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(71) Applicant: adidas AG  
91074 Herzogenaurach (DE)

(72) Inventors:  
• THOMPSETT, Benjamin Alexander  
91074 Herzogenaurach (DE)  
• WITTE, Matthias  
91074 Herzogenaurach (DE)  
• ETZOLD, Matthias  
91074 Herzogenaurach (DE)  
• CROZIER, Finn  
91074 Herzogenaurach (DE)  
• LIU, Pan  
91074 Herzogenaurach (DE)  
• ROEHRIG, Patrick  
91074 Herzogenaurach (DE)  
• GORDON, Andrew  
91074 Herzogenaurach (DE)

- SCHAEFKE, Hannes  
91074 Herzogenaurach (DE)
- VAN BEUNINGEN, Willem  
91074 Herzogenaurach (DE)
- DIETRICH, Stephan  
91074 Herzogenaurach (DE)
- ROEVENS, Kevin  
91074 Herzogenaurach (DE)
- HANSON, Henry  
91074 Herzogenaurach (DE)
- METCALFE, Kathryn  
91074 Herzogenaurach (DE)
- COONROD, Zachary C.  
Portland, OR 97217 (US)
- DELGADO, Christian Manuel Arias  
Portland, OR 97217 (US)
- B, Berin Skye  
Portland, OR 97217 (US)
- HANNAH, Iain  
Portland, OR 97217 (US)
- BLUME, Keith A.  
Portland, OR 97217 (US)
- KIRK, Robert Frank  
Portland, OR 97217 (US)

(74) Representative: Bardehle Pagenberg  
Partnerschaft mbB  
Patentanwälte Rechtsanwälte  
Prinzregentenplatz 7  
81675 München (DE)

(54) SOLE FOR A SPORTS SHOE

(57) An inner sole for a sports shoe includes a top surface arranged to face a foot of a wearer of a shoe when the inner sole is arranged in the shoe. The top surface of the inner sole includes at least two textured areas. The textured areas each include a plurality of protuberances, recesses, or holes. The top surface further includes at least one untextured area not having protuberances, recesses or holes. A first textured area is located in a toe region of the inner sole, and a second textured area is located in a heel region of the inner sole.

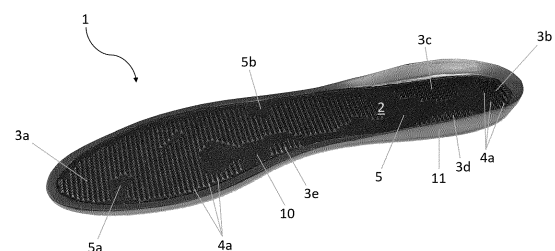


Fig. 1A

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## Description

### CROSS-REFERENCE TO RELATED APPLICATION

**[0001]** The present application is a continuation-in-part of U.S. Application No. 18/526,888, filed December 1, 2023, which is incorporated herein by reference in its entirety.

### TECHNICAL FIELD

**[0002]** Embodiments described herein relate to an inner sole for a sports shoe. Some embodiments described herein relate to a sole component for a sports shoe. Further embodiments relate to an upper for a sports shoe.

### PRIOR ART

**[0003]** A vast array of factors is known to influence sport performance. The most prevalent ones are related to human physiology, biomechanics and various motor control factors. Traditional sports equipment has been regarded for the longest time as a facilitator, or enhancer of these factors in order to improve core performance and minimize injury and discomfort. During the last fifty to sixty years, academic and industry based researchers and engineers have pushed the boundaries of both sports theoretical knowledge and practical applications by means of developing ever increasingly sophisticated materials, product designs and training routines aimed at increasing performance.

**[0004]** While these developments are still ongoing, in certain areas the boundaries of what can be achieved from an engineering and design perspective have been reached, and the industry is in search of other venues that could lead to novel performance products that have a significant and perceivable effect on performance.

**[0005]** A relatively new class of sport products focuses on manipulating perception and attention in order to optimize game performance. One of the underlying mechanisms is called proprioception (also kinesthesia) and relates to the sense of self-movement, force, and body position. Proprioception is mediated by proprioceptors, mechanosensory neurons located within the skin, muscles, tendons, and joints. Proprioceptive signals are transmitted to the central nervous system, where they are integrated with information from other sensory systems, such as the visual system and the vestibular system, to create an overall representation of body position, movement, and acceleration. Sensory feedback from proprioceptors is important for stabilizing body posture and coordinating body movement.

**[0006]** For example, US 2022/0134046 A1, refers to a mechanoreception stimulation garment having a plurality of protuberances disposed across an interior surface of a fabric garment, said plurality of protuberances configured in size, grouping, and spacing to specifically target cutaneous receptors when brought in contact with a user.

**[0007]** US 2005/252039 A1 relates to a method for providing an insole and an insole for footwear for increased sensory stimulation of a foot in the footwear. The method includes preselecting positions on the foot with nerves at these positions to be stimulated and providing means for stimulating elevation of said insole at said preselected positions during step movement of said foot on said insole.

**[0008]** DE 10 2005 053768 A1 relates to a method for producing an insole, in particular a proprioceptive insole for footwear, which has at least one predetermined raised area, generally several such areas, on an essentially flat support with an essentially constant thickness.

**[0009]** Background information on the stimulation of cutaneous receptors or afferents can for example be found in Kennedy et al.: "Distribution and behaviour of glabrous cutaneous receptors in the human foot sole" (Journal of Physiology (2002), 538.3, pp. 995-1002) as well as Katic et al.: "Modeling foot sole cutaneous afferents: FootSim" (iScience 26, 105874, January 20, 2023).

**[0010]** However, known sports shoes still leave room for improvement with respect to proprioception and athletic performance, in particular with respect to the location of stimulation of the foot but also with respect to considering other aspects that result in a positive training and competition experience, such as a comfortable feeling and reducing unnecessary pressure on the foot.

### SUMMARY OF THE INVENTION

**[0011]** The above-mentioned objects are at least partially achieved by the claimed subject-matter. Additional embodiments are the subject of the dependent claims, and other suitable embodiments are described through the overall disclosure of the present application.

**[0012]** In one aspect, these objects are addressed by an inner sole for a sports shoe having a top surface arranged to face a foot of a wearer of a shoe when the inner sole is arranged in the shoe, wherein the top surface includes at least two textured areas, wherein the textured areas each include a plurality of protuberances, recesses, holes, or a combination thereof, wherein the top surface includes at least one untextured area not having any protuberances, recesses or holes, wherein a first textured area is located in a toe region of the inner sole and a second textured area is located in a heel region of the inner sole.

**[0013]** An inner sole in the context of the present application is understood as being adapted to be arranged in or being arranged in a shoe, such that a foot of a wearer would touch the inner sole with a sole of the wearer's foot when wearing the shoe in a usual manner. An inner sole is sometimes called insole or sockliner. It generally has a flat shape and extends from a toe region of the shoe to a heel region. In the context of the present application, the inner sole can be fixedly or removably attached to a shoe. The top surface of the inner sole is understood as the surface of the inner sole facing a foot of

a wearer when the inner sole is arranged in a shoe. It is understood that a shoe as well as the inner sole may be "left" or "right" and that a "left" inner sole is intended to be inserted or assembled into a "left" shoe and a "right" inner sole is intended to be inserted or assembled into a "right" shoe.

**[0014]** According to some embodiments, the inner sole includes at least two textured areas. An area is understood as a portion of the top surface of the inner sole. A textured area includes a plurality of protuberances, recesses, holes, or a combination thereof. Generally, a protuberance is understood as a protruding feature of the top surface that includes a pronounced tip, a recess is understood as an indentation in the top surface that does not form a hole, and a hole is understood as an aperture that extends to the opposing bottom surface. In some embodiments, the textured areas include a plurality of such protuberances, recesses, holes, or a combination thereof. Thus, the textured areas can be distinguished from other areas not having such protuberances, recesses, or holes, which are denoted as untextured areas. In some embodiments, untextured area may be an area of top surface that is smooth, flat, or planar.

**[0015]** It is understood that the textured areas may either include just protuberances, just recesses, just holes or combinations of protuberances, recesses, or holes. Thus, a textured area may include just protuberances, or it may include just recesses, or it may include just holes, or it may include just protuberances and recesses, or it may include just protuberances and holes, or it may include just recesses and holes, or it may include protuberances, recesses, and holes. Also, the first textured area may include one of the mentioned combinations and the second textured area may include another one of the mentioned combinations. For example, the first textured area may include just recesses, whereas the second textured area may include just protuberances or vice versa. Surprisingly, the inventors found out that a proprioceptive effect can be achieved by protuberances, recesses and holes.

**[0016]** Further, according to some embodiments, a first textured area is located in a toe region of the inner sole. The toe region of the inner sole is understood as the area in which the toes of a wearer would be located when the inner sole is properly arranged in a shoe the wearer is wearing. Generally, throughout this description, any reference to anatomical areas or regions on the inner sole or on a shoe upper or sole of a shoe is understood in relation to a human foot wearing a shoe having such inner sole, upper or sole. Thus, a heel area or region is understood as any area or region being located at a heel of a human foot. Similar definitions apply for "metatarsal", "arch", "metatarsal-to-arch transition", "medial" and "lateral" areas or regions.

**[0017]** Further, according to some embodiments, a second textured area is located in a heel region of the inner sole. Thus, the inner sole defines at least two textured areas being located in a toe region and in a heel

region, respectively, and furthermore at least one untextured area. The inventors discovered that this arrangement of protuberances, recesses or holes allows for an optimal stimulation of the most important cutaneous receptors or afferents. By stimulating at least the toe and the heel region of an athlete, proprioception in the foot is able to measurably increase athletic performance, responsiveness and agility. On the other hand, the untextured area adds to the comfort because not all areas of the human foot are similarly important for proprioception and protuberances, recesses or holes in high pressure areas of the foot might be perceived as uncomfortable. Furthermore, stimulating targeted locations of the foot increases the proprioceptive effect.

**[0018]** Thus, the inner sole according to embodiments described herein strikes a balance between a pronounced proprioceptive effect on athletic performance and a comfortable feeling. In addition, protuberances, recesses and holes formed in the inner sole add to the ventilation of the foot. While air may directly ventilate through holes formed in the inner sole, protuberances and recesses formed on and in the inner sole lead to the formation of lateral air channels under the foot. Slight movements of the foot in the shoe facilitate the flow and exchange of air which leads to a certain thermoregulation.

**[0019]** Another advantageous effect of the embodiments of the present application is a massage effect on the foot which fosters blood circulation. Consequently, the foot does not get numb so easily compared to untextured surfaces. Furthermore, the surface texture formed by protuberances, recesses and holes increases the friction between the inner sole and the foot or sock which adds to the overall stability of the shoe. Also, holes generally help to save material and weight of the shoe.

**[0020]** It is understood that an inner sole according to embodiments described herein may be a separate element, i.e. distinct from other components of a shoe, or an integral component, i.e. integral with another component or components of a shoe. For example, the inner sole may be integral with a midsole, outsole or outsole plate of a shoe. It is also possible that the inner sole is integral with a lasting board or a Strobel sole. Thus, the protuberances, recesses or holes would be arranged on the inner surface of the midsole, outsole or outsole plate. Alternatively, the protuberances, recesses or holes may be arranged on an inner surface of a lasting board or Strobel sole.

**[0021]** The textured areas may correspond to areas of a human foot having a higher density of mechanoreceptors compared to areas of the human foot corresponding to untextured areas of the inner sole. In this way, a targeted stimulation is possible in areas of the foot resulting in the most pronounced advantageous proprioceptive effect. Areas of the inner sole corresponding to a lower density of mechanoreceptors may be untextured which adds to the comfortable feeling and allows a more differentiated and anatomically precise stimulation. "Me-

chanoreceptors" as used herein are understood as cutaneous receptors or afferents in the sole of the human foot that are able to sense mechanical pressure or skin stretch or absence thereof on the skin of the human foot.

**[0022]** Another advantage of the inner sole according to embodiments described herein is that it may reduce foot movement within the footwear, which may also improve comfort and performance during certain movements. Thus, the protuberances, recesses or holes increase the friction between the inner sole and a foot or sock of a wearer. In this way, the inner sole helps to specifically create interactions between the inner sole or sockliner and a sock, skin or foot. Those interactions have a higher friction than in existing footwear and even allow reducing the amount of stability required from an upper of the shoe which in turn could save manufacturing costs but also results in a more lightweight shoe. Also, often athletes and players wear specific grip socks, the need for which could potentially be reduced by the inner sole according to embodiments described herein. Rather, athletes or players could wear socks that focus on comfort rather than grip.

**[0023]** The first textured area and the second textured area may be distinct and separated by the untextured area. Thus, the first and second textured areas form separated and distinct regions on the top surface of the inner sole. The untextured area according to this particular embodiment is at least partially arranged between the textured areas to separate them. This allows a very targeted stimulation of the mechanoreceptors in the human foot while the untextured area between the two stimulating textured areas adds a contrast in stimulation which adds to the proprioceptive effect as well as the wearing comfort. In addition, a distinct pattern of textured and untextured areas might also provide movement-specific stimulation. For example, specific stimulation can be provided during different phases of a gait cycle such as rolling through the stance phase, push-off, landing, etc.

**[0024]** The second textured area may be located in a rearmost portion of the heel region. The inventors have found that this particular location on the human foot is important for a positive proprioceptive effect.

**[0025]** The inner sole may further include a third textured area located in a lateral portion of the heel region and a fourth textured area located in a medial portion of the heel region. This arrangement of textured areas advantageously stimulates the heel during side motions in which the strain on the foot, and thus on the shoe and inner sole is more on the lateral or medial side. The third and fourth areas may be separate and distinct from each other. For example, an untextured area may be arranged between the third and fourth textured areas.

**[0026]** The first untextured area may be located in a central portion of the heel region. Usually, the highest pressure of the heel of a human foot on a plane surface such as an inner sole is exerted by the central portion of the heel. Anatomically, the heel bone or calcaneus is

located in the heel which has a globular shape that gives rise to such a peak-like pressure distribution. By arranging the untextured area in this central heel region, an uncomfortable feeling due to protuberances, recesses or holes is avoided. Yet, textured areas like for example the third and fourth textured areas mentioned above, which may be arranged around the central heel region, still provide for sufficient proprioception to achieve a measurable positive effect on athletic performance and responsiveness.

**[0027]** The first untextured area may extend from the heel region along a medial region into a metatarsal region and may not extend into a toe region. The lack of protuberances, recesses or holes on the medial side and in a part of the metatarsal region does not negatively affect proprioception but instead increases the wearing comfort.

**[0028]** The first textured area may extend from the toe region along a lateral region in a midfoot region and may end before the heel region. The inventors found that these regions are important for proprioception and that protuberances, recesses or holes in these regions add to a positive proprioceptive effect.

**[0029]** An untextured area may be located in a big toe region. This adds to the general wearing comfort but does not impair the positive proprioceptive effect mentioned herein.

**[0030]** An untextured area may be located in a medial metatarsal region and surrounded by the first textured area. In this way, unnecessary pressure in the medial metatarsal region is avoided. Yet, as this area is surrounded by protuberances, recesses or holes, a pronounced proprioceptive effect is achieved.

**[0031]** The untextured area may be located at a lateral metatarsal-to-arch transition region. Similar to the location mentioned above, unnecessary pressure is avoided, yet a pronounced proprioceptive effect is achieved.

**[0032]** The inner sole may further include a fifth textured area located in a medial metatarsal-to-arch transition region. The inventors have found that this particular location advantageously adds to the proprioceptive effect. This is due to the fact that this particular area shows a high density of mechanoreceptors.

**[0033]** The density of protuberances, recesses or holes may be higher on a first portion of the inner sole compared to a second portion of the inner sole. For example, the density of protuberances, recesses or holes may be higher on a lateral side of the inner sole compared to a medial side of the inner sole. The density of mechanoreceptors is generally higher on the lateral side of a human foot such that a higher density of protuberances, recesses or holes on this side generally achieves a pronounced positive proprioceptive effect, while the medial side may have a lower density of protuberances, recesses or holes which adds to the wearing comfort, but also tangibly contrasts with the lateral side which again amplifies the proprioceptive effect. Density in the context of the present application is understood as the number of

protuberances, recesses or holes per surface area, e.g. protuberances, recesses or holes per square centimeter. The surface area may encompass textured and untextured areas of the inner sole, such that the density is understood as an average value.

**[0034]** The hardness of the protuberances may vary across the inner sole. In some embodiments, a first textured area may have protuberances of a first hardness, and a second textured area may have protuberances of a second hardness that differs from the first hardness. In this way, the hardness may be adapted to the density and sensitivity of mechanoreceptors in the human foot. Additionally, or alternatively, the hardness may reflect the local hardness of the skin of the human foot with harder protuberances being placed in harder areas of the skin of the human foot compared to softer areas. In another example, the hardness of the protuberances may reflect the thickness of fat tissue in the human foot.

**[0035]** The hardness of the protuberances may correlate with the hardness of the skin of a human foot. Thus, harder protuberances are placed in areas of the human foot having a higher skin hardness and softer protuberances may be placed in areas of the human foot having a lower skin hardness. In this way, underlying mechanoreceptors may still be sufficiently stimulated even in case of harder skin covering those mechanoreceptors. On the other hand, mechanoreceptors covered by softer skin are not excessively stimulated. Moreover, the wearing comfort is increased by targeting the hardness of the protuberances to the surface properties of the human foot.

**[0036]** The untextured areas may be located in areas having a local maximum of a pressure distribution of pressure caused by a human foot standing on the inner sole. The pressure distribution of the human foot can generally be measured by pressure plates resulting in a distribution of pressure, i.e. a particular pressure value associated with a particular location on the pressure plate. When the inner sole described herein is arranged in a shoe, the pressure distribution of the foot of the wearer will be similar, if not identical to the measured pressure distribution. The pressure distribution will show local maxima in which the pressure is highest compared to surrounding locations. Arranging untextured areas in such local maxima of the pressure distribution adds to the wearing comfort.

**[0037]** At least one local maximum of the pressure distribution may be surrounded by a textured area. In this way, a proprioceptive effect described herein is achieved while avoiding negative effects of protuberances, recesses or holes being located in the local pressure maximum. A local maximum of pressure may for example be present in the central region of the heel and in the central region of the ball of the toe. Protuberances, recesses or holes may be perceived as uncomfortable in those locations.

**[0038]** The protuberances may have a pyramidal shape. The inventors found out that this shape allows

for a very pronounced positive proprioceptive effect. Also, pyramids are advantageous from a production perspective and may for example be obtained by molding.

