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(54) A HELMET FOR IMPACT PROTECTION

(57) According to an embodiment, the invention relates to helmet (100) for protecting a wearer's head (107) comprising a protective layer (106) configured to, when the helmet (100) is impacted by a force (105), absorb the normal component (102) thereof by compression and rupture (211, 212, 510, 601) when the tangential component (103) of the force exceeds a predefined threshold.

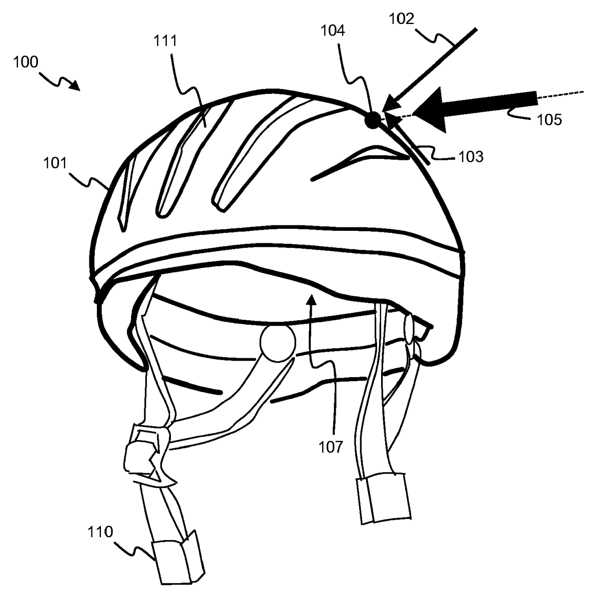

Fig. 1A

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Description

Field of the Invention

[0001] The present invention generally relates to protective headwear. More specifically, the present invention relates to helmets protecting a wearer's head against impacts.

Background of the Invention

[0002] To prevent or reduce injuries when a person risks impacting his head, for example in sporting or industrial environments, a helmet is used for absorbing energy caused by the impact, thereby safeguarding the brain. For example, helmets are customarily used when cycling, skiing, playing ice hockey, or any other activity during which a person risks on falling with his head on the underground, and/or be hit by an object, such as a hockey puck.

[0003] A helmet typically comprises a shock absorbent material as an inner pad to absorb energy upon impact. Generally, an outer casing or outer shell covers the inner pad for purposes of additional protection, smooth aerodynamic characteristics and aesthetic reasons.

[0004] A force impacting the outer shell comprises in real life situations both a normal and a tangential component. The two components will then be transferred to the inner pad. Subsequently, the normal component causes a linear impact on the wearer's head by pushing on it, depending on the linear absorbing characteristics of the inner pad and the magnitude of the force. The tangential component on the other hand causes a rotational movement of the brain within the skull, depending on the direction and, likewise, the magnitude.

[0005] Since brain injuries caused by a rotational impact are different compared to those caused by linear impacts, and are severe like bridging vein rupturing, acute subdural hematoma, and diffuse axonal injury, a helmet may be designed in such a way that it reacts differently based on the magnitude and direction or angle of the impacted force on the helmet.

[0006] In WO2015089646A1 such a helmet is disclosed comprising an inner pad configured to react differently on the normal and tangential component of an impacted force. Hereto, the inner pad comprises a complex arrangement of a variety of materials arranged as shock absorbers connected to an array of connectors which deform elastically in response to a tangential component of an impacted force. Hereby, the outer shell of the helmet can move relatively to the shock absorbers such that the tangential component will only partly be transferred to the wearer's head, thereby reducing the risk of an injury due to a rotational rotation of the brain. It is however a disadvantage that the helmet is hard to assemble due to the complex arrangement.

[0007] Another solution is disclosed in US20040168246A1 wherein a tangential component of an impacted force is absorbed by rigid rupturing means located at different locations of the helmet such as, for example, the extremities thereof. The rupturing means rigidly connect the outer shell of the helmet to an inner shell and are configured to rupture when the tangential component of the force impacts the outer shell by guiding the impacted force to these means. A disadvantage however is that the outer shell needs to be completely round to efficiently guide the impacted force to the means. Furthermore, since the rupturing means fixedly attach the outer shell to the inner layer, a solid connection arises at these fixing points thereby reducing the capability of absorbing linear impacts, especially at those connection points.

[0008] It is an object of the present invention to alleviate the above drawbacks and to provide an improved solution for reducing a risk of injuries due to a rotational acceleration of the brain when a helmet is impacted by a force.

Summary of the Invention

[0009] This object is achieved by a helmet for protecting a wearer's head comprising:

- a protective layer configured to, when the helmet is impacted by a force, absorb the normal component thereof by compression and rupture when the tangential component of the force exceeds a predefined threshold.

[0010] The helmet protects the head of a wearer when wearing it, for example, during sporting activities, like cycling, skiing, or playing ice hockey. The helmet is thus a protective gear worn by the wearer to protect the head from injuries, and more in particular the wearer's brain.

[0011] The helmet further comprises a protective layer. The protective layer covers the wearer's head, and has a certain thickness, which may depend on the type of activity the helmet is suitable for and the level of comfort it needs to provide in relation to this type of activity. The protective layer may further comprise ventilation holes, without restricting its protective characteristics.

[0012] The protective layer is, on the one hand, configured to absorb a normal component from an impacted force, thus when the helmet is impacted by the force on its surface. The normal component is the component comprising a direction pointing to the head's center of gravity at the point of impact on the surface. This force, for example, originates from a wearer's fall on the ground with his head, or from an object hitting the helmet, for example a hockey puck. The normal component of the impacted force is then absorbed by compression. In other words, the protective layer protects the wearer's head, and thus his brain, against the normal component by deforming elastically, or plastically depending on the magnitude of the impacted force and the modulus of elasticity of the protective layer. In other words, the protective layer does not transfer the tangential component to the wearer's head or to an additional elastic or plastic layer but absorbs the tangential components largely by the rupturing of the protective layer.

[0013] Furthermore, the impacted force may also comprise a tangential component, depending on the angle by which the force impacts the curved surface and transfers it to the protective layer. The tangential component is thus the tangent component at the point of impact perpendicular to the normal component. Thus, on the second hand, the protective layer is configured to rupture when the tangential component of the force exceeds a predefined threshold. In other words, when the tangential component of the force exceeds the predefined threshold, the protective layer breaks or ruptures. Thus, the protective layer absorbs the tangential component by rupturing instead of compression. Differently formulated, the energy originating from the tangential component of the impacted force ruptures the protective layer. Thus, during oblique impacts, the effects of the tangential component are mitigated through cracking under the loading distribution that the tangential component creates.

