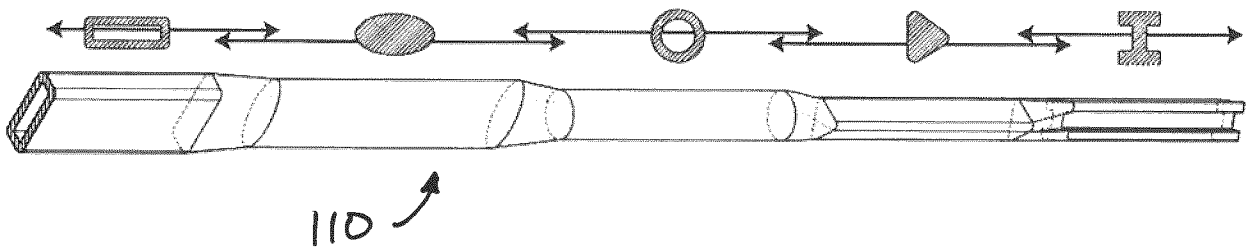


FIG. 15

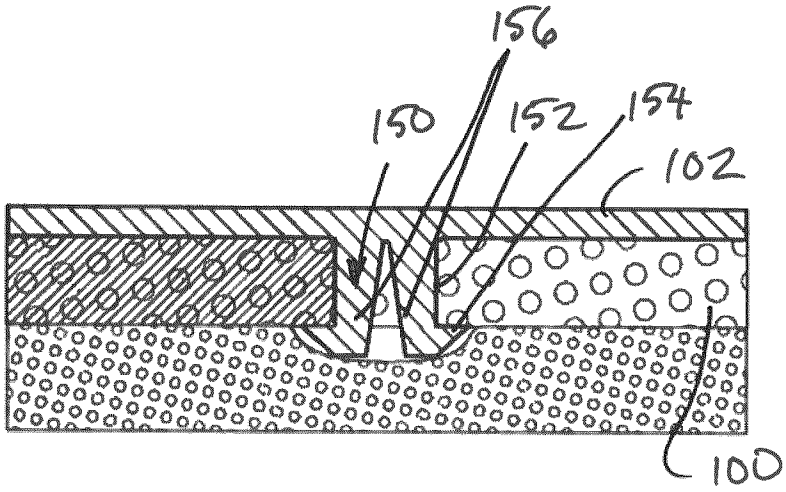


FIG. 16

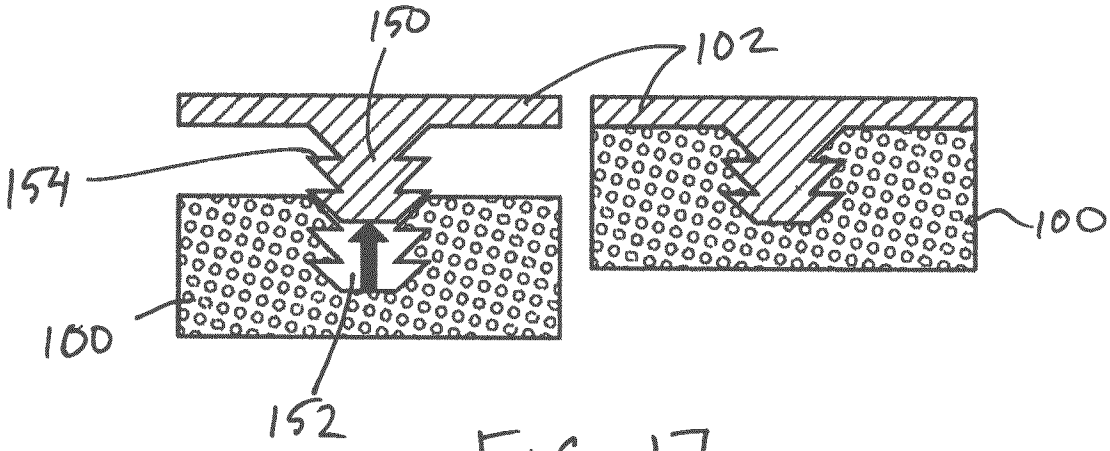


FIG. 17

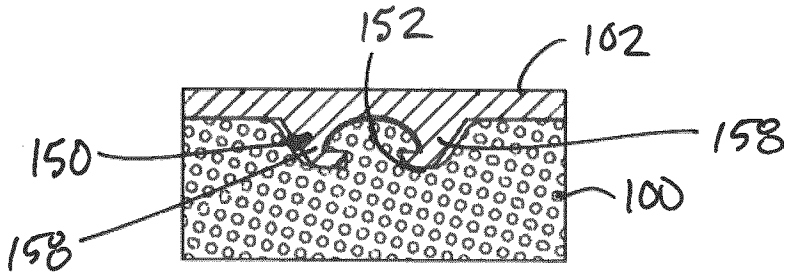


FIG. 18

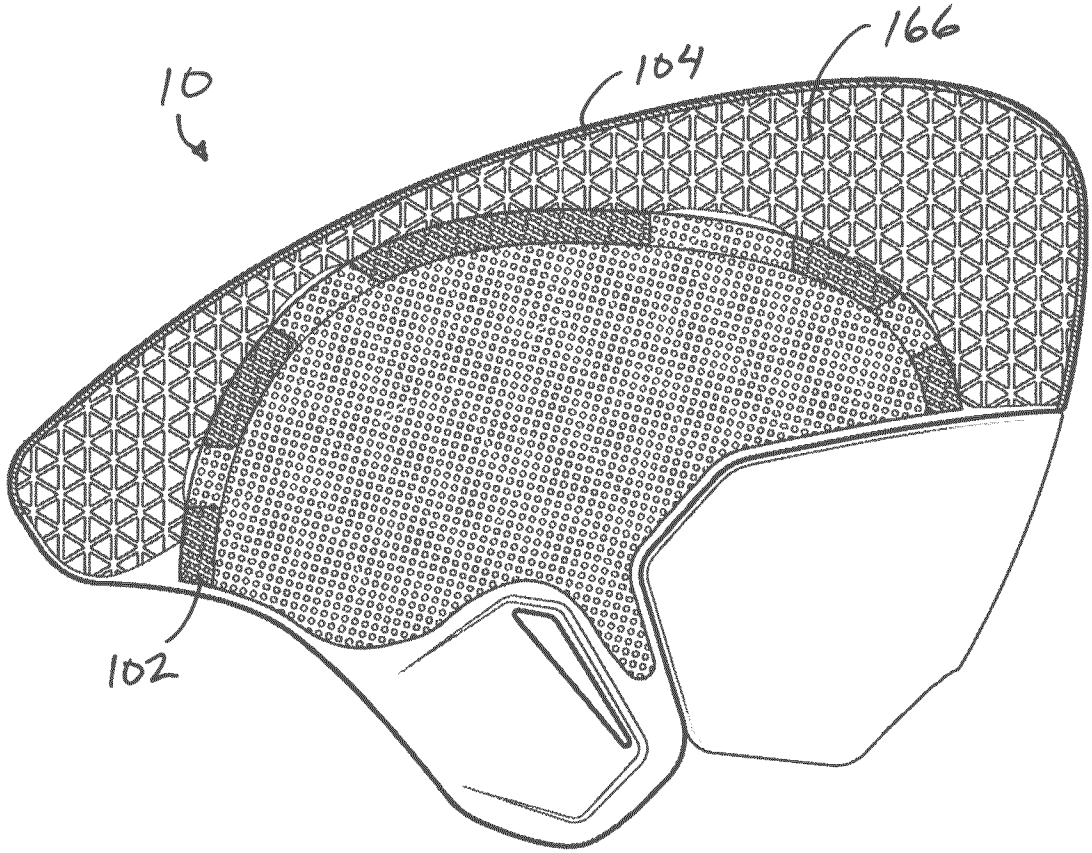


FIG. 19

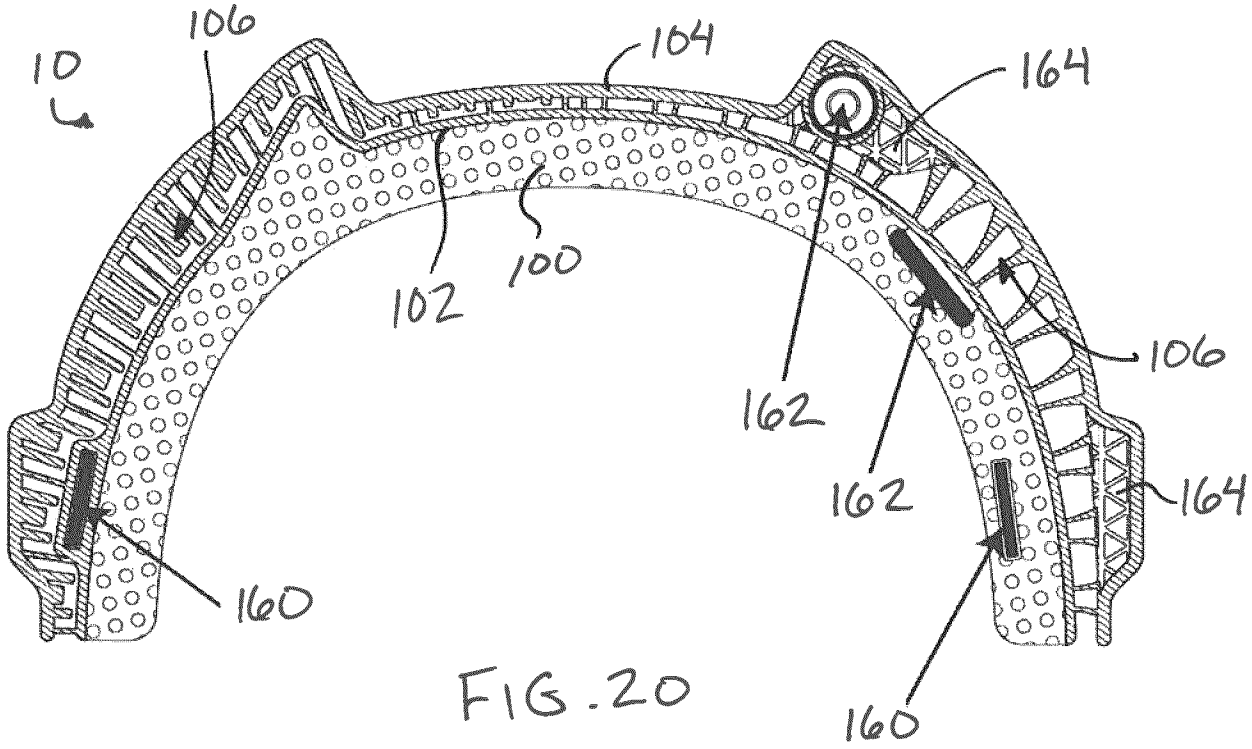


FIG. 20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2024/051050

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***A42B 3/14*** (2006.01), ***A42B 3/06*** (2006.01)

CPC: A42B 3/14 (2013.01), A42B 3/064 (2013.01)

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)
IPC: ***A42B 3/06*** (2006.01), ***A42B 3/14*** (2006.01), ***A63B-071/08*** (2006.01), ***A63B-071/10*** (2006.01), ***A63B-071/12*** (2006.01), ***A63B-071/14*** (2006.01)