5 **[0039]** The pyramids may have a rounded tip. The inventors found that rounded tips do not impair proprioception, but are perceived as more comfortable compared to pointed tips. Also, the wear of socks is reduced with rounded tips.

10 **[0040]** The protuberances may have an average diameter of 1-10mm, 2-5mm, or 3-4mm. The inventors found that these dimensions produce the desired proprioceptive effect on the mechanoreceptors of a human foot yet are perceived as comfortable.

15 **[0041]** The protuberances may have an average height of 0.5-5mm, 0.75-3mm, or 1-1.5mm. The inventors found that these ranges of height produce the desired proprioceptive effect on the mechanoreceptors of a human foot yet are perceived as comfortable.

20 **[0042]** The protuberances have a hardness of 40-70 Shore-A, or 50-60 Shore-A. The inventors found that this hardness range produces the desired proprioceptive effect on the mechanoreceptors of a human foot yet are perceived as comfortable.

25 **[0043]** The inner sole may further include a textile layer, wherein the protuberances, recesses or holes are arranged on the textile layer. A textile layer adds to a comfortable feeling. Moreover, textiles have the ability to wick moisture which is an important aspect for an inner sole.

30 **[0044]** The inner sole may further include a foam layer, wherein the textile layer is arranged on the foam layer. A foam layer produces a soft feeling on the foot and is able to compensate for different foot anatomies of different wearers. In addition, it may provide some level of cushioning. Despite a foam layer, the protuberances, recesses or holes on the inner sole still provide the positive proprioceptive effect described herein.

35 **[0045]** The foam layer may include a polymeric foam, in particular, at least one of polyurethane (PU) foam, such as thermoplastic polyurethane (TPU) foam, polyamide (PA) foam, polyether-block-amide (PEBA) foam, thermoplastic polyester ether elastomer (TPEE) foam. Alternatively the foam layer may include a particle foam material, in particular one or more of the following materials: expanded thermoplastic polyurethane (eTPU); expanded polyamide (ePA); expanded polyether-block-amide (ePEBA); expanded polylactide (ePLA); expanded polyethylene terephthalate (ePET); expanded polybutylene terephthalate (ePBT); expanded thermoplastic polyester ether elastomer (eTPEE).

40 **[0046]** The foam particles may be made of, or include, expanded thermoplastic materials, especially thermoplastic polyurethane (TPU), polylactate (PLA), polyamide (PA), polyether block amide (PEBA), polyethylene terephthalate (PET), polybutylene terephthalate (PBT), or thermoplastic polyester ether elastomer (TPEE). The foam particles may be a bead containing multiple poly-

mer types in one foam particle or the foam particles may be a mixture of different particles of different foam polymers or combinations thereof. The foam particles may include 90 % by weight of one or a mixture of these materials. These foam particles are particles that include a so-called bead foam, also known in the art as a pellet or particle foam. Often the foams derived from the use of connected foam particles are given the designation "e" to denote the bead form of the polymer foam component, for example, eTPU.

**[0047]** Generally, the foam layer may have multiple hardness components or materials. For example, the foam layer may have a higher hardness in a heel region as compared to a toe region. In another example, the foam layer may include EVA and PU.

**[0048]** The height of the protuberances may vary across the inner sole. For example, the protuberances may be higher in a heel region of the inner sole compared to other regions of the inner sole. In general, the size of the protuberances may be adapted to the sensitivity of regions of the foot.

**[0049]** The shape of the protuberances may vary across the inner sole. In general, the shape of the protuberances may be adapted to the sensitivity of regions of the foot.

**[0050]** The inner sole may have been manufactured by an additive manufacturing process. Exemplary additive manufacturing processes include material extrusion, stereolithography, liquid additive manufacturing and laser sintering. Additive manufacturing allows for geometries that are not possible with molding and has a high potential for customization.

**[0051]** The inner sole may be integral with a sole component of a shoe. The sole component may be a midsole, outsole or outsole plate. Thus, the protuberances would protrude from the midsole, outsole or outsole plate. An integral inner sole advantageously reduces the weight of the shoe but also avoids a movement of the inner sole in the shoe.

**[0052]** The inner sole according to embodiments described herein may be an orthopedic insert. Thus, the orthopedic insert may include protuberances, recesses or holes as described herein. An orthopedic insert may be customized for a particular wearer and may compensate for orthopedic issues the wearer might have. As such, an orthopedic insert may not cover the entire foot of a wearer. For example, an orthopedic insert may extend along a medial or lateral side only. In another example, an orthopedic insert may not extend over the full length of a foot. For example, an orthopedic insert may just cover a heel region, an arch region or a toe region of a foot.

**[0053]** Some embodiments described herein relate to a shoe having an inner sole as described herein. It goes without saying that the technical properties shown or described for the inner sole, the advantages and the improvements over the state of the art are likewise applicable to the shoe, which is in particular a sports shoe. Same applies vice versa.

**[0054]** The shoe may further include a midsole, outsole or outsole plate, wherein the inner sole may be a separate element from the midsole, outsole or outsole plate, or wherein the inner sole may be integral with the midsole, outsole or outsole plate. In this way, the advantageous effects described herein may be provided by the midsole itself or by a separate element. This allows for either a highly integrated solution or for the option to customize the inner sole.

**[0055]** Some embodiments relate to a method of manufacturing an inner sole as described herein. The method includes the steps of providing a base layer; and molding the protuberances to the base layer to form the textured and untextured areas. Again, it goes without saying that the technical properties shown or described for the inner sole, the advantages and the improvements over the state of the art are likewise applicable to the method.

**[0056]** Generally, a sports shoe in embodiments described herein may be a soccer shoe, a running shoe, and outdoor shoe or a basketball shoe. This list is not exhaustive but the inventors have noticed advantageous proprioceptive effects in particular with the mentioned types of sports shoes.

**[0057]** Some embodiments described herein relate to an article of footwear that includes an inner sole comprising a first surface opposite a second surface, wherein the first surface comprises an untextured area, and wherein a plurality of protuberances are arranged on the second surface. The article of footwear includes a midsole having a top surface having a plurality of mating elements, wherein the inner sole is removably securable to the midsole. When the second surface of the inner sole is arranged facing the top surface of the midsole, the plurality of protuberances are engaged by the plurality of mating elements and the second surface of the inner sole is in facing engagement with the top surface of the midsole.

**[0058]** In any of the various embodiments described herein, the plurality of mating elements may include a plurality of recesses.

**[0059]** In any of the various embodiments described herein, the plurality of mating elements may be arranged in a pattern corresponding to a pattern of the plurality of protuberances.

**[0060]** In any of the various embodiments described herein, the first surface may have no protuberances.

**[0061]** In any of the various embodiments described herein, the second surface may have protuberances arranged in a first region and no protuberances arranged in a second region.

**[0062]** In any of the various embodiments described herein, a toe region includes first protuberances, a heel region includes second protuberances, and the midfoot region includes an untextured area with no protuberances.

**[0063]** In any of the various embodiments described herein, the midsole is made of a foam material.

**[0064]** In any of the various embodiments described

herein, the plurality of protuberances may be formed by a liquid polymer application process.

**[0065]** In any of the various embodiments described herein, the plurality of protuberances may be integrally formed with the inner sole.

**[0066]** Some embodiments described herein relate to a sole assembly for an article of footwear that includes a first sole layer having a first surface opposite a second surface, and a plurality of holes extending through the first sole layer from the first surface to the second surface in one or more regions of the first sole layer and configured to provide a proprioceptive effect. The sole assembly further includes a second sole layer coupled to the second surface, wherein the second sole layer comprises no holes and is configured to be placed in contact with a foot of a wearer.

**[0067]** In any of the various embodiments described herein, the first sole layer includes a foam material.

**[0068]** In any of the various embodiments described herein, the second sole layer includes a textile material.

**[0069]** In any of the various embodiments described herein, first holes of the plurality of holes may be arranged in a toe region, and second holes of the plurality of holes may be arranged in a heel region. In some embodiments, an untextured area may be arranged in a midfoot region of the first sole layer.

**[0070]** Some embodiments described herein relate to a sole for an article of footwear that includes an inner sole having a top surface, a toe region, a midfoot region, and a heel region and configured to support a foot of a wearer. The sole includes first protuberances arranged at a toe region of the inner sole, second protuberances arranged along a lateral side of a midfoot region of the inner sole, third protuberances arranged on a heel region of the inner sole, and a first untextured area with no protuberances arranged at a medial side of the midfoot region.

**[0071]** In any of the various embodiments described herein, the sole may further include holes extending through the midfoot region.

**[0072]** In any of the various embodiments described herein, the second protuberances may have a size that is smaller than a size of the first protuberances.

**[0073]** In any of the various embodiments described herein, the sole may further include a second untextured area at a center of the heel region.

**[0074]** In any of the various embodiments described herein, the sole may further include a second untextured area at a lateral side of the toe region.

**[0075]** In any of the various embodiments described herein, an enlarged protuberance arranged at the toe region, wherein the enlarged protuberance comprises a generally triangular shape.

#### BRIEF DESCRIPTION OF THE FIGURES

**[0076]** In the following, embodiments of the present disclosure will be described in more detail with reference to the following figures:

FIGS. 1A-1C show an exemplary embodiment of an inner sole.

FIGS. 2A-2D show exemplary protuberances according to embodiments.

FIG. 3 shows a textile with protuberances to be used in an inner sole according to embodiments.

FIG. 4 shows an illustration of a method of manufacturing an inner sole according to an embodiment.

FIG. 5 shows an exemplary embodiment of a sole component according to some embodiments.

FIGS. 6A-6D show exemplary embodiments of 3D printed inner soles or sole components according to embodiments.

FIG. 7 shows an embodiment of an inner sole.

FIGS. 8A-8D illustrate embodiments of inner soles with differently shaped protuberances.

FIG. 9A shows an embodiment of an inner sole having both protuberances and holes.

FIG. 9B shows a shoe having the inner sole of FIG. 9A.

FIG. 9C shows the upper of the shoe of Fig. 9B in more detail.

FIGS. 10A-10C show embodiments of a shoe, inner sole and midsole according to embodiments.

FIG. 11 shows an exemplary embodiment of an upper.

FIG. 12A shows a perspective view of a first side of an inner sole according to an embodiment.

FIG. 12B shows a perspective view of a second side of the inner sole of FIG. 12A.

FIG. 13 shows a midsole for use with inner sole of FIGS. 12A-12B according to an embodiment.

FIG. 14A shows the inner sole of FIG. 12A arranged in the midsole of FIG. 13.

FIG. 14B shows the inner sole of FIG. 12B arranged in the midsole of FIG. 13.

FIG. 15A and 15B show cross sectional views of first and second sides of an inner sole positioned for coupling with a midsole according to an embodiment.

FIGS. 16A and 16B show top and bottom views of a sole assembly according to an embodiment.

FIG. 17 shows a cross sectional view of a sole assembly having first and second layers according to an embodiment.

FIG. 18A shows a top down view of a top side of an inner sole according to an embodiment.

FIG. 18B shows a cross sectional view of protuberances of the inner sole of FIG. 18A.

FIG. 18C shows a cross sectional view of an enlarged protuberance of FIG. 18A.

FIG. 19 shows a top down view of a top side of an inner sole according to an embodiment.

#### DETAILED DESCRIPTION

**[0077]** In the following only some possible embodiments are described in detail. However, the present

application is not limited to these embodiments, and a multitude of other embodiments are applicable without departing from the scope of the present disclosure. The embodiments described herein can be modified in a number of ways and combined with each other whenever compatible and certain features may be omitted in so far as they appear dispensable. In particular, the disclosed embodiments may be modified by combining certain features of one embodiment with one or more features of another embodiment.

**[0078]** It is to be understood that not all features of the described embodiments have to be present for realizing the technical advantages provided by the present disclosure, which is defined by the subject-matter of the claims. The disclosed embodiments may be modified by combining certain features of one embodiment with one or more features of another embodiment. Specifically, the skilled person will understand that features and functional elements of one embodiment can be combined with technically compatible features and functional elements of any other embodiment of the present disclosure given that the resulting combination falls within the definition of the present disclosure.

**[0079]** While the embodiments below are described primarily with reference to a sole for a shoe, in particular for a sports shoe, the skilled person will recognize that the disclosure can equally be applied in a plurality of different technical fields or use cases.

**[0080]** Throughout the present application, the same reference numerals refer to the same elements. For the sake of clarity and conciseness, certain aspects of components or steps of certain embodiments are presented without undue detail where such detail would be apparent to those skilled in the art in light of the teachings herein or where such detail would obfuscate an understanding of more pertinent aspects of the embodiments.

**[0081]** As understood by the skilled person and in order to avoid redundancies, reference is also made to the explanations in the preceding sections, which also apply to the following description. Further, not all features, parts, elements, aspects, components or steps are expressly indicated by reference signs for the sake of brevity and clarity. This particularly applies, where the skilled person recognizes that such features, parts, elements, aspects, components or steps are present in a plurality.

**[0082]** Generally, as far as protuberances are shown in the figures and mentioned in the following description, it is understood that those could be replaced by recesses or holes to achieve a similar proprioceptive effect. Similarly, as far as holes are shown in the figures and mentioned in the following description, it is understood that those could be replaced by protuberances or recesses. Similarly, as far as recesses are shown in the figures and mentioned in the following description, it is understood that those could be replaced by protuberances or holes. In particular, any particular pattern of protuberances could be replaced by a similar pattern of recesses or holes, any particular

pattern of holes could be replaced by a similar pattern of protuberances or recesses and any particular pattern of recesses could be replaced by a similar pattern of protuberances or holes.

**[0083]** Figures 1A and 1B show an embodiment, wherein Fig. 1A shows an inner sole 1 in a side view from the medial side of the inner sole 1 and Fig. 1B shows the same inner sole 1 in a rear view. An inner sole 1 is sometimes denoted as an insole or sockliner and is generally intended to be placed in a shoe (not shown in the figures). As such, the inner sole 1 will be placed inside the shoe, such that a foot of a wearer of the shoe may rest on the inner sole 1. Thus, the inner sole 1 defines a top surface 2 which is adapted to face the foot of a wearer and a bottom surface (not shown in the figures) which is adapted to face a midsole of the shoe.

**[0084]** In the exemplary embodiment of Figures 1A and 1B, the inner sole 1 includes multiple layers. A base layer is formed by a foam layer 11 which makes up the majority of the inner sole 1 and generally defines its shape. The foam layer 11 may for example be made from ethylene-vinyl acetate (EVA) but other materials might be used as well. For example, the foam layer 11 may include a polymeric foam, in particular, at least one of polyurethane (PU) foam, such as thermoplastic polyurethane (TPU) foam, polyamide (PA) foam, polyether-block-amide (PEBA) foam, or thermoplastic polyester ether elastomer (TPEE) foam.

**[0085]** Alternatively, the foam layer 11 may include a particle foam material, in particular one or more of the following materials: expanded thermoplastic polyurethane (eTPU); expanded polyamide (ePA); expanded polyether-block-amide (ePEBA); expanded polylactide (ePLA); expanded polyethylene terephthalate (ePET); expanded polybutylene terephthalate (ePBT); or expanded thermoplastic polyester ether elastomer (eTPEE).

**[0086]** The foam particles may be made of, or include, expanded thermoplastic materials, especially thermoplastic polyurethane (TPU), polylactate (PLA), polyamide (PA), polyether block amide (PEBA), polyethylene terephthalate (PET), polybutylene terephthalate (PBT), or thermoplastic polyester ether elastomer (TPEE). The foam particles may also be a bead containing multiple polymer types in one foam particle or the foam particles may be a mixture of different particles of different foam polymers or combinations thereof. In some embodiments, the foam particles are 90 % by weight of one or a mixture of these materials. These foam particles are particles that include a so-called bead foam, also known in the art as a pellet or particle foam. Often the foams derived from the use of connected foam particles are given the designation "e" to denote the bead form of the polymer foam component, for example, eTPU.

**[0087]** Generally, the foam layer 11 may include multiple hardness components or materials. For example, the foam layer 11 may have a higher hardness in a heel region as compared to a toe region. In another example,



the foam layer 11 may include EVA and PU.

**[0088]** On top of the foam layer 11, a textile layer 10 is arranged. The textile layer 10 in the example of Figures 1A and 1B is a knitted fabric which may be warp or weft knitted. Generally, other textiles such as woven fabrics, meshes or non-woven fabrics may be used. It should be noted that the inner sole 1 in other embodiments includes a single layer or more than two layers.

**[0089]** In the embodiment of Figures 1A and 1B, a plurality of protuberances 4a are arranged on the textile layer 10. The protuberances 4a are shown in more detail in Fig. 1C which is the same exemplary inner sole 1 as in Figures 1A and 1B but shown in a close-up view. As shown in Fig. 1C, the protuberances 4a have a pyramidal shape with a rounded tip 6 which is shown in more detail in Figures 2A and 2B. In the exemplary embodiment of Figures 1A, 1B and 1C, the protuberances 4a are made from polyurethane (PU), but other materials might be used as well, such as rubber.

**[0090]** Figures 2A and 2B show illustrations of the protuberances 4a used in the exemplary embodiments of Figures 1A, 1B and 1C. Each of the protuberances 4a has a rounded tip 6. In alternative embodiments, the tips would not be rounded as will be described with respect to Figures 2C and 2D. In the dimensioned illustration of Fig. 2B, the protuberances 4a have a height of 1.2mm and a base area of 2.5mm x 2.5mm as shown by the dimensions 7, 8 and 9, respectively. In other embodiments, the dimensions would be different. Also, the present disclosure is not restricted to pyramidal shaped protuberances and in other embodiments the protuberances could have a hemispherical, diamond-like or elliptical shape to name just a few non-limiting examples.

**[0091]** Figures 2C and 2D show alternative shapes of the protuberances 4a. In this embodiment, the protuberances 4a have a pyramidal shape as well. However, the tips 6 of the pyramids are not rounded but sharp. Similar to the protuberances 4a of Figures 2A and 2B, the pyramids shown in Figures 2C and 2D have an exemplary height of 1.2 mm, and an exemplary base area of 2.5mm x 2.5mm as shown by the dimensions 7, 8 and 9, respectively. In other embodiments, the dimensions may be different.