[0014] It is an advantage that since the protective layer absorbs the normal component of the impacted force by decompression over its volume, no hard nodes are present. Such hard nodes are detrimental to the wearer's head when the force is impacted at such a node. The wearers head is thus protected, since it is the protective layer that compresses thereby limiting the transfer of the normal component of the impacted force to the brain of the wearer.

[0015] Furthermore, a rotational movement of the brain within the skull is prevented as well, since a transfer of the tangential component is hindered due to the absorption of the component by the rupturing. Moreover, since the protective layer may rupture, its capacity of absorbing a tangential component is higher compared to an elastically, or even plastically deformation. This way, a rotational movement or acceleration of the skull is prevented when the wearer falls on the ground or is hit by an object. Moreover, the tangential component may be absorbed over the whole volume of the helmet layer and doesn't have to be firstly guided to any other means which could absorb this component.

[0016] Additionally, the rupturing has the further advantage that it becomes easily visible that the helmet is unsuitable for further use. This way, it is prevented that the wearer continues to wear the helmet when its protective characteristics are significantly reduced, or even absent. Differently formulated, a continuous elastically or plastically deformation as a reaction to a tangential component of an impacted force results in a reduction of the protective characteristics of the helmet, especially when the material is frequently bended or sheared and a deterioration over time therefrom is inside the material, while this remains invisible to the wearer, and therefore doesn't prevent a further inappropriate use. The rupturing on the other hand is not only immediately visible, but also ensures that the helmet will no further be used when its protecting capacity may no longer be assured.

[0017] According to an embodiment, the protective layer comprises closed-cell foam configured to perform said absorbing and said rupturing.

[0018] The protective layer is thus a light-weighted material with a solid structure like, for example, polyethylene foam or polystyrene foam, that is effective in absorbing a linear impact. Furthermore, by using a closed-cell foam, the protective layer may easily be shaped in a desired form in an efficiently and economical manner. Additionally, with a closed-cell foam no clean-cut or sharp edges will arise when rupturing due to the tangential component of the impacted force. In other words, the protective layer will rupture without causing harmful or dangerous spots.

[0019] The closed-cell foam material further allows to provide, besides the desired shape, ventilation holes. Finally, the protective layer may be produced using only one material, which reduces an occurrence of making errors during the fabrication process

[0020] According to an embodiment, the closed-cell foam comprises expanded beads.

[0021] The protective layer is thus, for example, an inmold expanded polystyrene comprising expanded beads which may be compressed and fused. The protective layer may then be fabricated using a mixture of beads with different characteristics to achieve the anisotropic strength characteristics of the protective layer. A rupture may then be initiated at beads having a lesser density compared to other beads. This way, zones in the protective layer may be selected which will be more prone to rupture compared to other zones, such that the helmet may be adapted to the type of activity wherein it will be mainly used. Additionally, or simultaneously, beads of a particular colour may be used, or even a mixture of colours for aesthetic reasons or other reasons, such as, for example, when there is a need to distinguish athletes based on the colour of the helmet such as in team sporting. This way, there is no need on further painting the protective layer in a desired colour, yet it may be produced directly in said colour.

[0022] According to an embodiment, the protective layer comprises:

- a first layer; and
- protuberances extending from the first layer; and

wherein the protuberances are configured to rupture from the first layer when exceeding the predefined threshold.

[0023] In other words, the first layer and the protuberances extending therefrom form the protective layer, wherein the protuberances are configured and designed to rupture for protecting the wearer's brain against a rotational movement or acceleration when the tangential component of the impacted force exceeds the predefined threshold. Furthermore, the rupturing can be controlled as it will appear or initiate at the transition between the layer and protuberances. This way, a good control over the rupturing characteristics by the dimensioning and number of protuberances is achieved.

[0024] The protuberances may be faced towards the wearer's head when the helmet is worn. This way, the head is in contact with the protective layer at these protuberances, and simultaneously allowing air to flow between the protuberances such that the head remains cool during intensive sporting activities, and at the same time a protection against a rotational movement or acceleration is guaranteed.

[0025] The protuberances may also be faced away from the wearer's head such that the head is in direct contact with the first layer. This may also be beneficial, for example, when the helmet through the first layer is shaped such that it covers the head in a comfortable and safe manner, while at the outside the protuberances likewise assure a protection against a rotational movement or acceleration.

[0026] According to an embodiment, the protective layer further comprises a second layer covering the protuberances.

[0027] The second layer may cover the protuberances either on the outside when the protuberances face away from the wearer's head, either on the inside when the protuberances face towards the wearer's head. In the first configuration, the protuberances are protected against external conditions, such as rain and/or dust. Similarly, when the second layer covers the wearer's head when the helmet is worn, the second layer may be suitable to absorb sweat during sporting activities and may easily be replaced afterwards, thereby keeping the protuberances of the first layer clean.

[0028] According to an embodiment, the second layer also comprises protuberances configured to rupture from the second layer when exceeding the predefined threshold.

[0029] In other words, a double protection against a rotational movement or acceleration is provided, both by the protuberances of the first and the second layer.

[0030] According to an embodiment, the protuberances of the first layer and the protuberances of the second layer face towards each other.

[0031] The first or the second layer covers the wearer's head, and the other layer, thus the layer not covering the wearer's head is located on the outside of the helmet. In between the two layers, the protuberances are present, one extending from the first layer, and one extending from the second layer. The protuberances of the first and the second layer protect the wearer's brain against a rotational movement or acceleration. Additionally, this way the first and second layer may further relatively move to each other, which also provides an additional protection against a rotational movement or acceleration. Furthermore, this way the protective layer is easily to produce, since the first layer with its protuberances may in a straightforward manner put on the second layer with its protuberances.

[0032] According to an embodiment, the first and second layer are connected with each other by the protuberances.

[0033] In other words, the protuberances extending from both layers facing each other may formally or shapely correspond to each other and be arranged on their respective layer in such a way that they may clasp with an opposite protuberance, thereby connecting the first with the second layer.

[0034] Advantageously, the helmet may be assembled by two parts, namely the first layer with protuberances and the second layer likewise with protuberances, from which one is regarded as an outer layer, this is facing the outside, and one layer as the inner layer, this is the layer covering a wearer's head. The inner layer may then be equal for all type of helmets and thus economically be produced, while the outer layer may be adapted to the type of activity it will be used for and afterwards clasp on the inner layer.