CPC: A42B 3/064 (2013.01), A42B 3/063 (2013.01), A42B 3/14 (2013.01), A63B-071/08 (2013.01), A63B-071/10 (2013.01), A63B-071/12 (2013.01), A63B-071/14 (2013.01), A63B-2071/12+ (2013.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Databases: Orbit (FAMPAT)
Keywords: shell, inner, interior, outer, exterior, resilient, spring, rubber, deform+, coupl+, connect+, fasten+, attach+, 3D print+, track, channel, rail, socket, protru+, ball, head, slid+, rotat+, goalie, goaler, catch+, damp+, absorb+, impact+, shock+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 2016/0369861 A1 (PHIPPS et al.) 22 December 2016 (22-12-2016) * Figs. 1-6; para. [0002], [0032], [0034], [0043]-[0044], [0059], [0066], [0103] *	1-3, 9-10, 14, 62-64, 70-71 and 75; 11-12 and 72-73; 4-8, 13, 15-52, 65-69, 74 and 76
X Y A	US 2019/0133235 A1 (DOMANSKIS et al.) 09 May 2019 (09-05-2019) * Figs. 2, 6-8, 24, 26-28; para. [0013], [0020], [0076]-[0077], [0085], [0093], [0107] *	1, 13, 15, 19, 21-30, 32-40, 42-45, 49-52, 62, 74 and 76; 16-18, 20, 31, 41, 46 and 48; 2-12, 14, 47, 63-73 and 75

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"D"	document cited by the applicant in the international application
"E"	earlier application or patent but published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"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
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search 07 November 2024 (07-11-2024)	Date of mailing of the international search report 14 November 2024 (14-11-2024)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Eric E. Breton (819) 639-7829