**[0092]** Also, in other embodiments, the shape of the protuberances 4a could vary across the surface of the inner sole 1. Thus, the protuberances 4a could have a different shape in the toe region compared to the heel region. Likewise, while in the embodiment of Figures 1A, 1B and 1C, the protuberances 4a have the same dimensions irrespective of their location on the top surface 2 of the inner sole 1, in other embodiments, the dimensions could vary. Thus, the protuberances 4a could have a smaller diameter in the toe region compared to the heel region. As far as reference is made herein to the dimensions of the protuberances 4a, this could also be understood as an average value, e.g. with respect to some region of the inner sole 1, e.g. the toe region and the heel region. Also, the term "diameter" is not necessarily under-

stood as referring to a circular shape but refers to the general dimension of the base portion of the protuberances 4a or, alternatively, to the distances between the tips of the protuberances 4a. As such, the protuberance 4a depicted in Fig. 2A has a quadratic base portion with a length 8 and a width 9. Thus, the diameter of this particular protuberance 4a is said to be its length or width. Alternatively, the length of the diagonal could be taken as the diameter which, in the example of Figures 2B and 2D would be  $\sqrt{2}$  of the length 8 or width 9. Thus, the term "diameter" as used herein relates to the order of magnitude of the protuberances.

**[0093]** The protuberances 4a in the exemplary embodiment of Figures 1A, 1B and 1C have a hardness of 40-70 Shore-A, and may have a hardness of 50-60 Shore-A. In other embodiments, the hardness would be different. In still other embodiments, the hardness could vary across the inner sole 1, e.g. by using different materials in different regions of the inner sole 1. For example, a stiffer material for the protuberances 4a could be used in the toe region as compared to the heel region.

**[0094]** In some embodiments, protuberances, recesses, or holes may be arranged in one or more rows or columns, with rows extending in a direction between medial and lateral sides of inner sole 1 and columns extending in a direction between toe region and heel region. Thus, protuberances, recesses, or holes may be arranged in a grid-like pattern. The number of protuberances, recesses, or holes in each row or column may differ to provide the desired layout of textured areas.

**[0095]** Inner sole may include one or more textured areas, as shown in Figs. 1A-1C. Textured areas may be spaced from one another, and may be separated by one or more untextured areas 5a. Textured areas of inner sole 1 may have different shapes and arrangements. Further, protuberances of each textured area may differ in one or more of shape, dimensions, density, or material, as discussed in further detail herein. In the embodiment of Figs. 1A-C the protuberances 4a form a first textured area 3a in the toe region, a second textured area 3b in the heel region, a third textured area 3c in a lateral portion of the heel region, a fourth textured area 3d in a medial portion of the heel region, and a fifth textured area 3e in a medial metatarsal-to-arch transition region. In some embodiments, second textured area 3b may be arranged in a rearmost portion of the heel region. An untextured area 5a is located in a medial metatarsal region. A further untextured area 5b is located in a lateral metatarsal-to-arch transition region. In other embodiments, the arrangement of textured and untextured areas could be different.

**[0096]** Fig. 3 shows an exemplary textile layer 10 with overmolded protuberances 4a. The textile layer 10 is shown before cutting and before it would be attached to the foam layer 11, e.g. by gluing, stitching or welding.

**[0097]** Fig. 4 illustrates an exemplary method 100 of manufacturing an exemplary inner sole 1 as described herein. Method steps 110, 120 and 130 relate to manu-

facturing a foam layer 11 and method steps 140, 150 and 160 relates to manufacturing a textile layer 10 with over-molded protuberances 4a. Finally, method step 170 relates to attaching the textile layer 10 to the foam layer 11. Thus, method steps 110, 120 and 130 could be performed simultaneously with method steps 140, 150 and 160. In other embodiments, the foam layer 11 could be manufactured before the textile layer 10 and in still other embodiments, the textile layer 10 could be manufactured first.

**[0098]** In a step 110, an EVA foam layer is cut from a block of EVA material. Cutting can be done by a knife, laser, a water jet, etc. The process of cutting can be automated, e.g. by a robot arm. Alternatively, the EVA foam layer is directly molded in a mold. To this end, EVA raw material (e.g. as a granulate) is placed in a mold and formed to shape using pressure and/or heat. In step 120 the cut or molded EVA foam layer is cold pressed, and in step 130 the EVA foam layer is trimmed to the desired shape.

**[0099]** In step 140 PU is poured in a mold having indentations corresponding to the protuberances 4a on the inner sole to be manufactured. The PU is then molded to a textile, e.g. a textile as shown in Fig. 3. In step 160 the textile is trimmed to the desired shape, e.g. by cutting or punching. Finally, in step 170 the textile is attached to the foam layer to obtain an inner sole 1 as shown for example in the embodiment of Figures 1A, 1B and 1C.

**[0100]** To demonstrate the effectiveness of the inner sole as described herein, a study with 20 participants was performed. The study investigated the differences between the textured insoles as described herein and control insoles having a smooth top surface in side-cut and start-stop tasks. In the side-cut task, participants were asked to perform a running exercise on a grass turf, where two parallel lines were marked with cones. Participants began on either the left or right side, were selected randomly, and ran along the designated line for 50 meters while maintaining a consistent speed. Throughout this exercise, they listened for an auditory cue, the word "now". Upon hearing the cue, they were required to make an immediate and sharp (45-degree) cut in their running direction, transitioning to the other parallel line. This task was designed to test agility and the ability to change direction quickly.

**[0101]** In the start-stop task, which took place along a similar 50-meter straight track, participants were asked to commence running upon hearing the word "start" and cease immediately upon hearing the word "stop". Throughout the task, auditory cues were repeatedly administered, with each participant hearing a total of 15 commands (start, stop, and now) in each task, each "start" command was consistently followed by a "stop" command, and vice versa. These stimuli were separated at random intervals ranging from 2500 to 5000 milliseconds during which participants were expected to respond appropriately.

**[0102]** A third test ("acoustic stroop") consisted of a

series of 16 randomized words "right" or "left" (8 each). The words were recorded using a two channel (stereo) recorder such that each individual word is only heard in one ear (right or left) when wearing a headset. For half of these words the meaning of the word corresponded to the ear in which it is heard ("right" - right ear; "left" - left ear) while the other half were switched ("right" - left ear; "left" - right ear). The order of the consonant and dissonant word-ear pairs was randomized and so was the time gap between consecutive words (random times between 2.5 and 5 seconds). Participants were instructed to react immediately after hearing the word and respond "Correct" for consonant word-ear situation and "Wrong" for the dissonant word-ear situation. The response was recorded on the same AV track as the stimulus using a remote phone recording device. During processing, the audio files were digitized to create a sound envelope for both the stimulus and the response, and the time between the peak of the stimulus and the response was quantified and recorded as the "reaction time".

**[0103]** The participants then completed all three tests and the reaction times for each test were recorded. The entire dataset recorded for the study consisted of 120 independent sessions (40 sessions for each of the independent tests: acoustic stroop, side-cut and start-stop). Of these, data from 7 sessions (5.8%) were not usable due to data recording or synchronization issues. The results of the study showed that the participants who wore the inner soles described herein showed a significant increase in reaction times ( $p$ -value=0.044) for the side-cut task. The reaction time for the start-stop task was virtually identical ( $p$ -value=0.33) for the two conditions. The mean reaction time for the textured insoles was 1.34s for the side-cut task and 1.40s for the start-stop task. The mean reaction time for the control condition was 1.41s for the side-cut task and 1.42s for the start-stop task. The mean acoustic stroop test reaction values were 606ms for the control condition and 526ms for the textured insole condition. The difference between the two conditions was significant ( $p$ -value=0.003).

**[0104]** The study shows that the textured inner sole as described herein reduces the reaction time by a significant amount for a standard cognitive task (acoustic stroop test) and also led to the improvement of a common football task (side cut). The side cut time improvement reached statistical significance for 20 subjects. Thus, the study demonstrates the effectiveness of the inner sole described herein.

**[0105]** Fig. 5 shows an embodiment relating to another embodiment, namely a sole component 20 for a sports shoe, which in the embodiment of Fig. 5 is a midsole. Generally, the sole component 20 according to this aspect may be a midsole, a Strobel sole, a lasting board or similar component that is arranged to contact a foot of a wearer. In other embodiments, the sole component may be a portion of the upper, e.g. in Moccasin-type shoe constructions in which the upper extends under the foot and is partly arranged between the foot and the midsole

or outsole. The midsole 20 includes a top surface 2 which is arranged to face a foot of a wearer of a shoe in which the midsole would be arranged. The top surface 2 includes a plurality of protuberances 4a and holes 4b. Therefore, what has been described herein with respect to the protuberances 4a on an inner sole, such as the inner sole 1 shown exemplarily in Figures 1A-C, 3, 6A-D, 7, 8A-D, 9A and 10C is applicable to this embodiment relating to a sole component as well. In particular, the mentioned advantages and the described proprioceptive effect of the protuberances 4a apply to the sole component as well. Similarly, the holes 4b also provide for a proprioceptive effect as described herein.

**[0106]** The midsole 20 in the exemplary embodiment of Fig. 5 is made from a foam material. As an example, an upper portion of the midsole 20 is made from EVA and a lower portion of the midsole 20 is made from a supercritical foam material. In other embodiments, the sole component 20 may include a polymeric foam, in particular, at least one of polyurethane (PU) foam, such as thermoplastic polyurethane (TPU) foam, polyamide (PA) foam, polyether-block-amide (PEBA) foam, or thermoplastic polyester ether elastomer (TPEE) foam.

**[0107]** Alternatively, the sole component may include a particle foam material, in particular one or more of the following materials: expanded thermoplastic polyurethane (eTPU); expanded polyamide (ePA); expanded polyether-block-amide (ePEBA); expanded polylactide (ePLA); expanded polyethylene terephthalate (ePET); expanded polybutylene terephthalate (ePBT); or expanded thermoplastic polyester ether elastomer (eTPEE).

**[0108]** The foam particles may be made of expanded thermoplastic materials, especially thermoplastic polyurethane (TPU), polylactate (PLA), polyamide (PA), polyether block amide (PEBA), polyethylene terephthalate (PET), polybutylene terephthalate (PBT), or thermoplastic polyester ether elastomer (TPEE). The foam particles may also be a bead containing multiple polymer types in one foam particle or the foam particles may be a mixture of different particles of different foam polymers or combinations thereof. In some embodiments, the foam particles are 90 % by weight of one or a mixture of these materials. These foam particles are particles that include a so-called bead foam, also known in the art as a pellet or particle foam. Often the foams derived from the use of connected foam particles are given the designation "e" to denote the bead form of the polymer foam component, for example, eTPU.

**[0109]** The protuberances 4a in the exemplary embodiment of Fig. 5 have an average height of 1.3mm which could be different in other embodiments. Generally, protuberances of a sole component according to this embodiment may be larger (e.g. 1-4mm) than protuberances on an inner sole as described herein.

**[0110]** In the embodiment of Fig. 5, the shoe in which the midsole 20 is to be integrated would not have an inner sole arranged on top of the midsole 20. In other embodi-

ments, an inner sole would be arranged on top of the midsole 20. In this case, the inner sole would include a plurality of apertures such that the plurality of protuberances 4a of the midsole 20 would protrude through the plurality of apertures. The height of the protuberances 4a and the thickness of the inner sole in this embodiment could be adapted such that the protuberances 4a protrude above the top surface of the inner sole, e.g. by 0.5mm. In this way, the positive proprioceptive effect described herein could be achieved. In addition, the inner sole could have protuberances 4a as described herein. Thus, embodiments relating to the inner sole 1 and the sole component 20 can generally be combined.

**[0111]** The protuberances 4a in the embodiment of Fig. 5 have a dome-like shape. In other embodiments, the shape would be different, e.g. ball-like, pyramidal, etc. Also, the location of the protuberances 4a can be different. For example, protuberances may alternatively or additionally be located in a toe region or in the arch region to provide arch support. Also, the shape, height, diameter, or hardness of the protuberances 4a may vary across the sole component 20. Generally, these properties may be adapted to the density or sensitivity of mechanoreceptors of the human foot or the pressure exerted by a human foot onto the sole component 20. Similar considerations apply in this context as described with respect to the inner sole 1.

**[0112]** In the following, embodiments relating to the sole component 20 are described:

1. Sole component for a sports shoe including a top surface arranged to face a foot of a wearer of the sports shoe, wherein the top surface includes a plurality of protuberances.
2. Sole component according to embodiment 1, wherein the sole component is a midsole, a Strobel sole or a lasting board.
3. Sole component according to one of the previous embodiments, wherein the protuberances are arranged in a toe region of the sole component.
4. Sole component according to one of the previous embodiments, wherein the protuberances are arranged in a heel region of the sole component.
5. Sole component according to one of the previous embodiments, wherein the protuberances have a diameter of 1-8mm, 2-6mm, or 3-4mm.
6. Sole component according to one of the previous embodiments, wherein the protuberances have a height of 0.5-6mm, 0.8-5mm, or 1-4mm.
7. Sole component according to one of the previous embodiments, wherein the protuberances are located around areas having a local maximum of a pressure distribution of pressure caused by a human foot standing on the sole component.
8. Sole component according to the previous embodiment, wherein no protuberances are arranged in a local maximum of the pressure distribution.
9. Sole component according to one of the previous

embodiments, wherein the sole component has been manufactured by an additive manufacturing process.

10. Sports shoe having a sole component according to one of the previous embodiments.

11. Sports shoe according to the previous embodiment, further including an inner sole arranged on the sole component, wherein the inner sole includes a plurality of apertures such that the plurality of protuberances of the sole component protrude through the plurality of apertures.

12. Sports shoe according to the previous embodiment, wherein the inner sole has an average thickness, such that the plurality of protuberances protruding through the plurality of apertures protrude from a top surface of the inner sole by 0.1-1mm, 0.2-0.8mm, or 0.3-0.7mm.

13. Sports shoe according to one of the previous embodiments, wherein the inner sole has been manufactured by an additive manufacturing process.

**[0113]** Figures 6A, 6B, 6C and 6D show further exemplary embodiments in which the inner sole 1 or the sole component 20 have been manufactured by an additive manufacturing process. Thus, Figures 6A, 6B, 6C and 6D and the following description are applicable to both an additively manufactured inner sole as well as an additively manufactured sole component such as a midsole or a portion thereof. Exemplary additive manufacturing processes include material extrusion, stereolithography, liquid additive manufacturing and laser sintering. Additive manufacturing is also denoted as 3D printing.

**[0114]** Fig. 6A shows a top layer of a 3D printed lattice structure including a plurality of arches 61 which form protuberances 4a causing a proprioceptive effect as described herein. The lattice structure may be provided to an inner sole 1 or to a sole component 20 as described herein. Similarly, holes 4b are formed between the arches 61 which also cause a proprioceptive effect as described herein. The arches 61 are compressible to some extent so as to provide a comfortable feeling to a foot. The arches 61 form a textured area 3a of the inner sole 1 or sole component 20 shown in Fig. 6A. An untextured area 5, which is also 3D printed, is also provided.

**[0115]** Fig. 6B shows a highly crushable (highly compressible) layer of thick beams forming an inner sole 1. The inner sole 1 in this exemplary embodiment was obtained by 3D printing and is arranged on top of a midsole 20 which is 3D printed as well. In the embodiment of Fig. 6B, the inner sole 1 is a separate element from the midsole 20, i.e. it has been manufactured in a separate 3D printing process and then arranged on top of the midsole 20. In other embodiments, the inner sole 1 can be manufactured in a single 3D printing process together with the midsole 20 so that both are integral parts. The thick beams of the inner sole 1 or midsole 20 form holes 4b in between which cause a proprioceptive effect as described herein. Alternatively, the thick beams can be

interpreted as protuberances which cause a proprioceptive effect.

**[0116]** Fig. 6C shows a 3D printed inner sole 1 or sole component 20 having elevated arch 62 and heel areas 63 for increased support and deformation. In this example, the top layer includes "tabletop" elements 4a which are identical in the heel and in the medial arch areas. Those elements are protuberances 4a as described herein and cause a proprioceptive effect.

**[0117]** Fig. 6D illustrates a 3D printed inner sole 1 or sole component 20 having protruding nodes 4a off the top surface which interact with the foot. The nodes have a mushroom-like shape and form protuberances 4a providing a proprioceptive effect as described herein. In other embodiments, the nodes could have a different shape. Also, the nodes 4a form a textured area 3a adjacent an untextured area 5 which is also 3D printed.

**[0118]** Fig. 7 shows an embodiment of an inner sole 1 according to an embodiment. The inner sole 1 according to this embodiment is a two-layered construction with a bottom foam layer and a textile layer on top of the foam layer. The inner sole 1 includes a plurality of holes 4b. A first subset of the holes 4b have a larger diameter than a second subset of the holes 4b. Thus, the holes define a first textured area 3a in a toe region of the inner sole 1. The first textured area includes holes with a large diameter and holes with a small diameter. Another textured area 3b is located in a heel region. The area 3b just contains holes with a large diameter. In an arch region of the inner sole 1 holes having a small diameter are located, whereas in a region between the toes and the arch a mixture of holes with large and small diameters is located. The embodiment of Fig. 7 is an example of an inner sole 1 just having holes as proprioceptive elements but no protuberances.

**[0119]** Figs. 8A-D illustrate embodiments of inner soles 1 according to embodiments with differently shaped protuberances. In Fig. 8A the protuberances 4a have a pyramidal shape similar to the embodiment of Figs. 1A-C. However, the number of pyramids is generally lower in the embodiment of Fig. 8A compared to the embodiment of Figs. 1A-C because the pyramids have a larger base area. Said differently, the density of the pyramids 4a is lower.

**[0120]** In the embodiment of Fig. 8B the protuberances 4a have a dome-like shape. In the embodiment of Fig. 8C the protuberances 4a have the shape of a prism. In the embodiment of Fig. 8D the protuberances 4a have a spike-like shape. An exemplary density of the spikes is 5 per cm<sup>2</sup>, an exemplary height of 7 mm, and an exemplary diameter of 2 mm.

**[0121]** Generally, for the embodiments of Figs. 8A-D, the arrangement of textured areas 3a-e and untextured areas 5 is similar to the embodiment of Figs. 1A-C. Accordingly, what has been said with respect to the textured and untextured areas with respect to the embodiment of Figs. 1A-C is applicable to the embodiments of Figs. 8A-D as well.