[0035] According to an embodiment, the protuberances of the first layer are interlinked with the protuberances of the second layer.

[0036] Preferably, the first and the second layer are interlinked or connected through the protuberances. The protective layer then comprises one whole comprising the first and second layer joined or interlinked with the protuberances. Between the protuberances, and thus also between the first and second layer, air or another gas may be present, thereby obtaining a light-weighted protective layer providing protection against a linear and rotational impact. This way, the protective layer and thus the helmet is suitable for sporting activities wherein a light-weighted helmet is beneficial for delivering a performance like, for example, during time trials. Moreover, the thickness of the protective layer may be reduced by, for example, reducing the space between the protuberances to a minimum. Furthermore, the protective layer may easily be assembled, since the protuberances of the first layer may be clicked in the protuberances of the second layer in a straightforward manner.

[0037] It is further another advantage that, by interlinking the two layers, a fixed connection is ensured such that the two layers stay connected when, for example, the helmet is used during dynamically and intensively moves during an activity such as, for example, playing ice hockey.

[0038] According to an embodiment, the protuberances comprise at least one of the group of:

- a tubular protuberance;
- a beam-shaped protuberance;
- a conical protuberance with an elliptic or polygonal base.

[0039] The protuberances may have different shapes, like tubes, beam-shapes or bars, and cones or pyramids. This way, the characteristics of the protuberances with respect to their capacity to rupture when the tangential component is exceeded may be adapted. For example, a conical protuberance comprises a base and apex, whereby, through the tapered or conical configuration from its base to its apex, the characteristics change in the longitudinal direction by its varying cross-sections. Hence, the apex will be more prone to rupture, thus prior to a rupturing of the base. This way dedicated spots in the protective layer may be selected which rupture more quickly compared to other spots. Furthermore, the bases may be elliptic, or may comprise circles, triangles, rectangles or any other polygonal. On other spots, an equal strength over the longitudinal direction may be preferred, thereby using tubular or beam-shaped protuberances. An alternating pattern of protuberances may thus arise and configured such that stresses originating from the tangential component are concentrated in dedicated positions of the protective layer.

[0040] According to another preferred embodiment, the protective layer comprises a mixture of the beads and second granules.

[0041] Alternatively, the protective layer may comprise, besides the mixture of beads also second granules. The second granules have a different composition compared to the beads and are arranged within the protective layer. The granules may also be arranged within the protective layer as clusters in a predefined shape.

[0042] According to an embodiment, the protective layer is further arranged such that the rupturing initiates at a border between the beads and the granules.

[0043] By using the granules, the rupturing may be initiated at the borders thereof, thus at the interfaces between the beads and the granules. This way, dedicated spots of the protective layer may be selected wherein the granules are arranged within the protective layer, such that at these borders or interfaces the rupturing is initiated when the tangential component exceeds the predefined threshold. Furthermore, this way a better control is obtained of sport where an initiation of the rupturing is preferred.

[0044] According to an embodiment, the bead and granules have a diameter of around 0.5mm to around 5mm, preferable around 1mm to around 3mm.

[0045] In other words, the beads and the granules may have the same diameter such that the protective layer may economically be produced by compressing and fusing the beads and granules. Furthermore, since the granules have an equal diameter, the beads will not be damaged by the granules while compressing and fusing.

[0046] According to an embodiment, the beads have a first density between 50 and $70m^{-3}$.kg, preferably $60m^{-3}$.kg; and the granules correspond to second beads having a second density between 90 and $110m^{-3}$.kg, preferably $100m^{-3}$.kg.

[0047] Differently formulated, the protective layer may also be assembled using a mixture of beads with different densities, namely a first density of preferably $60m^{-3}$.kg and a second density of preferably $100m^{-3}$.kg. The mixture of beads is then compressed and fused, thereby shaping the protective layer.

[0048] According to an embodiment, the mixture comprises between 25 and 75 weight percent, preferably 50 weight percent of the beads with the first density.

[0049] The weight percent of the beads with the second density is then determined by the weigh density of the beads with the first density.

Brief Description of the Drawings

[0050] Some example embodiments will now be described with reference to the accompanying drawings.

Fig. 1A illustrates a helmet according to an illustrative embodiment of the invention; and

Fig. 1B illustrates the helmet of Fig. 1A with a cross-sectional view; and

Fig. 2A illustrates a protective layer according to a first illustrative embodiment of the invention comprising a first and second layer and protuberances; and

Fig. 2B illustrates the protective layer of Fig. 2B comprising ruptured protuberances; and

Fig. 3A illustrates a protective layer according to a second illustrative embodiment of the invention comprising a first and second layer and protuberances; and

Fig. 3B illustrates a protective layer similar to the illustrative embodiment of Fig. 3A comprising protuberances that are reversely oriented; and

Fig. 4A illustrates a protective layer according to a third illustrative embodiment of the invention comprising a first and second layer and protuberances; and

Fig. 4B illustrates a protective layer according to a fourth illustrative embodiment of the invention comprising a first and second layer and protuberances; and

Fig. 5A illustrates a protective layer according to a fifth illustrative embodiment of the invention comprising a first layer and protuberances; and

Fig. 5B illustrates the protective layer of Fig. 5A comprising ruptured protuberances; and

Fig. 6 illustrates a protective layer according to a sixth illustrative embodiment of the invention.

Detailed Description of Embodiment(s)

[0051] Fig. 1A illustrates a helmet according to an illustrative embodiment of the invention and Fig. 1B illustrates the same helmet with a cross-sectional view. The helmet 100 is suitable to be worn during sporting activities like, for example, cycling or skiing. When the helmet 100 is worn, the wearer's head is in the position 107.

[0052] The helmet 100 may comprise a clasp or buckle 110 which can be wrapped around the wearer's chin when worn to secure a safe wearing of the helmet 100 on the head during activities. The helmet 100 may further comprise an outer shell 101, and ventilation holes 111. The outer shell 101 may function as a protective layer against external conditions, such as wind or rain, and the ventilation holes may function to manage a heat regulation of the wearer's head, and/or for reasons of aerodynamics, and/or aesthetics. It should be further understood that these functionalities 110 and 111 are illustrative and may vary on the type of activity for which the helmet is designed for, or even may be absent.