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 2021/0161241 A1 (KLEIN et al.) 03 June 2021 (03-06-2021) * Figs. 15-25, 33-34; para. [0084]-[0089] *	1, 9-10, 35-40, 42-44, 49-50, 62 and 70-71; 31; 2-8, 11-30, 32-34, 41, 45-48, 51-52, 63-69 and 72-76
X A	US 2022/0022586 A1 (POMERING) 27 January 2022 (27-01-2022) * Figs. 16-20; para. [0117]-[0123] *	1, 4-8, 62 and 65-69; 2-3, 9-52, 63-64 and 70-76
X A	US 2019/0231018 A1 (BOUTIN) 01 August 2019 (01-08-2019) * Figs. 7-12, 23; para. [0122], [0132], [0134] *	1-3 and 62-64; 4-52 and 65-76
Y	US 5101517 A (DOUGLAS) 07 April 1992 (07-04-1992) * Fig. 7; col. 3, line 63 to col. 4, line 3 *	16-18
Y	DE 29621145 U1 (SCHÖLLHORN) 23 January 1997 (23-01-1997) * Figs. 1-2; claims 1 and 6 *	20
Y	EP 3000341 A1 (ZÜLL) 30 March 2016 (30-03-2016) * Figs. 1-12 *	41
Y	US 2018/0160760 A1 (SUDDABY) 14 June 2018 (14-06-2018) * Figs. 1-4, para. [0044] *	46 and 48
Y	DE 202004012285 U1 (HEGENDÖRFER et al.) 30 September 2004 (30-09-2004) * Figs. 1-6 *	11-12 and 72-73

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2024/051050

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of the first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The claims are directed to a plurality of inventive concepts as follows:

Group A - Claims 1-52 and 62-76 wherein independent claims 1 and 62 commonly define an article of protective equipment (helmet) to be worn on a body part (head) of a user, the article comprising: an inner shell arranged to be worn against the body part of the user; an outer shell arranged to be mounted overtop of the inner shell so as to cover the inner shell; and a resilient coupling supporting the outer shell on the inner shell such that the outer shell is spaced radially outward from the inner shell and supporting the outer shell for resilient movement relative to the inner shell responsive to an impact to the outer shell and

Group B - Claims 53-61 are directed to a cage arranged for use with a helmet, the cage comprising: a plurality of bars mounted in an intersecting manner to define a boundary of the cage arranged to span over at least part of a facial area of the user when the cage is supported on the helmet; wherein the bars being formed integrally together with one another by three-dimensional printing.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claim Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim Nos.:

1-52 and 62-76

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2016369861A1	22 December 2016 (22-12-2016)	US9879741B2	30 January 2018 (30-01-2018)
		US2017050593A1	23 February 2017 (23-02-2017)
		US10029633B2	24 July 2018 (24-07-2018)
		US2013061371A1	14 March 2013 (14-03-2013)
		US9439469B2	13 September 2016 (13-09-2016)
		US2013185837A1	25 July 2013 (25-07-2013)
		US9089180B2	28 July 2015 (28-07-2015)
		US2015250246A1	10 September 2015 (10-09-2015)
		US9549582B2	24 January 2017 (24-01-2017)
		US9388873B1	12 July 2016 (12-07-2016)
US2019133235A1	09 May 2019 (09-05-2019)	CA3114644A1	02 April 2020 (02-04-2020)
		EP3855968A1	04 August 2021 (04-08-2021)
		EP3855968A4	06 July 2022 (06-07-2022)
		WO2020069497A1	02 April 2020 (02-04-2020)
US2021161241A1	03 June 2021 (03-06-2021)	US11992076B2	28 May 2024 (28-05-2024)
		AU2014259832A1	12 November 2015 (12-11-2015)
		AU2014259832B2	23 November 2017 (23-11-2017)
		CA2910671A1	06 November 2014 (06-11-2014)
		CA2910671C	14 March 2023 (14-03-2023)
		CA3187975A1	06 November 2014 (06-11-2014)
		CN105705052A	22 June 2016 (22-06-2016)
		CN105705052B	17 July 2020 (17-07-2020)
		CN111671194A	18 September 2020 (18-09-2020)
		JP2016524050A	12 August 2016 (12-08-2016)
		JP6545664B2	17 July 2019 (17-07-2019)
		US2018235305A1	23 August 2018 (23-08-2018)
		US10912345B2	09 February 2021 (09-02-2021)
		US2014325744A1	06 November 2014 (06-11-2014)
		US2016066642A1	10 March 2016 (10-03-2016)
		US9949523B2	24 April 2018 (24-04-2018)
		US2024306758A1	19 September 2024 (19-09-2024)
		WO2014179604A1	06 November 2014 (06-11-2014)
US2022022586A1	27 January 2022 (27-01-2022)	US11730223B2	22 August 2023 (22-08-2023)
		CA3110763A1	26 March 2020 (26-03-2020)
		CA3110763C	17 October 2023 (17-10-2023)
		CN112911959A	04 June 2021 (04-06-2021)
		CN112911959B	09 January 2024 (09-01-2024)
		EP3852565A1	28 July 2021 (28-07-2021)
		GB201815332D0	07 November 2018 (07-11-2018)
		GB201909979D0	28 August 2019 (28-08-2019)
		TW202019309A	01 June 2020 (01-06-2020)
		TWI811453B	11 August 2023 (11-08-2023)
		WO2020058446A1	26 March 2020 (26-03-2020)
US2019231018A1	01 August 2019 (01-08-2019)	US11517063B2	06 December 2022 (06-12-2022)
		CA3040596A1	26 April 2018 (26-04-2018)
		EP3525612A1	21 August 2019 (21-08-2019)
		EP3525612A4	05 August 2020 (05-08-2020)
		WO2018072017A1	26 April 2018 (26-04-2018)
US5101517A	07 April 1992 (07-04-1992)	None	
DE29621145U1	23 January 1997 (23-01-1997)	None	
EP3000341A1	30 March 2016 (30-03-2016)	DE102014113889A1	31 March 2016 (31-03-2016)

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2018160760A1	14 June 2018 (14-06-2018)	US11278076B2	22 March 2022 (22-03-2022)
		AU2013230501A1	23 October 2014 (23-10-2014)
		AU2014235767A1	05 November 2015 (05-11-2015)
		CA2866492A1	12 September 2013 (12-09-2013)
		CA2907200A1	25 September 2014 (25-09-2014)
		CN105357999A	24 February 2016 (24-02-2016)
		CN107404961A	28 November 2017 (28-11-2017)
		CN107404961B	04 December 2020 (04-12-2020)
		CN110167375A	23 August 2019 (23-08-2019)
		CN110167375B	09 December 2022 (09-12-2022)
		EP2822411A1	14 January 2015 (14-01-2015)
		EP2822411A4	13 January 2016 (13-01-2016)
		EP2967182A2	20 January 2016 (20-01-2016)
		EP3253244A1	13 December 2017 (13-12-2017)
		EP3253244A4	05 September 2018 (05-09-2018)
		EP3253244B1	15 January 2020 (15-01-2020)
		EP3516977A1	31 July 2019 (31-07-2019)
		EP3565427A1	13 November 2019 (13-11-2019)
		EP3565427B1	20 October 2021 (20-10-2021)
		JP2015513008A	30 April 2015 (30-04-2015)
		JP2016511339A	14 April 2016 (14-04-2016)
		US2016366969A1	22 December 2016 (22-12-2016)
		US10165818B2	01 January 2019 (01-01-2019)
		US2017251744A1	07 September 2017 (07-09-2017)
		US10517346B2	31 December 2019 (31-12-2019)
		US2015143617A1	28 May 2015 (28-05-2015)
		US10517347B2	31 December 2019 (31-12-2019)
		US2019082766A1	21 March 2019 (21-03-2019)
		US11109632B2	07 September 2021 (07-09-2021)
		US2013232668A1	12 September 2013 (12-09-2013)
		US2014173810A1	26 June 2014 (26-06-2014)
		US9795178B2	24 October 2017 (24-10-2017)
		US2017112220A1	27 April 2017 (27-04-2017)
		US9980531B2	29 May 2018 (29-05-2018)
		WO2013134063A1	12 September 2013 (12-09-2013)
		WO2014150694A2	25 September 2014 (25-09-2014)
		WO2014150694A3	08 January 2015 (08-01-2015)
		WO2016127095A1	11 August 2016 (11-08-2016)
		WO2018129447A1	12 July 2018 (12-07-2018)
DE202004012285U1	30 September 2004 (30-09-2004)	None	