**[0122]** In contrast, Fig. 9A shows an embodiment of an inner sole 1 having both protuberances 4a and holes 4b. The inner sole 1 of this exemplary embodiment is made from foam material. The protuberances 4a are integral with the foam material and obtained by molding the material in a mold having recesses corresponding to the protuberances 4a. The holes 4b are also formed during the molding process. Alternatively, the holes could be obtained by punching. In the embodiment of Fig. 9A the protuberances 4a form a first textured area 3a in the toe region of the inner sole 1 and a second textured area 3b in the heel region of the inner sole 1.

**[0123]** Fig. 9B shows a shoe 80 in which the inner sole 1 shown in Fig. 9A is inserted. The shoe 80 includes an upper 30 and a sole structure 81.

**[0124]** Fig. 9C shows just the upper 30 of the shoe 80 shown in Figure 9B. The upper 30 includes a plurality of protuberances 4a on its inside, i.e. the side facing a foot of a wearer of the shoe 80. The protuberances 4a in this exemplary embodiment are made from TPU and are applied to the upper 30 by printing. As described herein, also the protuberances 4a on the upper 30 cause a proprioceptive effect on the foot of a wearer of the shoe 80. Therefore, the upper 30 of the shoe of Fig. 9C is part of a further embodiment.

**[0125]** Fig. 10A shows another exemplary embodiment of a shoe 80 according to an embodiment. The shoe includes an inner sole 1 having holes. The inner sole 1 is shown in more detail in Fig. 10C and is made from a foam material. Fig. 10B shows the shoe 80 with the inner sole removed. As can be seen, the top surface of the sole component 20 of the shoe 80 includes protuberances 4a which are configured to protrude through corresponding holes 4b in the inner sole 1 as also shown in Fig. 10A. Thus, the protuberances 4a engage with some of the holes 4b of the inner sole 1. This causes the inner sole 1 to "register" with the sole component 20 which avoids a slipping of the inner sole 1 in the shoe. Furthermore, as the inner sole 1 is soft and compressible, it will be compressed if pressure is exerted by a foot such that the protuberances will contact the foot. Thus, a proprioceptive effect is achieved by both the protuberances 4a and the holes 4b. Depending on the amount of pressure, which will for example vary during a gait cycle, a stimulation of the foot will be predominantly caused by the protuberances 4a of the sole component 20 or by the holes 4b of the inner sole 1.

**[0126]** Some embodiments relate to an upper 30 for a sports shoe. An exemplary embodiment is shown in Fig. 11. The upper 30 includes a plurality of protuberances 4a. Thus, the positive proprioceptive effect described herein for the insole 1 is applicable to the upper 30 as well. In addition, embodiments relating to the inner sole 1 and the sole component 20 can generally be combined with embodiments of the upper 30. Thus, a sports shoe could include an inner sole 1 and an upper 30 as described herein. Alternatively, it could include a sole component 20 and an upper 30 as described herein.

**[0127]** The upper 30 in the example of Fig. 11 is based on a mesh fabric. Generally, in the context of this embodiment, the upper could be based on a knitted fabric, a woven or a non-woven, or combinations thereof. The protuberances 4a are visible in the embodiment of Fig. 11 as they shine through the mesh. In other embodiments, the protuberances 4a would not be visible from the outside as they protrude from the inner surface of the upper to provide proprioception to the foot of the wearer. Thus, the protuberances 4a define raised portions on the inner surface of the upper 30. The inner surface of the upper 30 is defined as the surface being adapted to face a foot of wearer of a shoe in which the upper 30 is incorporated.

**[0128]** The protuberances 4a may be provided during the manufacturing process of the textile making up the upper. For example, in case of a knitted upper, certain knit elements may be provided during the knitting process which protrude from the surface of the knitted textile. Alternatively, the protuberances may be provided to an existing textile, e.g. by gluing, welding or sewing. Another possibility is the molding of protuberances to a textile as described above with respect to the textile layer 10 of the inner sole 1.

**[0129]** Generally, the inner sole 1, sole component 20 and upper 30 as described herein having protuberances, recesses or holes to achieve a proprioceptive effect may be customized according to the needs of a wearer. In particular a first inner sole 1, sole component 20, upper 30 or a shoe including one or more of those components with a certain textured pattern may be provide to a wearer. Then the proprioceptive effect is measured, for example as described above. This provides information on which influence the inner sole 1, sole component 20 or upper 30 has on the performance of the wearer. The wearer's feedback is taken into account and the textured pattern may be re-designed and the inner sole 1, sole component 20, upper 30 or a shoe including one or more of such components is given again to the wearer for another round of testing. By such feedback loops, the inner sole 1, sole component 20 or upper 30 can be customized and performance further improved.

**[0130]** A user may wish to have the ability to choose whether an inner sole provides a flat or untextured surface for contact with the foot, or to have a textured area that provides a proprioceptive effect as described herein. Switching between different articles of footwear to provide a flat surface or a textured surface may be undesirable, as the user may need to purchase, store and travel with multiple pairs of footwear. Similarly, having multiple insoles that provide different textured and untextured surfaces may also be cumbersome. Thus, an article of footwear having a removable inner sole that has a first surface that is untextured and a second surface that is textured (e.g., includes protuberances, recesses or holes) may help to improve the versatility of the article of footwear and provide convenience to the user.

**[0131]** Figs. 12A and 12B show top and bottom per-

spective views of an inner sole 200 according to an embodiment. Inner sole 200 includes a first surface 210 opposite a second surface 220. Inner sole 200 includes a toe region 202, a midfoot region 204, and a heel region 206 generally corresponding to the toes, midfoot or arch, and heel of a wearer's foot, respectively, when the inner sole 200 is in use. Inner sole 200, also referred to as an insole or sockliner, may have features as described herein with respect to inner sole 1. Inner sole 200 may be formed in the same manner and using the materials as described herein with respect to inner sole 1.

**[0132]** First surface 210 of inner sole 200 may have no protuberances, recesses or holes. First surface 210 may be untextured. In some embodiments, a cover layer may be arranged on first surface 210 for contact with the wearer's foot. Cover layer may include a textile layer. Cover layer may improve wearer comfort, and/or provide moisture absorption and may reduce slippage of the wearer's foot against the inner sole 200.

**[0133]** Second surface 220 of inner sole 200 may include one or more regions having a textured area with one or more protuberances, recesses or holes 224. Protuberances, recesses, or holes may be arranged in one or more of toe region 202, midfoot region 204, heel region 206, medial side, or a lateral side of inner sole 200, and combinations thereof. Protuberances 224 may have a geometry and arrangement as described herein with respect to protuberances 4a. In some embodiments, one or more of toe region 202, midfoot region 204, and heel region 206 of second surface 220 may include protuberances, recesses or holes 224. One or more regions of second surface 220 may be untextured 226, and may be generally smooth or flat. Untextured area 226 has no protuberances, holes or recesses. In the embodiment of Fig. 12A, a plurality of first protuberances 224a are arranged in toe region 202. Midfoot region 204 is untextured 226 and includes no protuberances, recesses or holes. Heel region 206 includes a plurality of second protuberances 224b. First and second protuberances 224a, 224b may differ in geometry, size, arrangement, hardness, or combinations thereof. For example, first protuberances 224a may have a first shape, whereas second protuberances 224b may have a second shape that differs from first shape. In a further example, first protuberances 224a may have a first size, whereas second protuberances 224b may have a second size that differs from the first size. In a further example, first protuberances 224a may be arranged in a first pattern or may have a first density (number of protrusions per unit area), whereas second protuberances 224b may be arranged in a second pattern or may have second density.

**[0134]** In some embodiments, second surface 220 may include a cover layer thereon. Cover layer may include a textile layer. Cover layer may improve wearer comfort, and/or provide moisture absorption and may reduce slippage of the wearer's foot against the inner sole 200. Cover layer may conform to the protuberances, recesses or holes so that the protuberances, recesses or

holes can be felt by the wearer's foot through the cover layer.

**[0135]** The user may choose to position inner sole 200 in an article of footwear with either first surface 210 or second surface 220 facing the foot of the wearer. Thus, if the user wishes to have an untextured surface facing the user's foot, the user may position inner sole 200 with first surface 210 facing upward toward the foot of the wearer. This may provide comfort to the wearer. First surface 210 does not provide proprioceptive effect. In contrast, if the user wishes to have their foot engage the textured surface with protuberances 224, such as for a proprioceptive effect, user may position second surface 220 facing toward the wearer's foot.

**[0136]** In other embodiments, first surface 210 may have a first textured area, and second surface 220 may provide a second textured area that differs from first textured area. Thus, the user may choose which texture to have in contact with their foot. For example, first surface 210 may have protuberances in a first pattern and having a first geometry, and second surface 220 may have protuberances having a second pattern and/or second geometry. In a further example, first surface may include protuberances, whereas second surface may include recesses or holes.

**[0137]** A midsole 250 configured to removably receive inner sole 200 is shown in Fig. 13 according to an embodiment. Midsole 250 may include a foam material. Midsole 250 may include a toe region 252, a midfoot region 254, and a heel region 256. Midsole 250 is configured to support a foot of a wearer from heel to toe. A top surface 262 of midsole 250 may include one or more mating elements 264 for engaging protuberances 224 of inner sole 200. As shown in Fig. 13, mating elements 264 may include recesses for receiving protuberances of inner sole 200. However, in alternate embodiments where inner sole 200 includes recesses, midsole may include protuberances for arrangement within the recesses. Mating elements 264 may be arranged in a pattern corresponding to a pattern of protuberances 224 so as to align with and engage protuberances 224. In this way, second surface 220 of inner sole 200 may be placed in facing engagement with top surface 262 of midsole 250. As a result, the inner sole 200 is securely positioned on midsole 250 and without gaps or spaces between inner sole 200 and midsole 250.

**[0138]** In some embodiments, midsole 250 may include a rim 270 extending around all or a portion of a perimeter of top surface 262 of midsole 250. Rim 270 may extend upwardly from top surface 262 in a direction away from midsole 250. Inner sole 200 may be configured to be received on top surface 262 and within an area defined by rim 270 of midsole 250. Rim 270 may help to facilitate proper positioning of inner sole 200 on midsole 250.

**[0139]** Inner sole 200 received on midsole 250 as shown for example in Figs. 14A and 14B. As shown in Fig. 14A, first surface 210 of inner sole 200 is facing upward toward a foot of the wearer. First surface 210 is

untextured and provides a flat surface for contact with a wearer's foot. Protuberances on second surface are facing downward toward top surface of midsole 250 and are engaged within recesses of midsole 250. In contrast, if the wearer wishes to use a textured surface, wearer may position inner sole 200 on midsole 250 with second surface 220 facing upward toward a foot of the wearer as shown in Fig. 14B. First surface 210 is facing downward toward top surface of midsole.

**[0140]** When the user switches from first surface facing upward to second surface facing upward, the user switches which shoe the inner sole 200 is inserted into. For example, if the inner sole 200 is positioned in a left shoe with first surface 210 facing upward, in order to have second surface 220 facing upward, the user arranges inner sole 200 in the right shoe, and vice versa.

**[0141]** A cross sectional view of inner sole 200 arranged on midsole 250 according to an embodiment is shown in Figs. 15A and 15B. As shown in Fig. 15A, inner sole 200 is arranged with second surface 220 facing downward toward top surface 262 of midsole 250. Protuberances 224 align with and are received in mating elements 264, which are shown as recesses. Protuberances 224 may partially or complete fill recesses 264. Protuberances 224 and recesses 264 may have complementary shapes. For example, protuberances 224 may have a hemispherical shape, and recesses 264 may have a hemispherical shape. When protuberances 224 are received by mating elements 264, second surface 220 may be in facing engagement with, or flush against, top surface 262. In this way, first surface 210 may remain substantially flat.

**[0142]** Inner sole 200 arranged with second surface 220 facing upward toward a foot of the wearer is shown in Fig. 15B. In this way, protuberances 224 face toward a wearer's foot. First surface 210 is arranged facing downward toward top surface 262 of midsole 250. First surface 210 is substantially flat and rests against top surface 262 of midsole 250 with recesses 264 remaining empty or unfilled.

**[0143]** In some embodiments, inner sole 300 may have one or more layers. As shown in Fig. 16, inner sole 300 has at least a first sole layer 320 and a second sole layer 330. First sole layer 320 may include a foam material. Second sole layer 330 may include a textile material. Inner sole 300 may include protuberances, recesses or holes 324 formed in first sole layer 320, such as to provide a proprioceptive effect. As shown in Fig. 16A, first sole layer 320 includes a plurality of holes 324 formed therein. Holes 324 may extend fully through first sole layer 320 from a first surface 322 to an opposing second surface. As shown in Fig. 16A, first holes 324 may be arranged in toe region 302, such as at a medial side 307 of toe region 302. Toe region 302 may further include an untextured area 326 with no holes. Untextured area 326 may be arranged on a lateral side 309 of toe region 302. No holes are arranged in midfoot region 304, such that midfoot region 304 has an untextured area 326. Second holes

324 are arranged in heel region 306.

**[0144]** Second sole layer 330 may be arranged on a second surface of first sole layer 320. Second sole layer 330 may fully or partially cover second surface of first sole layer 320. Second sole layer 330 may include no protuberances, holes or recesses. Second sole layer 330 may cover holes 324 as shown in Fig. 16B. Second sole layer 330 may be thin so that a wearer can feel holes 324 on their foot when footwear including inner sole 300 is worn. Second sole layer 330 may cover holes 324 to prevent dirt and debris from entering holes 324. Second sole layer 330 may also serve to provide additional comfort, absorb moisture, and/or reduce slippage between the wearer's foot and inner sole 300.

**[0145]** As shown for example in Fig. 17, first sole layer 320 includes a plurality of holes 324 extending from first surface 322 to an opposing second surface 328. Second sole layer 330 is arranged on second surface 328. Second sole layer 330 does not include holes and covers holes 324 of first sole layer 320. Second sole layer 330 is sufficiently thin so that a wearer's foot may feel holes 324 in first sole layer 320 through second sole layer 330.

**[0146]** First sole layer 320 may be formed by molding a foam material, such as EVA, among other materials. Second sole layer 330 of a textile material is separately manufactured and is attached to a surface of first sole layer 320, such as second surface 328. Second sole layer 330 may be secured to first sole layer 320 by any of various means, including by glue or adhesives, among other fasteners and fastening methods known in the art. While first and second layers are shown, it is understood that additional layers may be present, such as multiple textile layers, and/or multiple foam layers. Further, sole layers may include additional components therein, such as a stiffening rod or plate, among others.

**[0147]** In some embodiments, midsole or footwear may include a sole having integrally formed protrusions, recesses or holes. In such embodiments, footwear may include sandals or slides. Slides may include a sole and an upper. Upper may include one or more straps configured to overlay or wrap around a portion of a wearer's foot to help secure slide to the wearer's foot. Sole may include a top surface having one or more protuberances, recesses or holes integrally formed therewith. Thus, sole and protuberances may be integrally formed, such as by molding the sole and protuberances as one-piece. This helps to simplify manufacturing. A user may wear the slides during training or in advance of a game or match and may switch to different footwear, such as a cleat or sneaker, for use during the game or match.

**[0148]** An inner sole 500 is shown according to some embodiments in Figs. 18A-C. Inner sole 500 may include a first surface 510 opposite a second surface 520, wherein the first surface 510 has protuberances, recesses or holes for contact with a foot of a wearer to provide a proprioceptive effect. Inner sole 500 includes first protuberances 514a extending along a medial side 507 of toe region 502 toward midfoot region 504. First protuber-

ances 514a may be arranged in an area corresponding to a wearer's big toe. A center of an area corresponding to the wearer's big toe may not include a protuberance. An untextured area may be arranged on a lateral side of toe region 502 in an area below the wearer's other toes to improve wearing comfort. Inner sole 500 includes second protuberances 514b extending along lateral side 509 of inner sole 500 from heel region 506, along midfoot region 504 and toward toe region 502 to provide a proprioceptive effect. Medial side 507 of midfoot region 504 may include an untextured area 516a. The untextured area may correspond to an arch of the wearer's foot and the untextured area may provide wearer comfort. Third protuberances 514c may be arranged in heel region 506 and on medial and lateral sides 507, 509. The protuberances may provide a proprioceptive effect. A center of heel region 506 may include an untextured area 516b. This may help to alleviate pressure on a center of wearer's heel.

**[0149]** As shown in Fig. 18B, protuberances 514 may have a rounded shape, and may have a hemispherical shape in a side cross-sectional view. Protuberances 514 may have a width or diameter D of about 3.5 mm. Protuberances 514 may have a maximum height H above first surface 510 of inner sole 500 of about 2.5 mm. In some embodiments, each protuberance 514 may have substantially the same shape and dimensions.

**[0150]** Inner sole 500 may further include one or more enlarged protuberances 518. Enlarged protuberance may be a mound. Enlarged protuberance 518 may be arranged in toe region 502 of inner sole. Enlarged protuberance 518 may enhance the connection of the wearer's foot to inner sole 500, and particularly to provide surface for a big toe of the wearer to grip. Enlarged protuberance 518 may be arranged centrally in toe region 502 and may extend between medial and lateral sides 507, 509 of inner sole 500. Enlarged protuberance 518 is shown as having a generally triangular or pyramidal shape. In other embodiments, enlarged protuberance 518 may have alternate shapes, such as an oval or circular shape, among others. Enlarged protuberance 518 may have a maximum height H of about 3.5 mm as measured from first surface 510 to peak 519 in a direction perpendicular to first surface 510, as shown in Fig. 18C. Enlarged protuberance 518 may slope downwardly from a peak 519 having maximum height H toward medial and lateral sides 507, 509, and may also slope downwardly toward a tip of toe region 502. Peak 519 may be arranged approximately centrally on toe region 502 between medial and lateral sides 507, 509.

**[0151]** An inner sole 600 according to an embodiment is shown in Fig. 19. Inner sole 600 includes one or more regions with protuberances to provide a proprioceptive effect and a one or more regions with an untextured area for comfort. Inner sole 600 includes first protuberances 614a of a first size arranged throughout toe region 602 and extending between medial side 607 and lateral side 609. Toe region 602 includes an untextured area 616a on lateral side 609 thereof. This area may correspond to the

second through fifth toes of the wearer, such that a protuberance 614 is arranged below the big toe, but not below the other toes of the wearer when the inner sole 600 is in use. This may provide a proprioceptive effect while retaining wearing comfort. In some embodiments, first protuberances 614a may decrease in size toward untextured area 616a so as to provide a gradual transition between area with protuberances and untextured area. Midfoot region 604 may include a plurality of apertures 614d arranged centrally in midfoot region 604. Second protuberances 614b having a second size may be arranged on lateral side 609 of midfoot region 604. Second protuberances 614b may have a smaller size than first protuberances 614a and may have a smaller diameter, smaller height, or both. First and second protuberances 614a, 614b are shown as each having a circular shape in a top-down view. However, in alternate embodiments, first and second protuberances 614a, 614b may differ in shape. In some embodiments, first protuberances 614a may gradually decrease in size toward midfoot region 604. Heel region 606 may include third protuberances 614c. Third protuberances 614c may extend throughout heel region 606 from medial side 607 to lateral side 609. Third protuberances 614c may have a third size. Third size may be the same as the first size. In some embodiments, third protuberances 614c may decrease in size toward midfoot region 604.