[0053] The helmet 100 comprises a protective layer 106, which is illustrated in the cross-sectional view 120 in Fig. 1B. The protective layer 106 has a curved surface 112 on the outside and it may further be covered by the outer shell 101. Alternatively, the curved surface 112 of the protective layer 106 may itself comprise the outer layer of the helmet 100, meaning that there is no outer shell 101.

[0054] During activities, the helmet 100 may be impacted by a force, illustrated by the impacted force 105. This force may, for example, originate from a fall on the ground, or from a hit by an object. The magnitude and direction of the impacted force 105 is a prior not known but may be presented by a vector 105 comprising a normal component 102 and a tangential component 103. The vector 105 further points to point 104 which represents the point of impact. It should be however further understood that the point of impact may also comprise an area or zone of impact depending on the surface whereupon the wearer of the helmet 100 falls, or the shape and size of the object that hits the helmet 100.

[0055] The impacted force 105 is further illustrated in Fig. 2A that illustrates the protective layer 106 comprising a first or outer layer 200 and a second or inner layer 201. The protective layer 106 in this first illustrative embodiment further comprises protuberances 202 extending from both layers 200 and 201 and connecting the layers 200 and 201 with each other.

[0056] The force 105 impacts the protective layer 106 at the outside therefrom thus at the curved surface 112, and the tangential component 103 thereof is transferred to the other zones of the protective layer 106. Likewise, the normal component 102 is transferred as well to the other zones of the protective layer 106.

[0057] Alternatively, when the helmet 100 comprises an outer shell 101, the impacted force 105 first impacts the outer shell 101, and the force 105 is subsequently transferred to the protective layer 106.

[0058] The normal component 102 is absorbed by the protective layer 106 through compression. In other words, the protective layer 106 compresses such that the outer layer 200, the protuberances 202 and the inner layer 201 come closer together during compression, and afterwards, when the impacted force 105 is no longer present, the layers 200 and 201 and protuberances 202 may return to their initial shape, or may be deformed plastically, depending on the magnitude of the normal component 102 with respect to the modulus of elasticity of the protective layer 106, yet without breaking or rupturing.

[0059] The tangential component 103 is transferred to the body of the protective layer 106, which is illustrated by arrow 210. Arrow 210 thus illustrates that, due to the tangential component 103 of the impacted force 105, that a relative movement of the outer layer 200 with respect to the protuberances 202 and/or the inner layer 201 occurs.

[0060] When the tangential component 103 exceeds a predefined threshold, the protuberances 202 of the protective layer 106 are configured to rupture. The rupturing is thus initiated by the tangential component 103 of the impacted force 105 and depends on the angle under which the impacted force 105 hits 104 the protective layer 106 and the magnitude thereof.

[0061] The rupturing of the protuberances 202 is illustrated by ruptures 211 and rupture 212. The protuberances 202 in this first illustrative embodiment comprises tubular or beam-shaped protuberances. Because of this the strength characteristics of the protuberances remain equal over their respective longitudinal direction. This means that the protuberances will rupture at a spot where its cross-section is no longer resistant to the predefined threshold. This may, for example, be at the middle of a protuberances, as illustrated by ruptures 211, or at an extremity as illustrated by rupture 212. The position will thus be determined by the location 104 of the impacted force 105 and the way it is transferred 210 to the protuberances 202. Depending on the magnitude and direction of the impacted force 105, a rupturing may also occur at the layer 200, as illustrated by rupture 213.

[0062] As a result of the rupturing, the outer layer 200 is detached 203 from the inner layer 201. It may further occur that only a part of the protuberances is ruptured. In other words, the rotational impact or acceleration originating from the impacted force 105 and more in particular the tangential component 103 thereof is then absorbed by the rupturing of a part of the protuberances, while other protuberances remain intact.

[0063] The protuberances may also comprise other shapes compared to a tubular or beam-shapes. In Fig. 3A and Fig. 3B a second illustrative embodiment of the invention is illustrated comprising conical protuberances 300 such as cone 302. It should be further understood that a cone is a three-dimensional geometric shape tapering smoothly from a base to an apex, wherein the base and the apex may be circular, but may also comprises any other polygonal shape. The protuberances 300 may thus also for example comprise pyramids.

[0064] The conical protuberances 300 are connected to the outer layer 200 by their respective apex, as illustrated by apex 311, and by their respective base to the inner layer 201, such as base 310. The configuration may also be reverse, this is the bases are connected to the outer layer 200 and the apexes to the inner layer 201, as illustrated by protuberances 301 of Fig. 3B.

[0065] Due to the tapered configuration of the protuberances 300 and 301, the strength characteristics vary because of the varying cross-sections. For example, when the tangential component 103 is transferred, stresses originating therefrom may be concentrated at the apex of the conical protuberances, such that the rupturing is initiated at these apexes. This is illustrated by rupture 312 at the outer layer 200, and by rupture 313 at the inner layer 201. Depending on the magnitude and direction of the impacted force 105, a rupturing may also occur at the outer layer 200, as illustrated by rupture 314.

[0066] Besides a uniform directional arrangement of the conical protuberances, such as configuration 300 where the bases are all located at the inner layer 201, or configuration 301 where all the apexes are located at the inner layer 201, the conical protuberances may also be arranged in an alternating pattern as illustrated in Fig. 4A by protuberances 400. In this third illustrative embodiment, the direction of the tapered configuration may be altered, and the embodiment may further comprise beam-shaped and/or tubular protuberances. In other words, the pattern of the protuberances may be adapted such that it comprises a variety of shapes, cross-sections and/or arrangement.

[0067] A part of the protuberances 400 may also extend from the outer layer 200, while the other part extends from the inner layer 201, whereby the outer 200 and inner 201 layer are connected to each other by the protuberances. The protuberances of both layers 200 and 201 may also be interlinked as illustrated in Fig. 4B by a fourth illustrative embodiment of the protective layer 106. The protuberances 401 are shaped in such a way that they interlink or clasp with opposite protuberances. For example, protuberance 403 extending from the outer layer 200 clasps with protuberance 402 extending from the inner layer 201. As a result, a pattern of interlinked protuberances 401 together with the inner 201 and outer 200 layer forms the protective layer 106.

[0068] According to a fifth illustrative embodiment, the protective layer 106 may comprise one layer with protuberances extending therefrom, as illustrated in Fig. 5A and Fig. 5B. The layer 500 from where the protuberances 502 extend may be the outer layer of the helmet 100, or may be the inner layer, thus where the wearer's head 107 is located when worn.