**[0152]** In some embodiments, protuberances as described herein may be formed by a liquid polymer application process as disclosed for example in U.S. Patent Application No. 18/806,358. A liquid polymer application process can be used to form a three-dimensional structure, such as a protuberance, e.g., a pyramid or column. The protuberances formed by liquid polymer application process may create additional grip and may help to minimize differences in grip between wet and dry conditions such that grip is maintained even in wet conditions.

**[0153]** The liquid polymer application process may include providing a polymer, providing a solvent, and mixing the polymer with the solvent to produce a liquefied polymer.

**[0154]** In some embodiments, the polymer used in the liquid polymer application process may be an elastomer or thermoplastic elastomer. The polymer may be selected from the group of polyurethanes (PU), thermoplastic polyamides (TPE-A or TPA), thermoplastic polyesters (TPE-E or TPE), thermoplastic styrenic block copolymers (TPE-S or TPS), thermoplastic polyurethanes (TPE-U or TPU), thermoplastic vulcanizates (TPE-V or TPV), rubber or ethylene-vinyl copolymer (EVA), thermoplastic polyurethanes (TPE-U or TPU), and/or combinations thereof.

**[0155]** In some embodiments, the solvent used in the liquid polymer application process is a mixture selected from the group of solvent-borne and/or water-borne solvents. A solvent may be selected from the group of solvent-borne solvents, or from the group of (C<sub>1</sub>-C<sub>6</sub>) ethers, (C<sub>1</sub>-C<sub>10</sub>) esters, (C<sub>1</sub>-C<sub>8</sub>) ketones, (C<sub>1</sub>-C<sub>8</sub>) al-



kanes, and/or combinations thereof. The solvent may be a mixture of one or more of tetrahydrofuran (THF), methyl ethyl ketone (MEK), cyclohexane (CYC), ethyl acetate, butyl acetate, THF and/or CYC.

**[0156]** The liquefied polymer is deposited in a desired location or locations, such as on a surface of a sole. The liquefied polymer may be deposited by brushing, coating, dipping, painting, automated dispensing, automated printing, controlled dispensing.

**[0157]** After the liquefied polymer is deposited at the desired location, the liquefied polymer may be textured or structured to provide the desired shape or pattern. The liquefied polymer can then be cured to form the protuberances on the sole. The curing step may be carried out using radiation, such as infrared radiation (IR). In this way, the liquefied component which is deposited on the second component is cured on the second component while at the same time removing the solvent and drying the deposited liquefied component.

**[0158]** The liquid polymer application process may be advantageous relative to forming protuberances by injection molding, which requires specially-constructed molds and may require removing or cutting excess material after molding. Further, the liquid polymer application process allows for the protuberances to be more precisely placed on the sole and without the use of glue or adhesives.

**[0159]** Embodiments described herein relate to an inner sole for a sports shoe that includes a top surface arranged to face a foot of a wearer of a shoe when the inner sole is arranged in the shoe. The top surface includes at least two textured areas, wherein the textured areas each include a plurality of protuberances, recesses or holes. The top surface includes at least one untextured area not having protuberances, recesses or holes. A first textured area is located in a toe region of the inner sole and a second textured area is located in a heel region of the inner sole. The inner sole may be removably securable to the article of footwear. A second or bottom surface of the inner sole may be untextured and may have no protuberances, recesses or holes. The inner sole may be positioned with the top or bottom surface facing upward toward the wearer's foot. A midsole of the article of footwear may include mating elements, for example recesses, for receiving protuberances of the inner sole. The protuberances may be formed on the top surface via a liquid polymer application process. The protuberances may be integrally formed with the top surface of the inner sole, such as by an additive manufacturing method or by an injection molding method. The inner sole may include a textile layer on the top surface and/or the bottom surface. The protuberances, recesses or holes may be felt by the wearer through the textile layer.

**[0160]** In any of the various embodiments described herein, the textured areas correspond to areas of a human foot having a higher density of mechanoreceptors compared to areas of the human foot corresponding to untextured areas of the inner sole.

**[0161]** In any of the various embodiments described herein, the textured areas are distinct and separated by the untextured area.

**[0162]** In any of the various embodiments described herein, the hardness of the protuberances correlates with the hardness of the skin of a human foot.

**[0163]** In any of the various embodiments described herein, the untextured area is located in an area corresponding to a local maximum of a pressure distribution of pressure caused by a human foot standing on the inner sole. In some embodiments, at least one local maximum of the pressure distribution is surrounded by a textured area.

**[0164]** In any of the various embodiments described herein, the protuberances have an average diameter of 1-10mm, 2-5mm, or 3-4mm.

**[0165]** In any of the various embodiments described herein, the protuberances have an average height of 0.5-5mm, 0.75-3mm, or 1-1.5mm.

**[0166]** In any of the various embodiments described herein, the protuberances have a hardness of 40-70 Shore-A or 50-60 Shore-A.

**[0167]** In any of the various embodiments described herein, the inner sole has been manufactured by an additive manufacturing process.

**[0168]** In any of the various embodiments described herein, the inner sole is integral with an additional sole component of a shoe.

**[0169]** Some embodiments described herein relate to a method of manufacturing an inner sole as described herein, the method including the steps of providing a base layer, and one or both of: molding protuberances to the base layer to form textured and untextured areas, and forming recesses or holes in the base layer to form the textured and untextured areas. In the following, further inventive embodiments are described:

Embodiment 1: An article of footwear, comprising:

an inner sole comprising a first surface opposite a second surface, wherein the first surface comprises an untextured area, and wherein a plurality of protuberances are arranged on the second surface; and

a midsole comprising a top surface having a plurality of mating elements, wherein the inner sole is removably securable to the midsole, and wherein when the second surface of the inner sole is arranged facing the top surface of the midsole, the plurality of protuberances are engaged by the plurality of mating elements and the second surface of the inner sole is in facing engagement with the top surface of the midsole.

Embodiment 2: The article of footwear of embodiment 1, wherein the plurality of mating elements comprise a plurality of recesses.

Embodiment 3: The article of footwear of embodiments 1 or 2, wherein the plurality of mating elements are arranged in a pattern corresponding to a pattern of the plurality of protuberances.

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Embodiment 4: The article of footwear of any one of the preceding embodiments, wherein the first surface comprises no protuberances.

Embodiment 5: The article of footwear of any one of the preceding embodiments, wherein the second surface comprises the protuberances arranged in a first region and no protuberances arranged in a second region.

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Embodiment 6: The article of footwear of any one of the preceding embodiments, wherein a toe region comprises first protuberances, a heel region comprises second protuberances, and the midfoot region comprises an untextured area with no protuberances.

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Embodiment 7: The article of footwear of any one of the preceding embodiments, wherein the midsole comprises a foam material.

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Embodiment 8: The article of footwear of any one of the preceding embodiments, the plurality of protuberances are formed by a liquid polymer application process.

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Embodiment 9: The article of footwear of any one of the preceding embodiments, wherein the plurality of protuberances are integrally formed with the inner sole.

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Embodiment 10: A sole assembly for an article of footwear, comprising:

a first sole layer comprising a first surface opposite a second surface,  
a plurality of holes extending through the first sole layer from the first surface to the second surface in one or more regions of the first sole layer and configured to provide a proprioceptive effect; and  
a second sole layer coupled to the second surface, wherein the second sole layer comprises no holes and is configured to be placed in contact with a foot of a wearer.

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Embodiment 11: The sole assembly of embodiment 10, wherein the first sole layer comprises a foam material.

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Embodiment 12: The sole assembly of embodiment 10 or 11, wherein the second sole layer comprises a textile material.

Embodiment 13: The sole assembly of any one of the preceding embodiments 10 to 12, wherein first holes of the plurality of holes are arranged in a toe region, and wherein second holes of the plurality of holes are arranged in a heel region.

Embodiment 14: The sole assembly of embodiment 13, wherein an untextured area is arranged in a midfoot region of the first sole layer.

Embodiment 15: A sole for an article of footwear, comprising:

an inner sole having a top surface, a toe region, a midfoot region, and a heel region and configured to support a foot of a wearer;  
first protuberances arranged at a toe region of the inner sole;  
second protuberances arranged along a lateral side of a midfoot region of the inner sole;  
third protuberances arranged on a heel region of the inner sole; and  
a first untextured area with no protuberances arranged at a medial side of the midfoot region.

Embodiment 16: The sole of embodiment 15, further comprising holes extending through the midfoot region.

Embodiment 17: The sole of embodiment 15 or 16, wherein the second protuberances have a size that is smaller than a size of the first protuberances.

Embodiment 18: The sole of any one of the preceding embodiments 15 to 17, further comprising a second untextured area at a center of the heel region.

Embodiment 19: The sole of any one of the preceding embodiments 15 to 18, further comprising a second untextured area at a lateral side of the toe region.

Embodiment 20: The sole of any one of the preceding embodiments 15 to 19, further comprising an enlarged protuberance arranged at the toe region, wherein the enlarged protuberance comprises a generally triangular shape.

#### List of Reference Numbers

#### [0170]

1	inner sole
2	top surface
3a-e	textured areas
4a	protuberances
4b	holes

5, 5a-b untextured areas  
 6 tip of protuberance  
 7 height of protuberance  
 8 length of protuberance  
 9 width of protuberance  
 10 textile layer  
 11 foam layer  
  
 20 sole component  
 30 upper  
 61 arches  
 62 arch area  
 63 heel area  
 80 shoe  
 81 sole structure  
 100 method of manufacturing an inner sole  
 110 cutting step  
 120 cold pressing step  
 130 trimming step  
 140 pouring step  
 150 molding step  
 160 trimming step  
 170 attaching step  
 200 inner sole  
 202 toe region  
 204 midfoot region  
 206 heel region  
 210 first surface  
 220 second surface  
 224a,b protuberance, hole or recess  
 226 untextured area  
 250 midsole  
 252 toe region  
 254 midfoot region  
 256 heel region  
 262 top surface  
 264 mating element  
 270 rim  
 300 inner sole  
 302 toe region  
 304 midfoot region  
  
 306 heel region  
 307 medial side  
 309 lateral side  
 320 first sole layer  
 324 holes  
 330 second sole layer  
 500 inner sole  
 502 toe region  
 504 midfoot region  
 506 heel region  
 507 medial side  
 509 lateral side  
 510 first surface  
 514a,b,c protuberance  
 516a,b untextured areas  
 518 enlarged protuberance

519 peak  
 520 second surface  
 600 inner sole  
 602 toe region  
 5 604 midfoot region  
 606 heel region  
 607 medial side  
 609 lateral side  
 610 top surface  
 10 614a,b,c,d protuberance, hole or recess  
 616a,b untextured area

### Claims

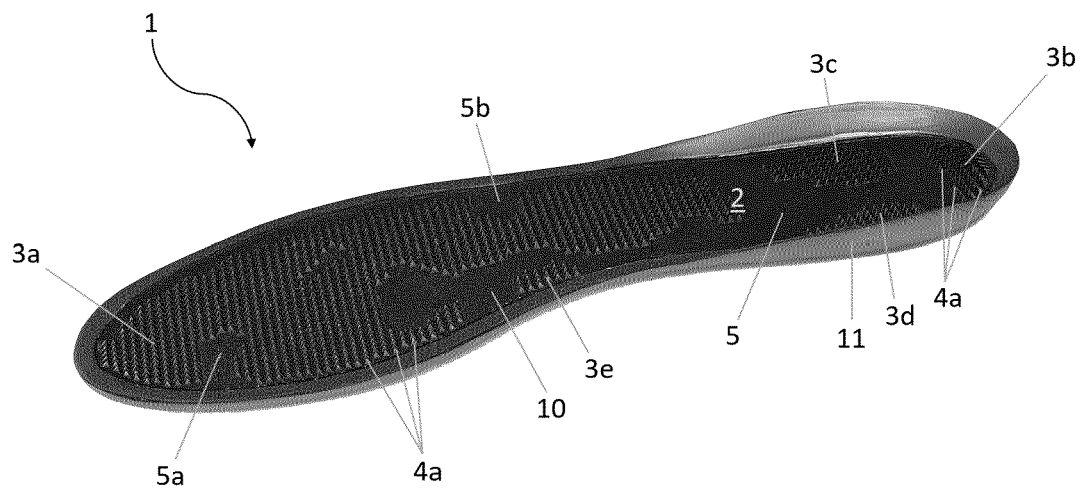
- 15 **1.** A sole for a shoe, comprising:
- 20 an inner sole (1) comprising a top surface (2) arranged to face a foot of a wearer of the shoe, when the inner sole (1) is arranged in the shoe, wherein the top surface (2) comprises a first textured area (3a) and a second textured area (3b), wherein the first and second textured areas (3a-b) each comprise a plurality of protuberances (4a), recesses or holes (4b),
- 25 wherein the top surface (2) comprises an untextured area (5, 5a-b) not comprising protuberances, recesses or holes, and wherein the first textured area (3a) is located in a toe region of the inner sole (1) and the second textured (3b) area is located in a heel region of the inner sole.
- 30
- 2.** The sole according to claim 1, wherein the second textured area (3b) is located in a rearmost portion of the heel region.
- 35
- 3.** The sole according to claim 1 or 2, further comprising a third textured (3c) area located in a lateral portion of the heel region and a fourth textured (3d) area located in a medial portion of the heel region.
- 40
- 4.** The sole according to any one of the preceding claims, wherein the untextured area (5) is located in a central portion of the heel region, wherein preferably the untextured area extends from the heel region along a medial region into a metatarsal region and does not extend into the toe region.
- 45
- 5.** The sole according to any one of the preceding claims, wherein the first textured area (3a) extends from the toe region along a lateral region in a midfoot region and ends before the heel region.
- 50
- 6.** The sole according to any one of the preceding claims, wherein the untextured area (5) is located in a big toe region.
- 55
- 7.** The sole according to any one of the preceding

claims, wherein the untextured area (5a) is located in a medial metatarsal region and is surrounded by the first textured area (3a); and/or wherein the untextured area (5b) is located at a lateral metatarsal-to-arch transition region.

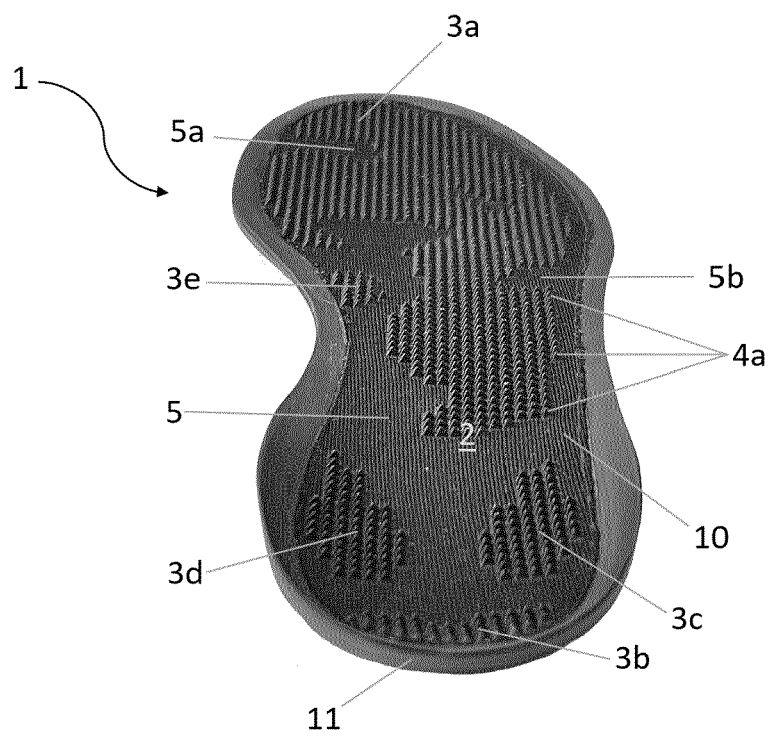
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8. The sole according to any one of the preceding claims, further comprising a fifth textured (3c) area located in a medial metatarsal-to-arch transition region. 10
9. The sole according to any one of the preceding claims, wherein a density of the plurality of protuberances, recesses or holes is higher on a lateral side of the inner sole (1) compared to a medial side of the inner sole. 15
10. The sole according to any one of the preceding claims, wherein the plurality of protuberances, recesses or holes comprises protuberances, and wherein a hardness of the protuberances varies across the inner sole (1). 20
11. The sole according to any one of the preceding claims, wherein the plurality of protuberances (4a), recesses or holes (4b) of the first or second textured areas comprises protuberances, and wherein one or more of the protuberances have a pyramidal shape, wherein preferably the one or more protuberances have a rounded tip. 25  
30
12. The sole according to any one of the preceding claims, further comprising a textile layer, wherein the plurality of protuberances (4a), recesses or holes (4b) are arranged on the textile layer, preferably further comprising a foam layer, wherein the textile layer is arranged on the foam layer. 35
13. The sole according to any one of the preceding claims, wherein the plurality of protuberances (4a), recesses or holes (4b) comprises protuberances, and wherein a height of the protuberances varies across the inner sole; and/or wherein a shape of the protuberances varies across the inner sole. 40  
45
14. A shoe comprising the sole according to any one of the preceding claims.
15. The shoe according to claim 14, further comprising a midsole, an outsole or an outsole plate, wherein the inner sole is integral with the midsole, the outsole, or the outsole plate. 50

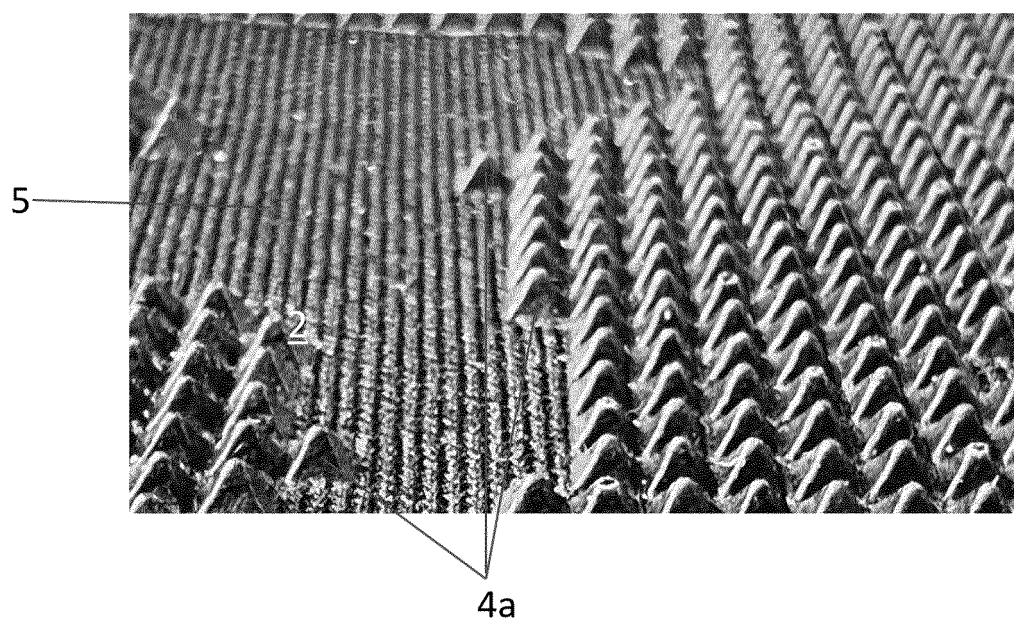
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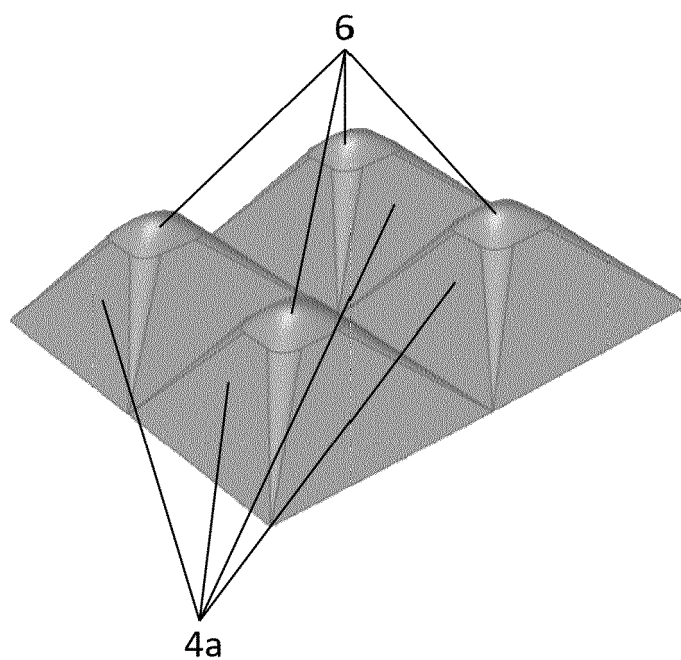
**Fig. 1A**