[0069] The impacted force 105 is then either transferred 503 to the protuberances 502, or the protuberances 502 are directly impacted by the force. The protuberances 502 are likewise configured to rupture when the tangential component 103 of the impacted force 105 exceeds the predefined threshold. This is illustrated by ruptures 510 in Fig. 5B.

[0070] The protective layer 106 may also, according to a sixth embodiment, comprise one whole shape 600, for example, an in-mold expanded polystyrene comprising expanded beads and granules 602. The granules 602 are arranged such that the rupturing, when the tangential component 103 exceeds the predefined threshold, is initiated at the borders of the granules 602. The rupturing may then result in a rupture 601 over a whole length of the protective layer 106.

[0071] The protective layer as illustrated in Fig. 6A may also comprises one whole shape without the granules 602 but comprising a mixture of beads with different densities. For example, a first mixture of beads with a density between 50 and 70m^{-3}.kg, preferably 60m^{-3}.kg, and a second mixture of beads having a density between 90 and 110m^{-3}.kg, preferably 100m^{-3}.kg. Both mixtures may then equally be divided, thus each 50 weight percent, or the first mixture may have between 25 and 75 weight percent, whereas consequently the second mixture has a weight percentage determined by that of the first mixture.

[0072] Although the present invention has been illustrated by reference to specific embodiments, it will be apparent to those skilled in the art that the invention is not limited to the details of the foregoing illustrative embodiments, and that the present invention may be embodied with various changes and modifications without departing from the scope thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein. In other words, it is contemplated to cover any and all modifications, variations or equivalents that fall within the scope of the basic underlying principles and whose essential attributes are claimed in this patent application. It will furthermore be understood by the reader of this patent application that the words "comprising" or "comprise" do not exclude other elements or steps, that the words "a" or "an" do not exclude a plurality, and that a single element, such as a computer system, a processor, or another integrated unit may fulfil the functions of several means recited in the claims. Any reference signs in the claims shall not be construed as limiting the respective claims concerned. The terms "first", "second", third", "a", "b", "c", and the like, when used in the description or in the claims are introduced to distinguish between similar elements or steps and are not necessarily describing a sequential or chronological order. Similarly, the terms "top", "bottom", "over", "under", and the like are introduced for descriptive purposes and not necessarily to denote relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and embodiments of the invention are capable of operating according to the present invention in other sequences, or in orientations different from the one(s) described or illustrated above.

Claims

1. A helmet (100) for protecting a wearer's head (107) comprising:

   - a protective layer (106) configured to, when the helmet (100) is impacted by a force (105), absorb the normal component (102) thereof by compression and rupture (211, 212, 510, 601) when the tangential component (103) of the force exceeds a predefined threshold.

2. The helmet (100) according to claim 1 wherein the protective layer (106) comprises closed-cell foam configured to perform said absorbing and said rupturing.

3. The helmet (100) according to claim 2 wherein the closed-cell foam comprises expanded beads.

4. The helmet (100) according to any one of the preceding claims, wherein the protective layer (106) comprises:

   - a first layer (200, 500); and
   - protuberances (202, 300, 301, 400, 401, 502) extending from the first layer (200, 500); and

   wherein the protuberances (202, 300, 301, 400, 401, 502) are configured to rupture (510) from the first layer (200, 500) when exceeding the predefined threshold.

5. The helmet (100) according to claim 4, wherein the protective layer (106) further comprises:

   - a second layer (201) covering the protuberances (202, 300, 301, 400, 401).

6. The helmet (100) according to claim 5, wherein the second layer (201) also comprises protuberances (202, 300, 301, 400, 401) configured to rupture (211) from the second layer (201) when exceeding the predefined threshold.

7. The helmet (100) according to claim 6 wherein the protuberances (202, 300, 301, 400, 401) of the first layer (200) and the protuberances (202, 300, 301, 400, 401) of the second layer (201) face towards each other.

8. The helmet (100) according to any one of claims 5 to 7 wherein the first (200) and second layer (201) are connected with each other by the protuberances (202, 300, 301, 400, 401).

9. The helmet (100) according to claim 7 and 8 wherein the protuberances (202, 300, 301, 400, 401) of the first layer (200) are interlinked with the protuberances of the second layer (201).

10. The helmet (100) according to any one of claims 5 to 9, wherein the protuberances (202, 300, 301, 400, 401, 502) comprise at least one of the group of:

    - a tubular protuberance (202);
    - a beam-shaped protuberance;
    - a conical protuberance (302) with an elliptic or polygonal base (310).

11. The helmet (100) according to any one of the preceding claims and claim 3, wherein the protective layer (106) comprises a mixture of the beads and second granules.

12. The helmet (100) according to claim 11 wherein the protective layer (100) is further arranged such that the rupturing initiates at a border between the beads and the granules.

13. The helmet (100) according to claim 11 or 12 wherein the beads and granules have a diameter of around 0.5mm to around 5mm, preferable of around 1mm to around 3mm.

14. The helmet (100) according to anyone of claims 11 to 13, wherein the beads have a first density between 50 and $70m^{-3}.kg$, preferably $60m^{-3}.kg$; and the granules correspond to second beads having a second density between 90 and $110m^{-3}.kg$, preferably $100m^{-3}.kg$.

15. The helmet (100) according to any one of claims 11 to 14, wherein the mixture comprises between 25 and 75 weight percent, preferably 50 weight percent of the beads with the first density.