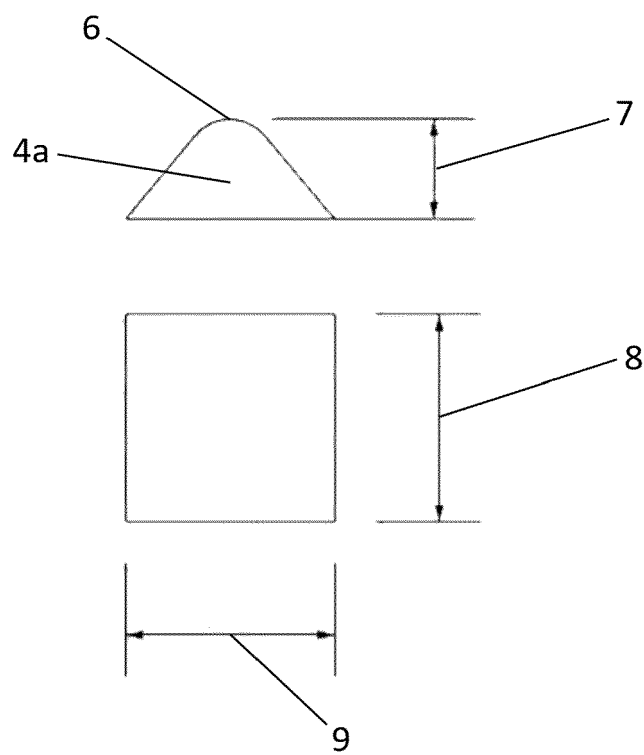
**Fig. 1B**



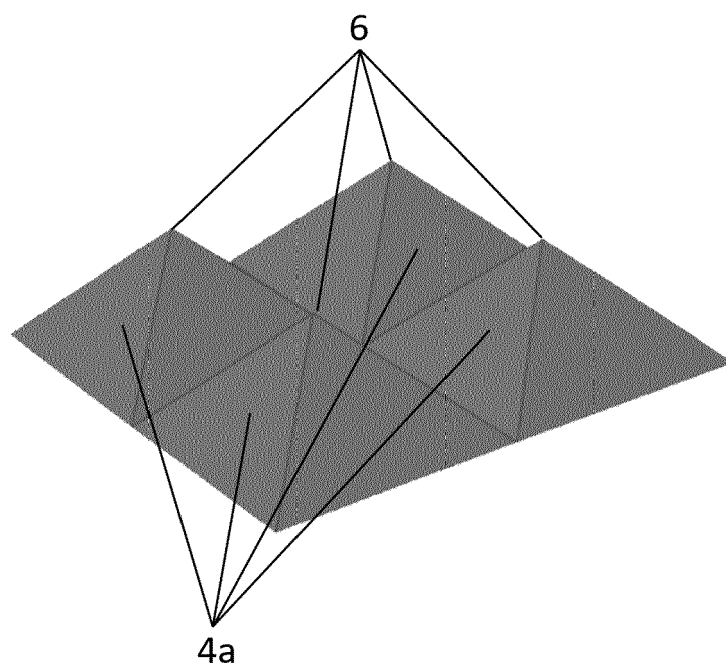
**Fig. 1C**



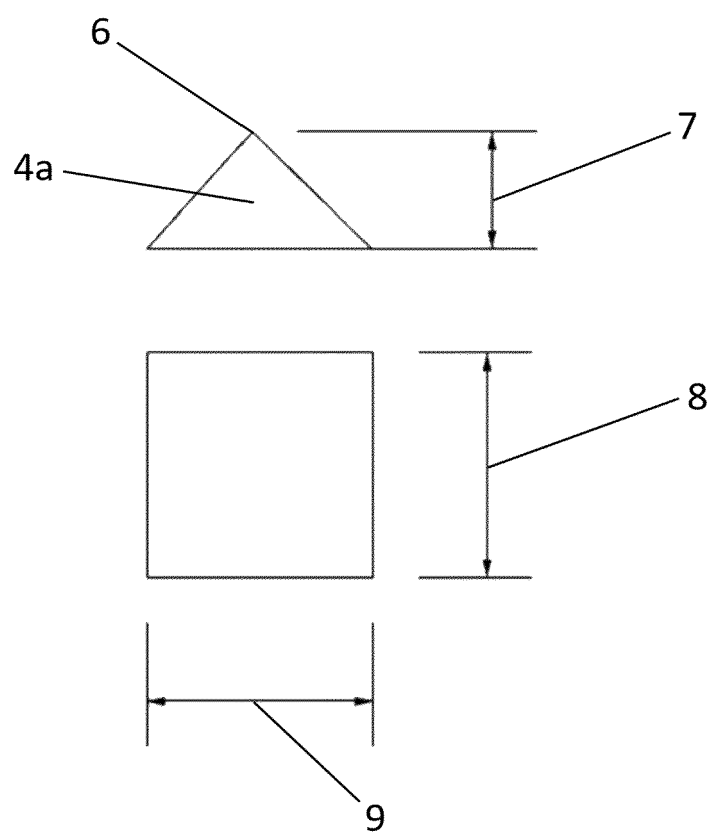
**Fig. 2A**



**Fig. 2B**

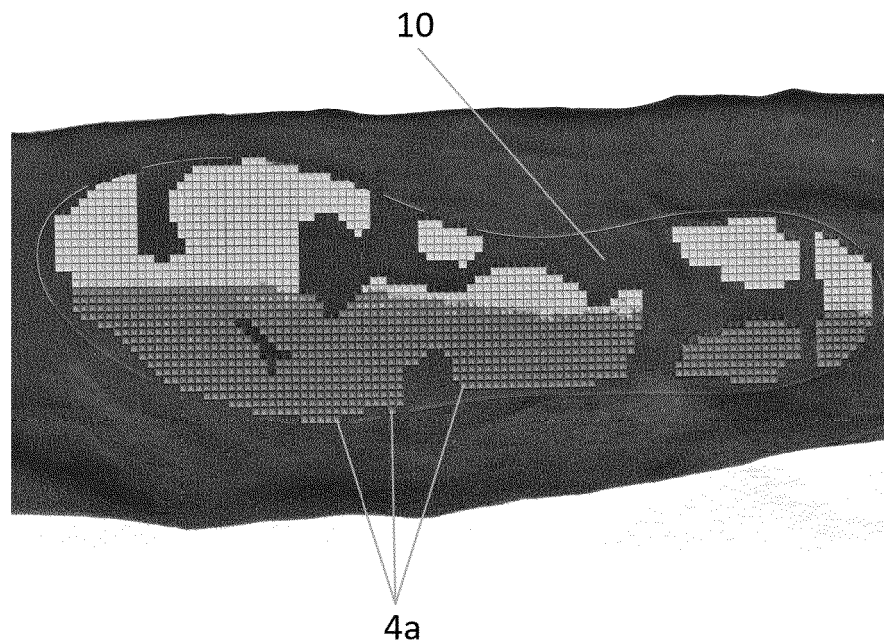


**Fig. 2C**

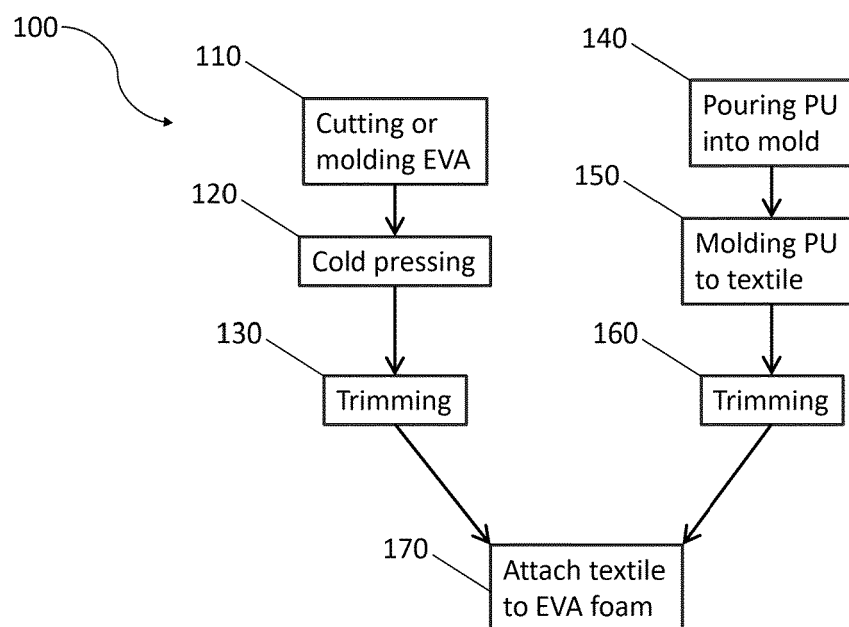


**Fig. 2D**





**Fig. 3**



**Fig. 4**

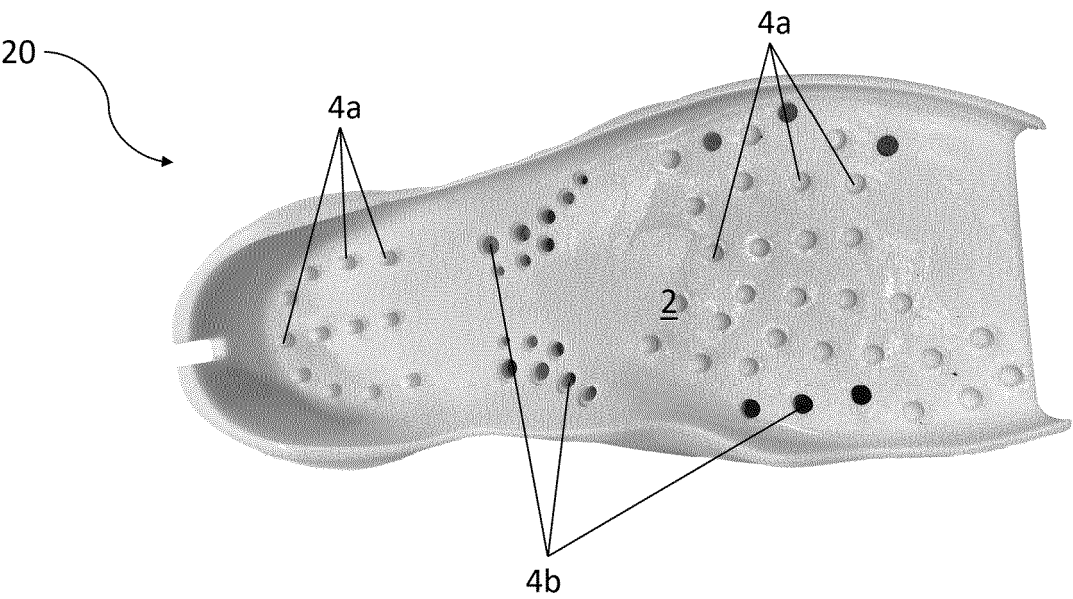


Fig. 5

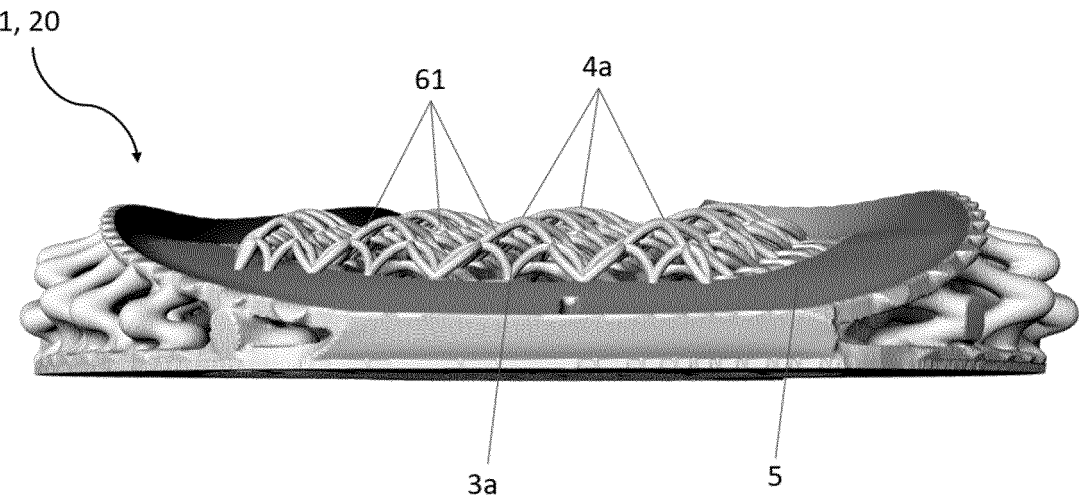


Fig. 6A

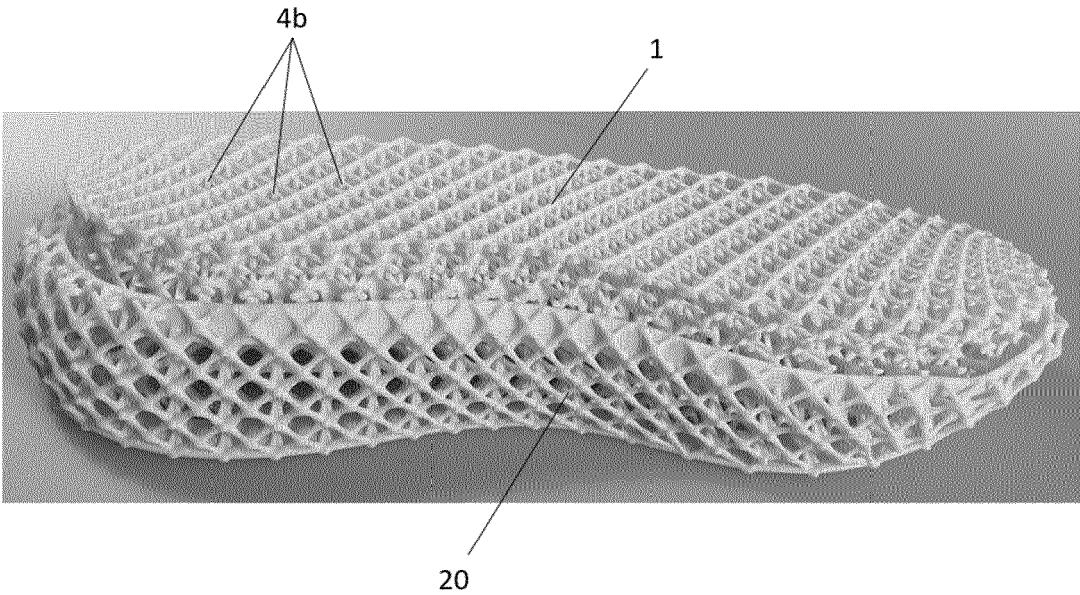


Fig. 6B

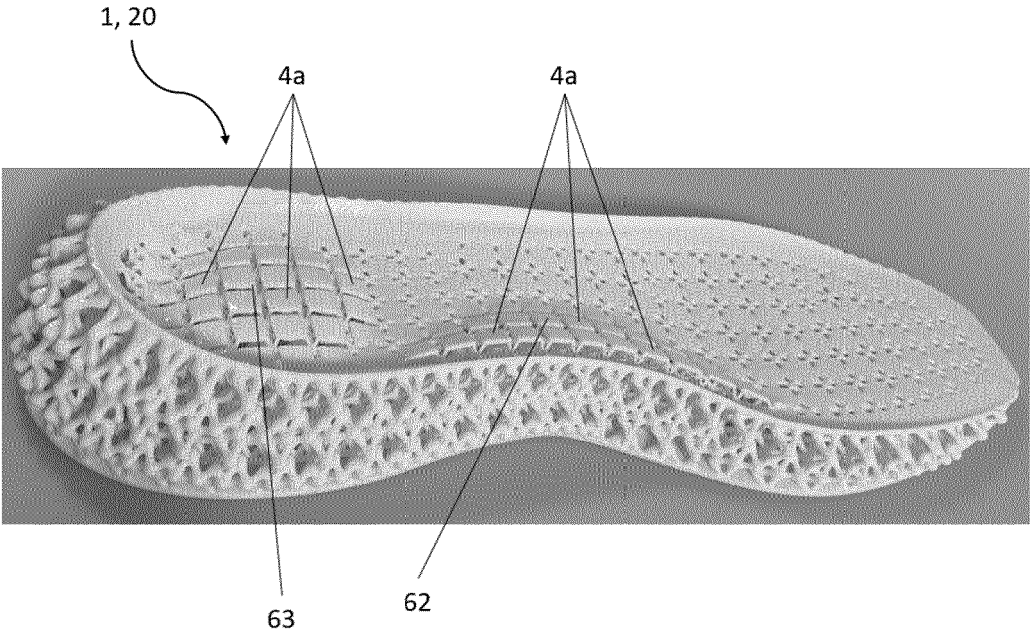


Fig. 6C

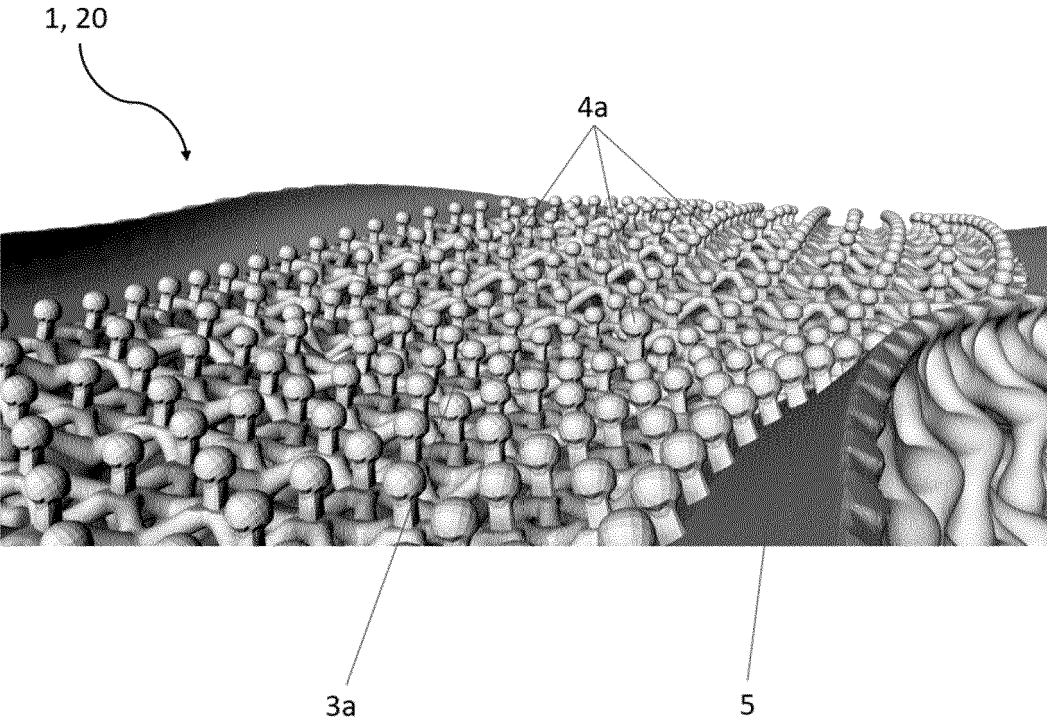


Fig. 6D

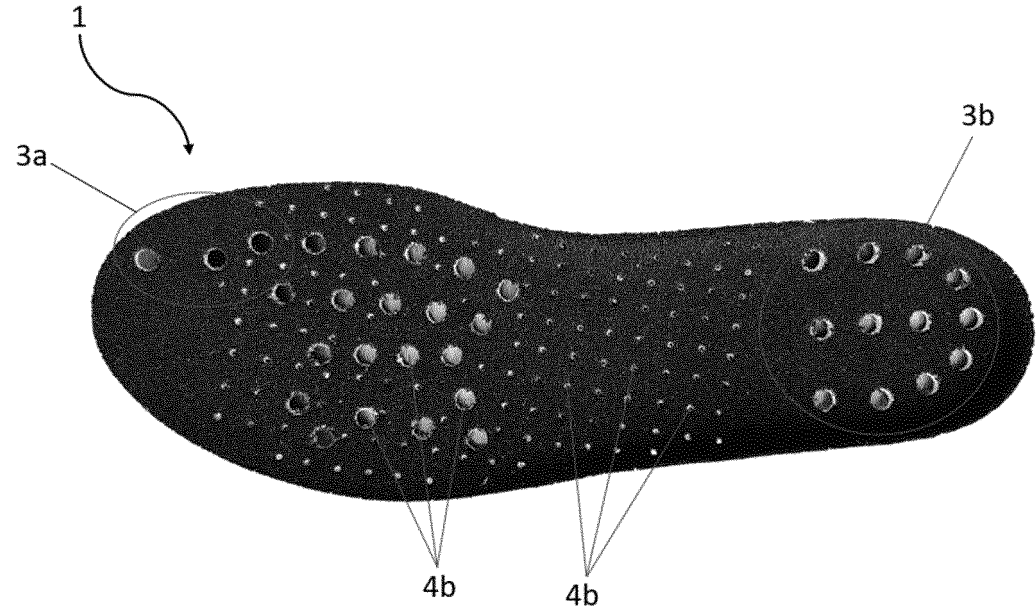


Fig. 7

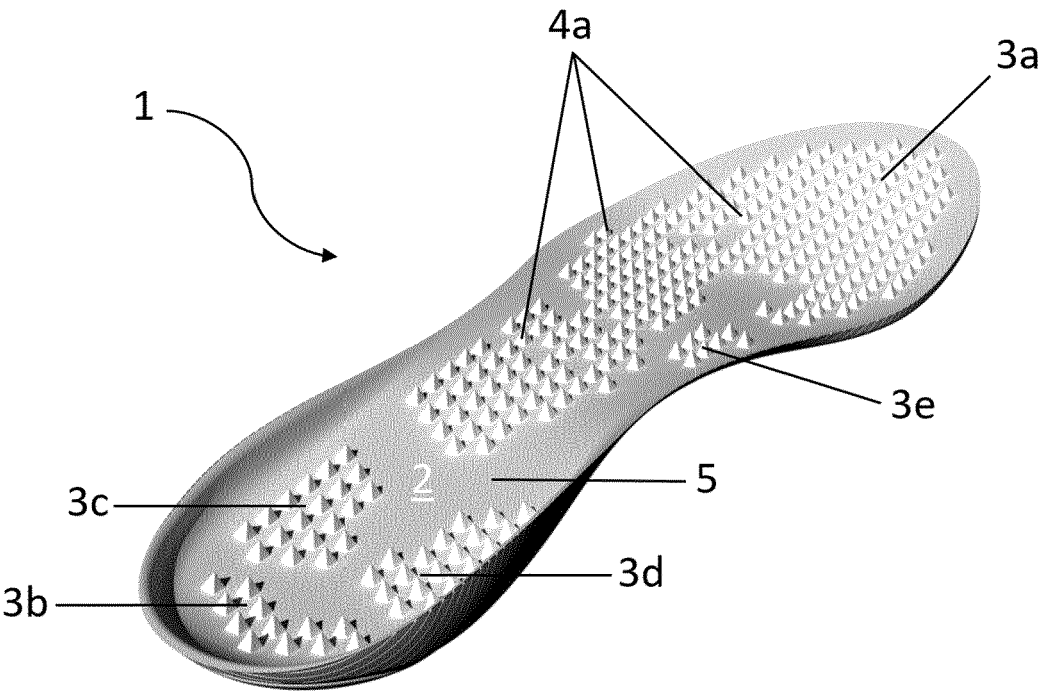


Fig. 8A