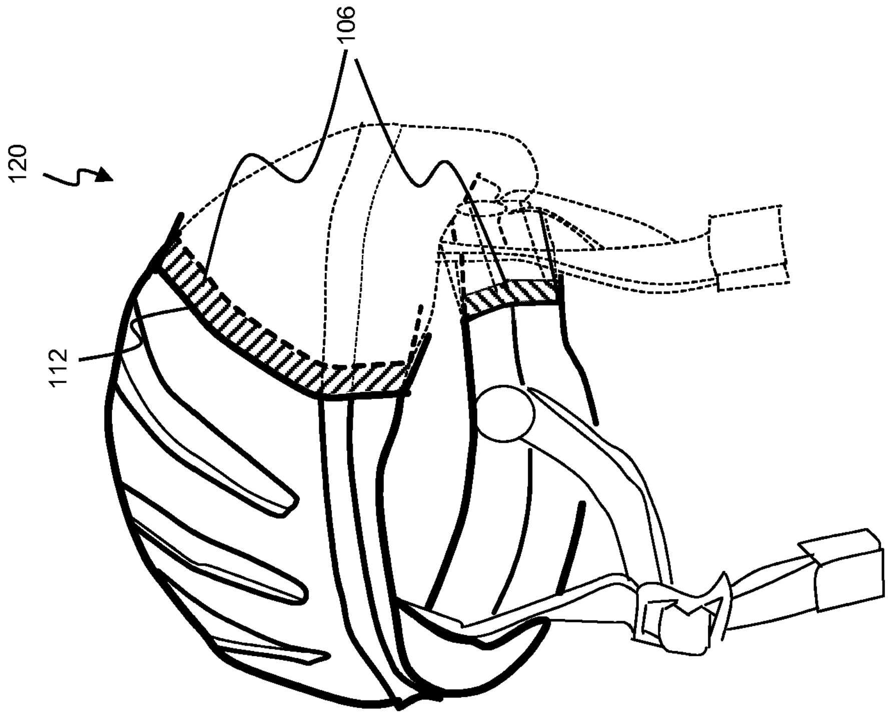

Fig. 1B

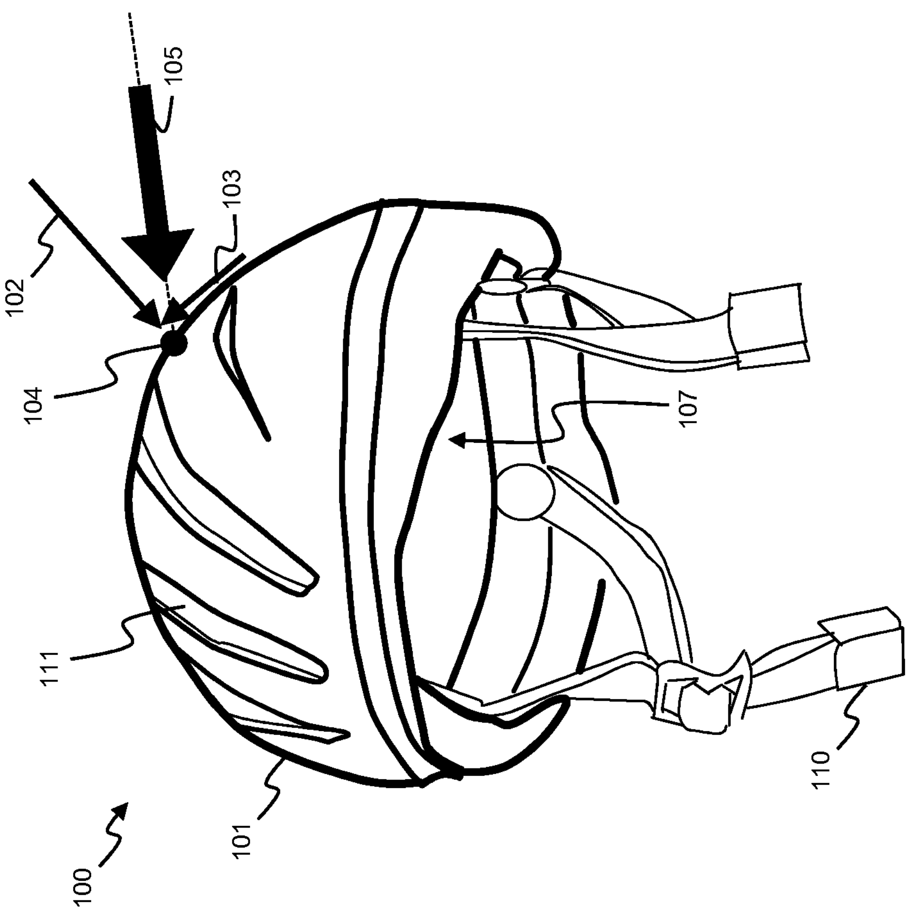

Fig. 1A

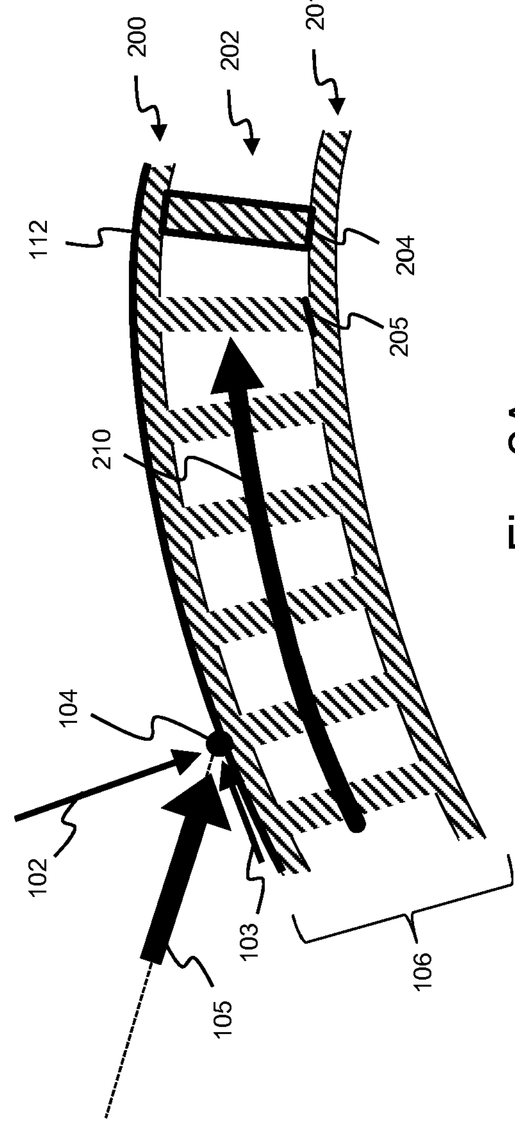
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Fig. 2A

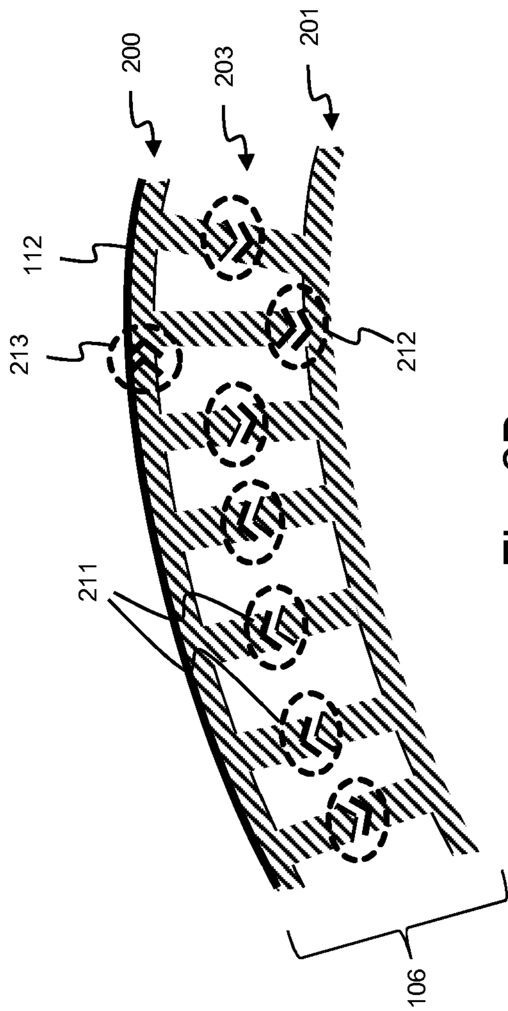
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Fig. 2B

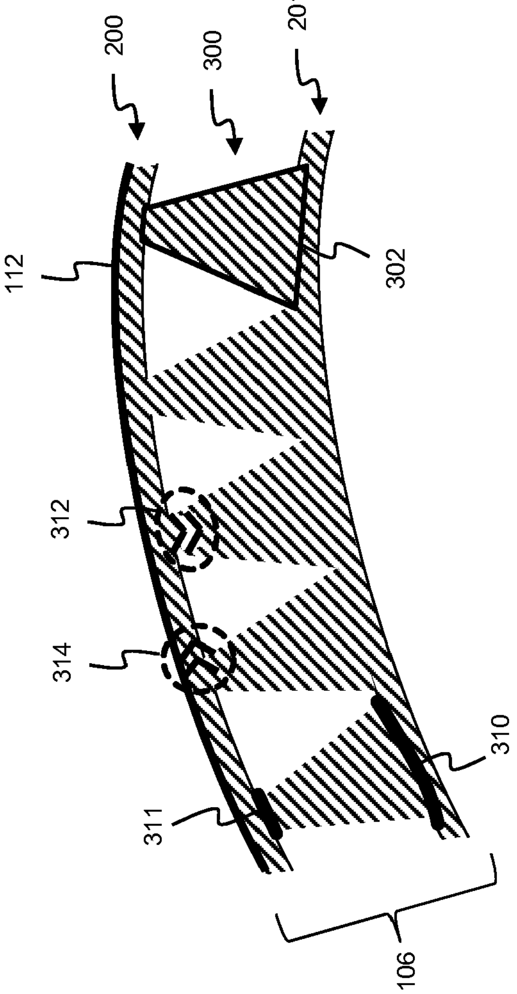

Fig. 3A

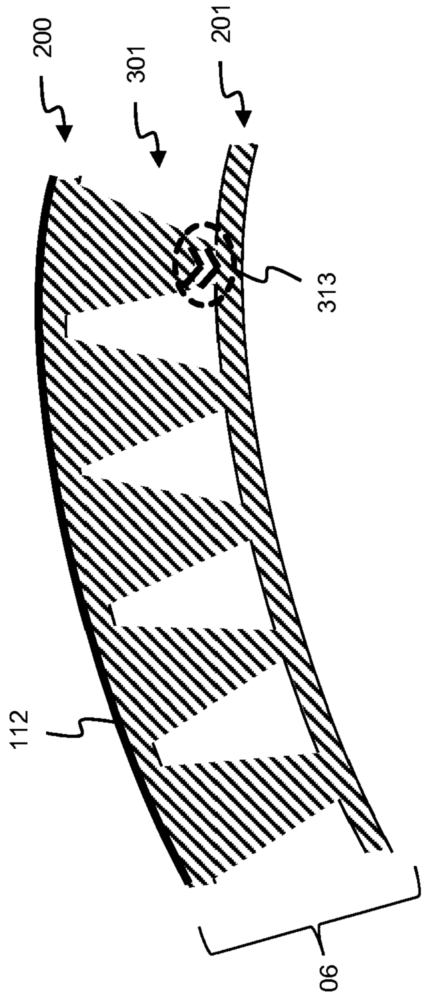

Fig. 3A

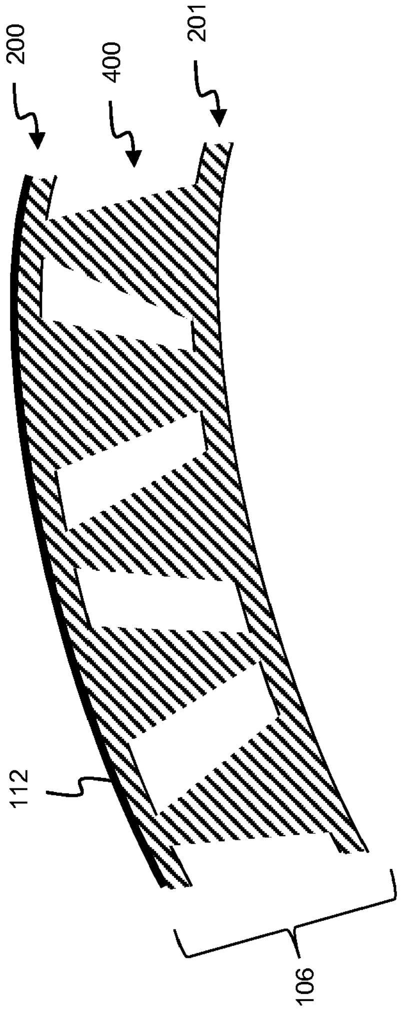

Fig. 4A

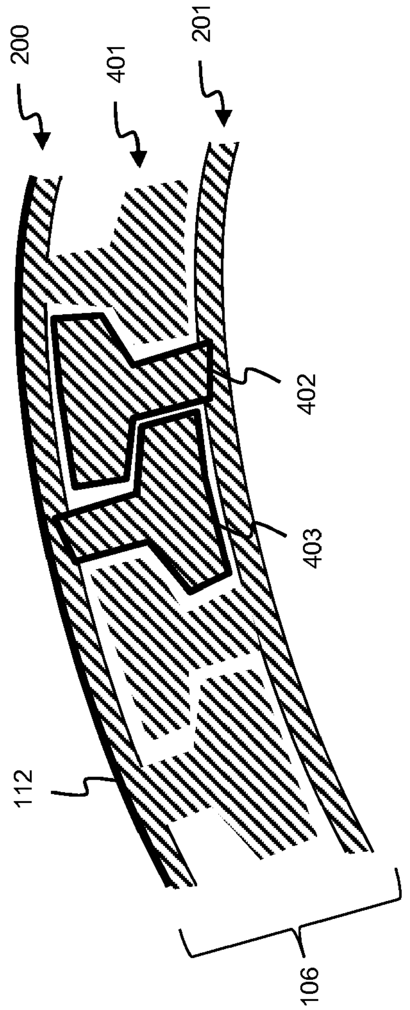

Fig. 4B

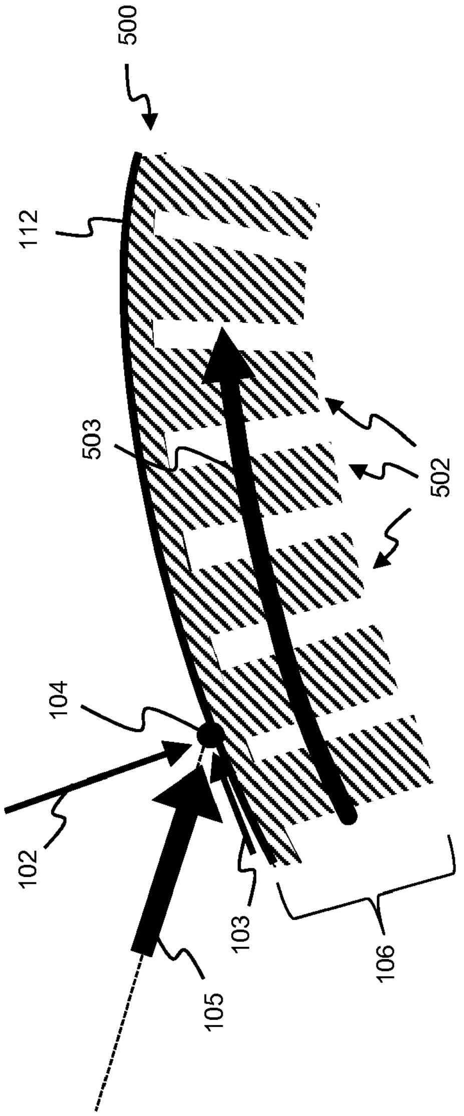

Fig. 5A

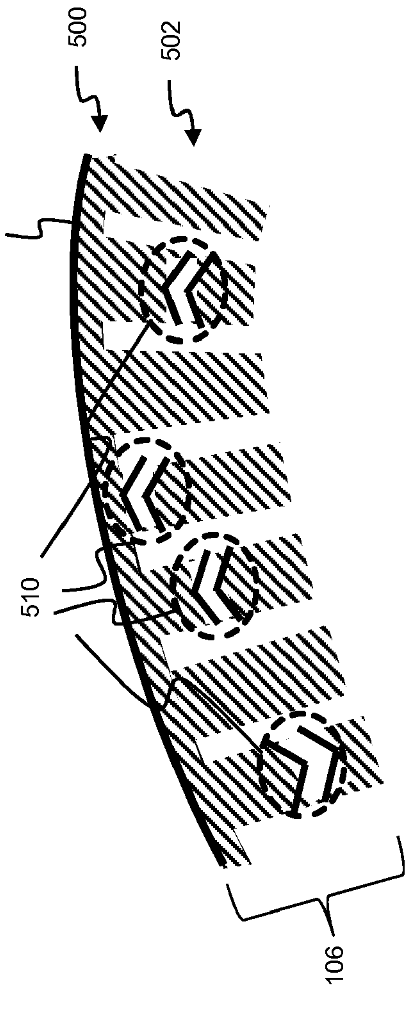

Fig. 5B

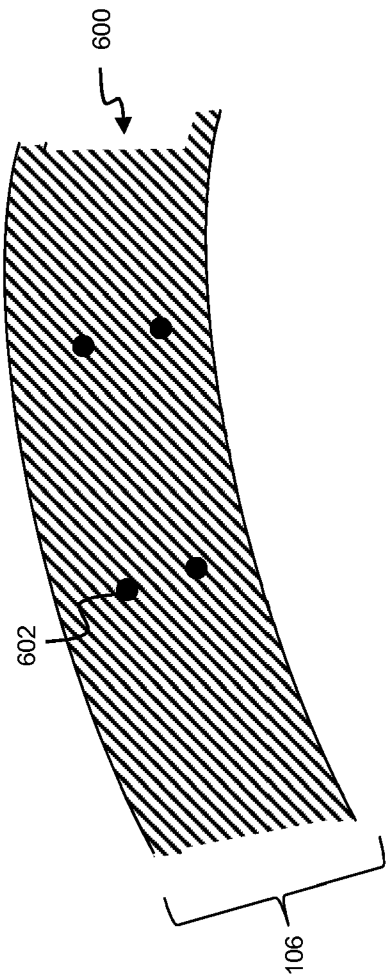

Fig. 6A

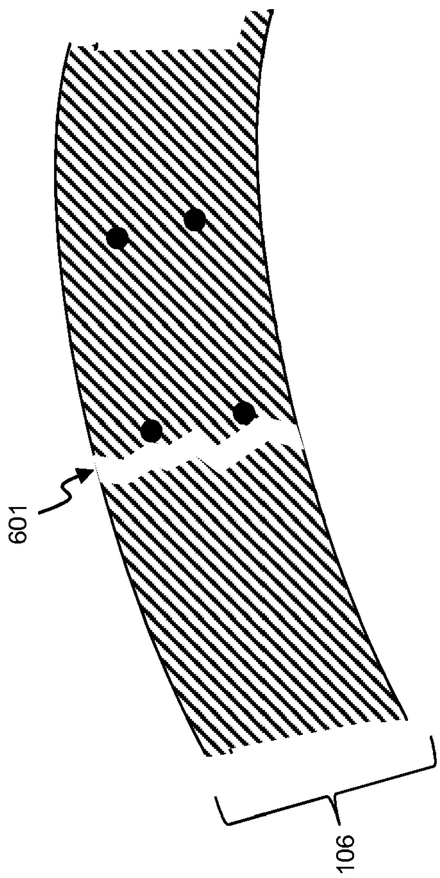

Fig. 6B

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EUROPEAN SEARCH REPORT

Application Number
EP 18 20 0835

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1

Place of search	Date of completion of the search	Examiner
The Hague	2 April 2019	D'Souza, Jennifer

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