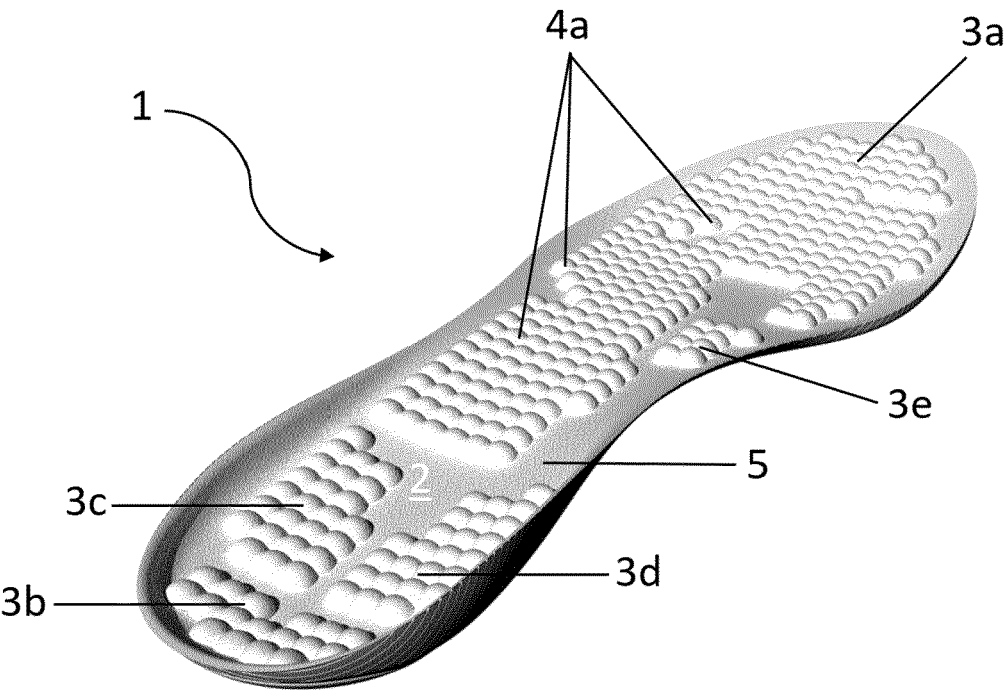


Fig. 8B

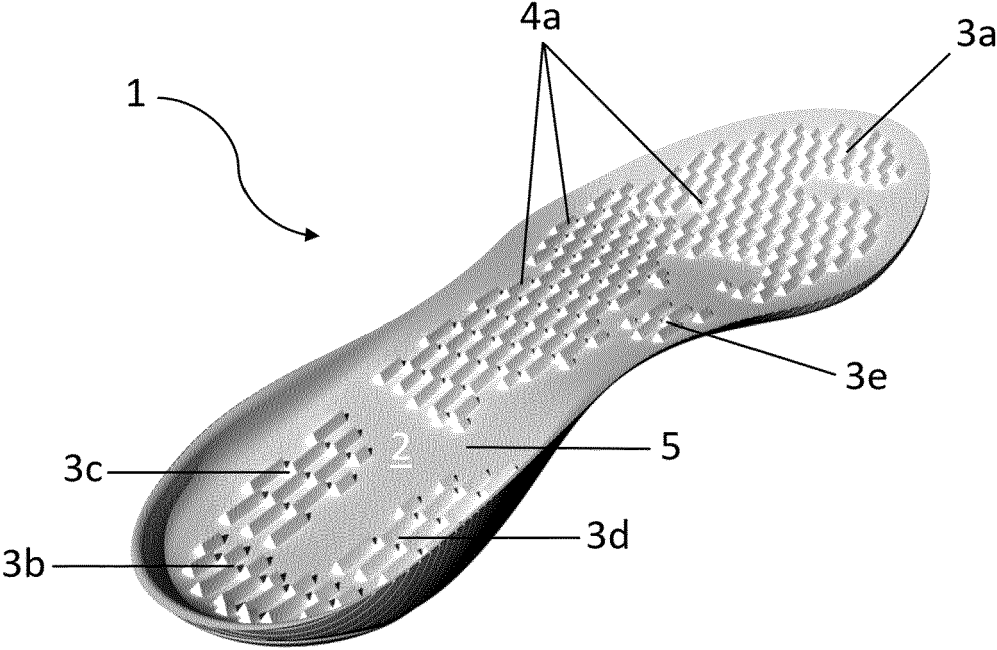


Fig. 8C

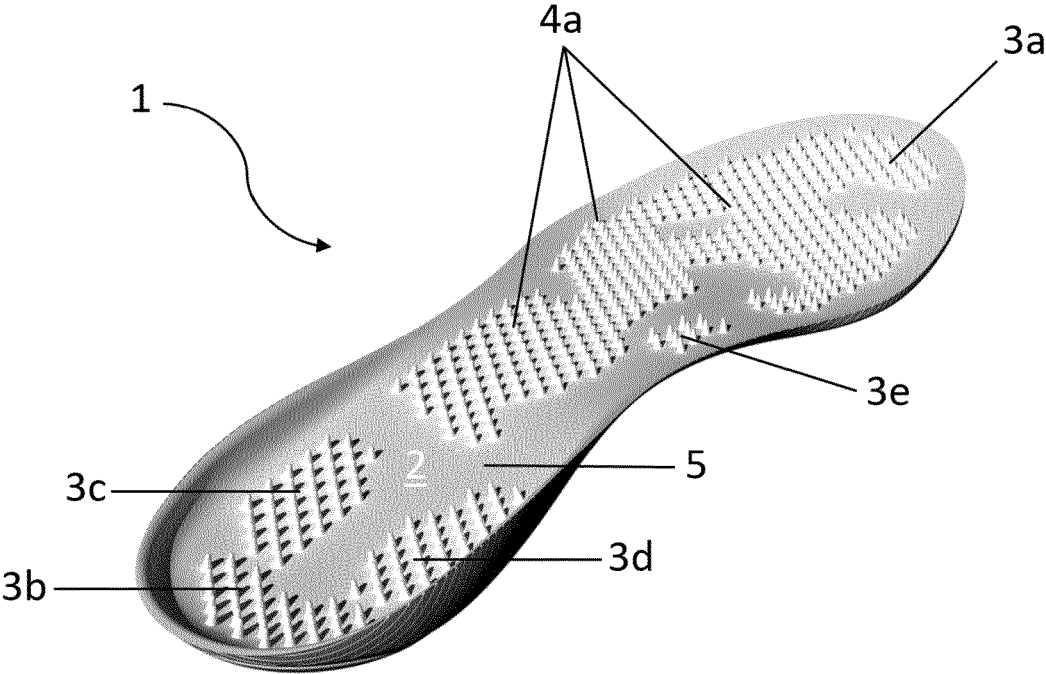


Fig. 8D

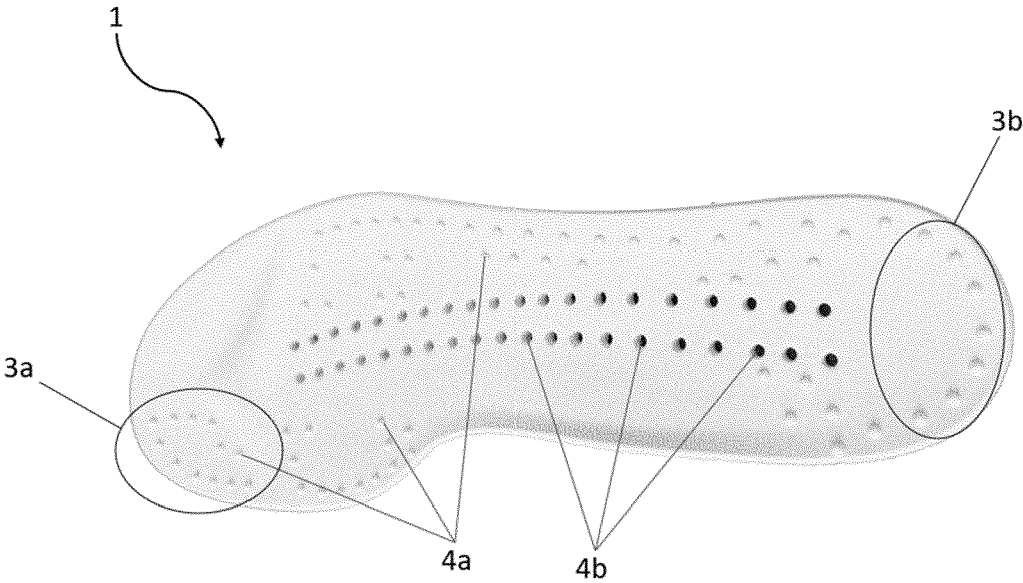


Fig. 9A

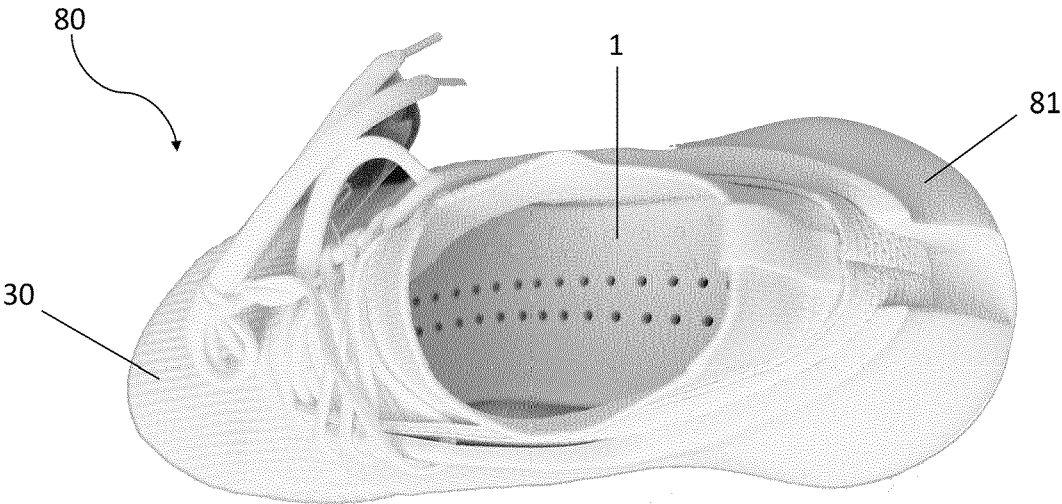
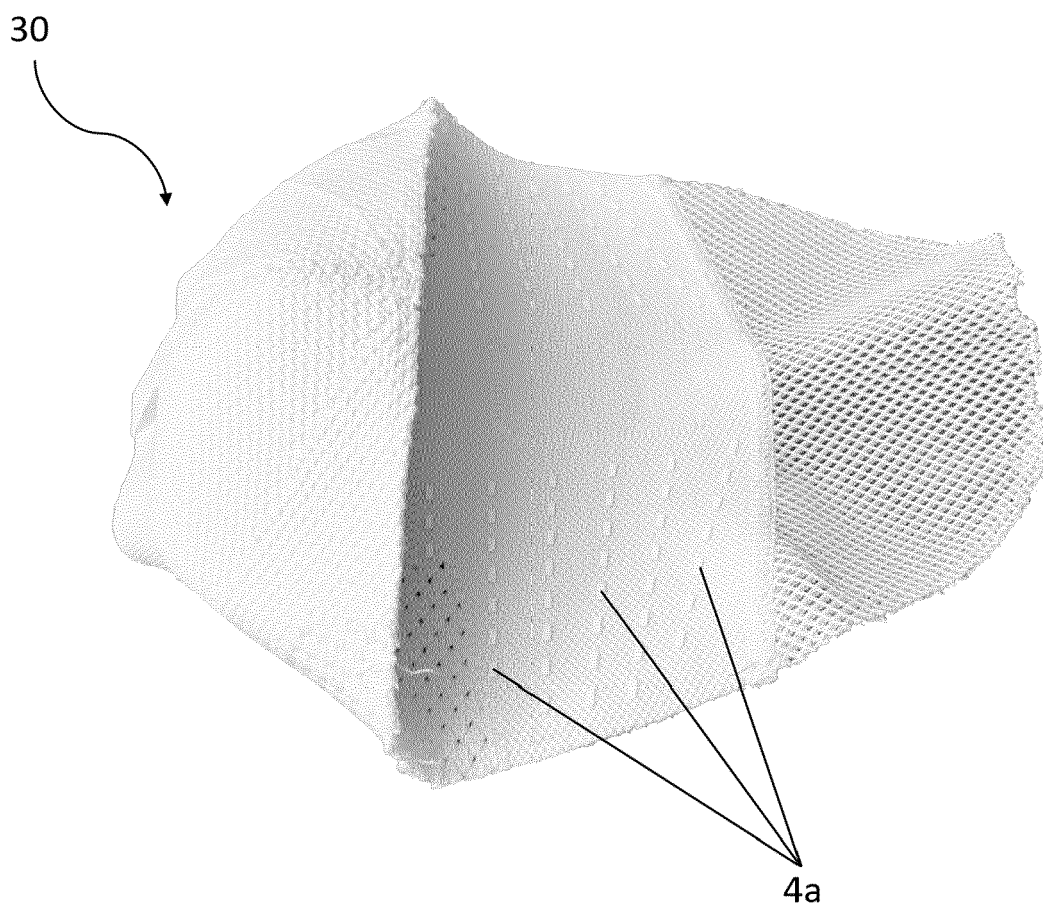


Fig. 9B



**Fig. 9C**



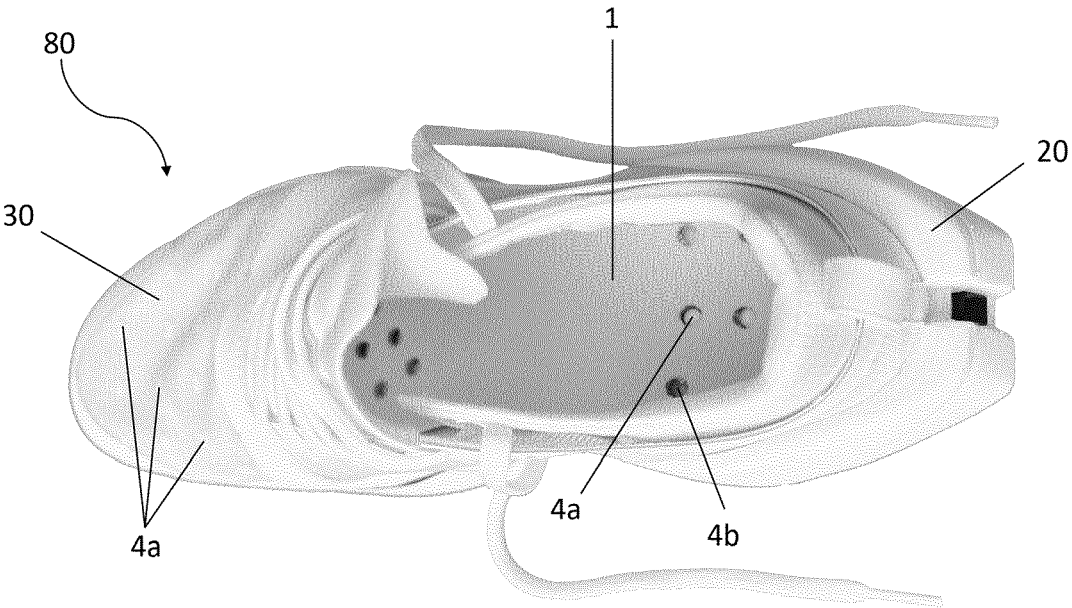


Fig. 10A

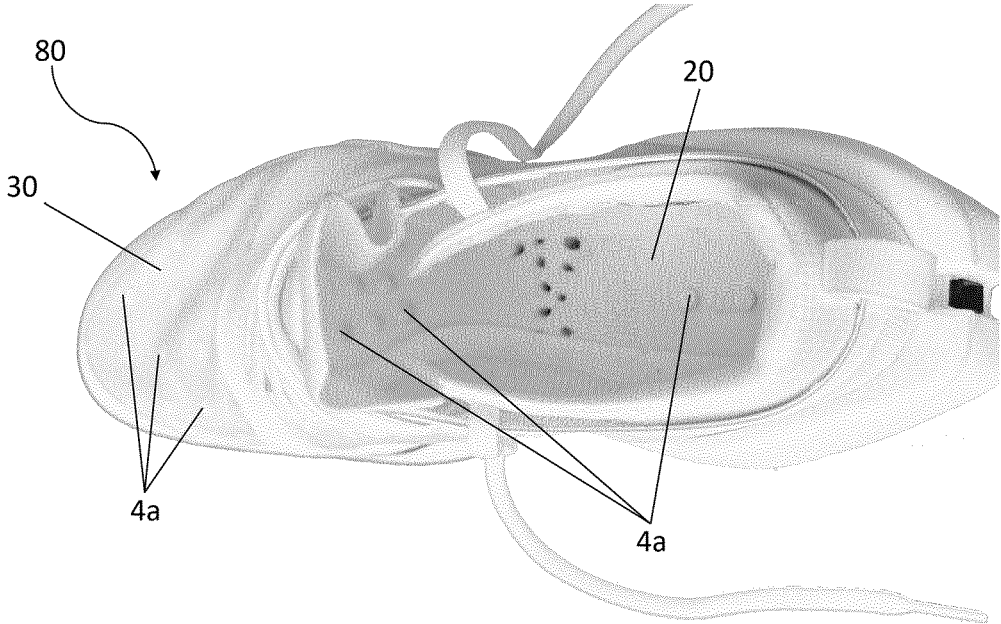
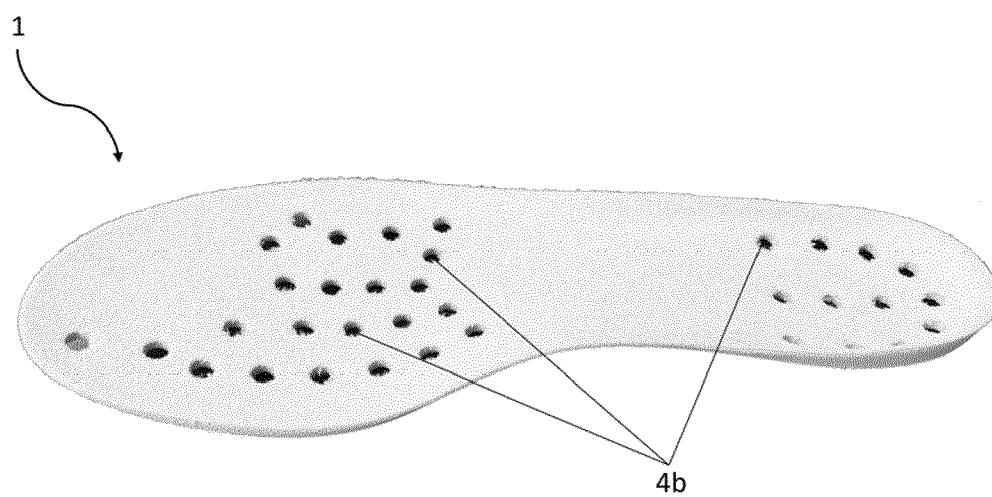
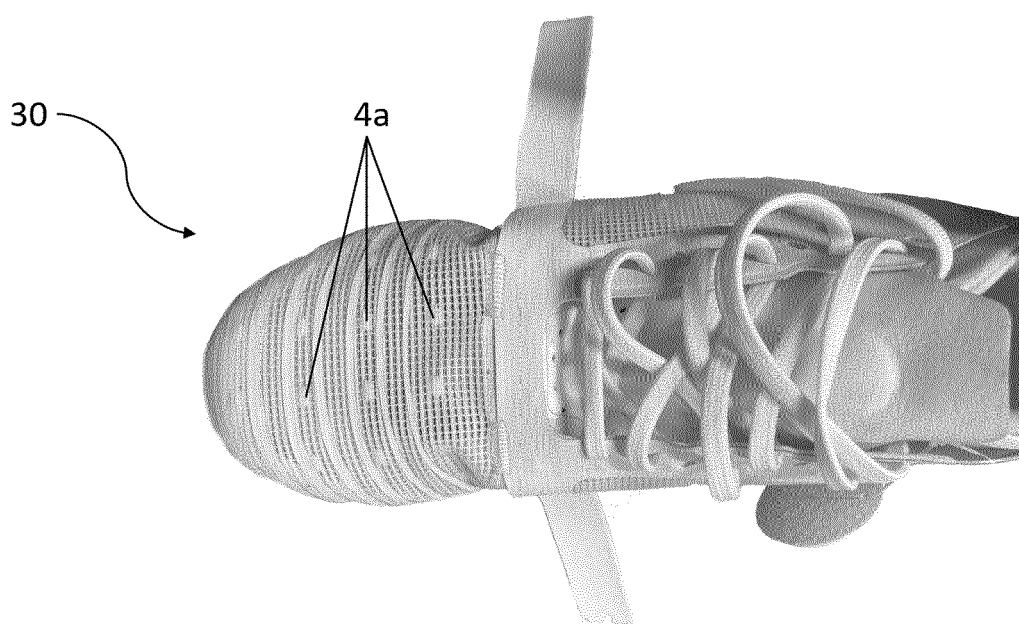


Fig. 10B



**Fig. 10C**



**Fig. 11**

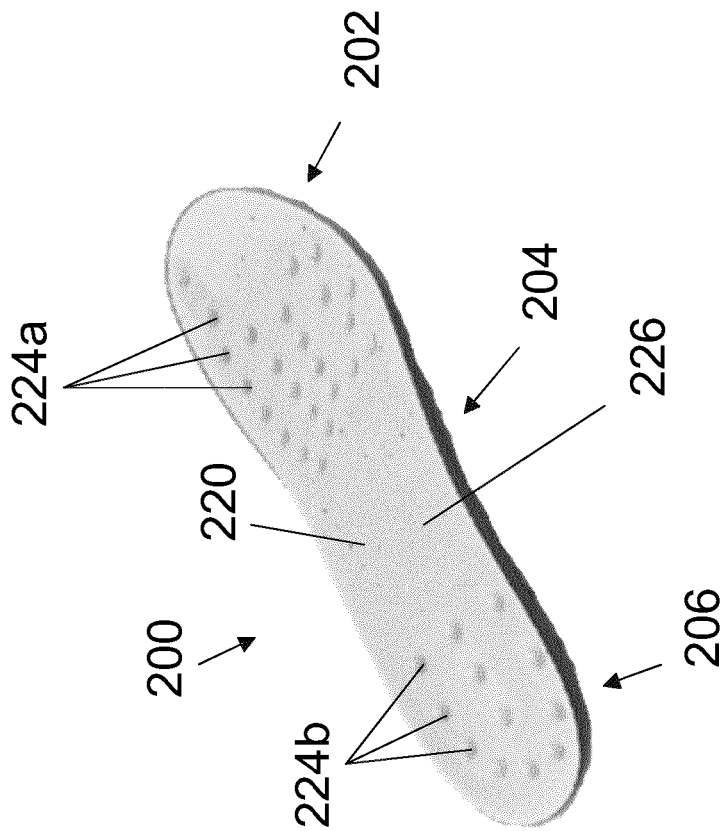


Fig. 12A

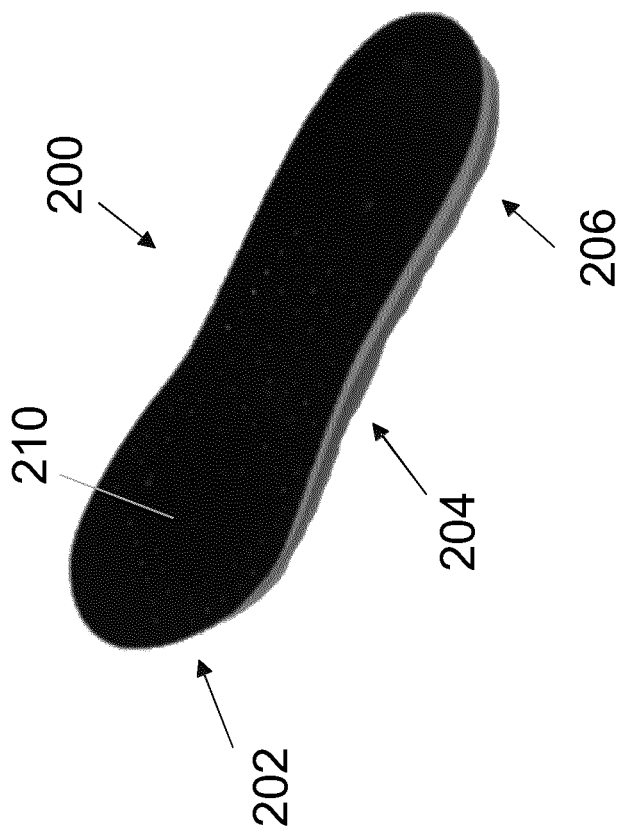


Fig. 12B

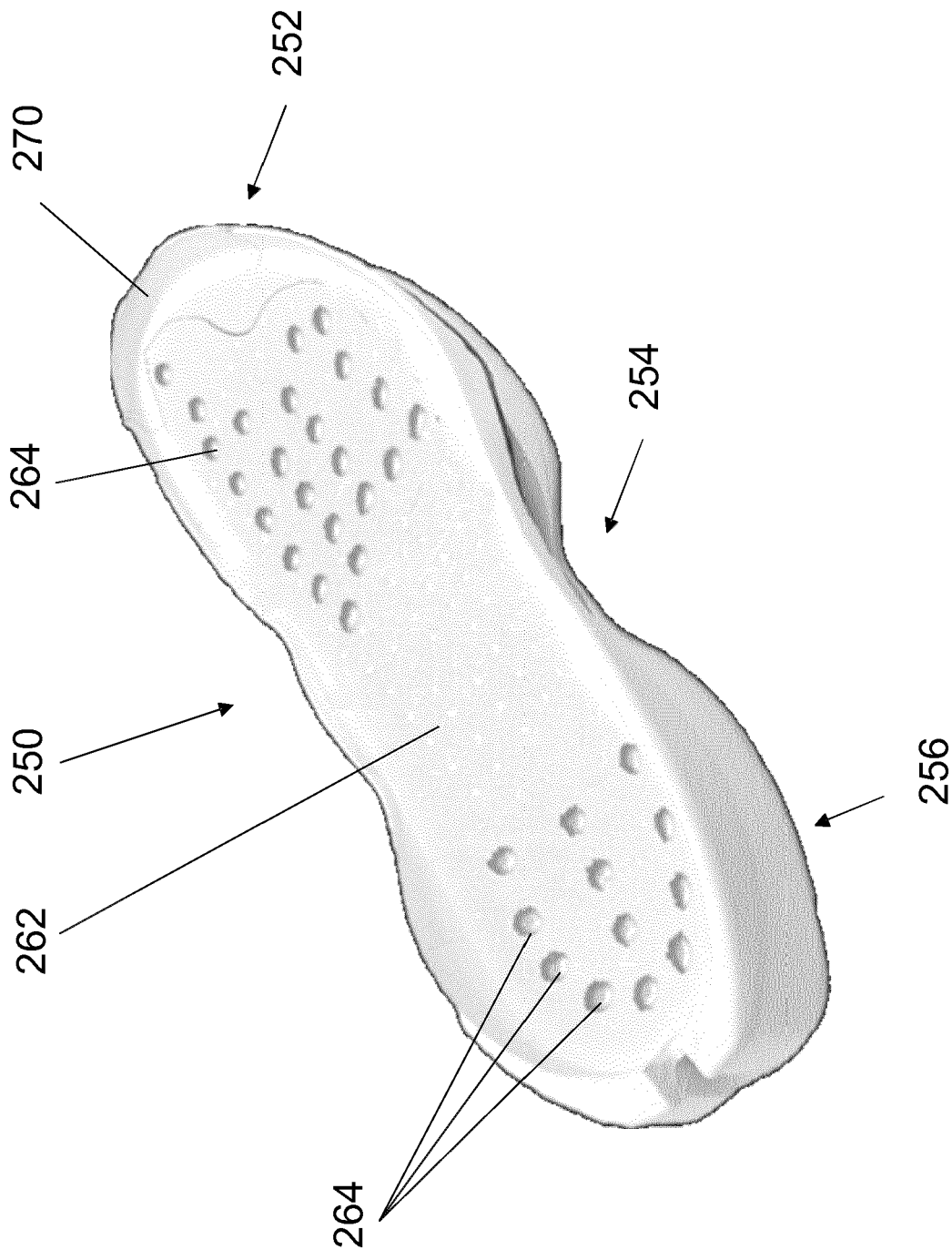


Fig. 13

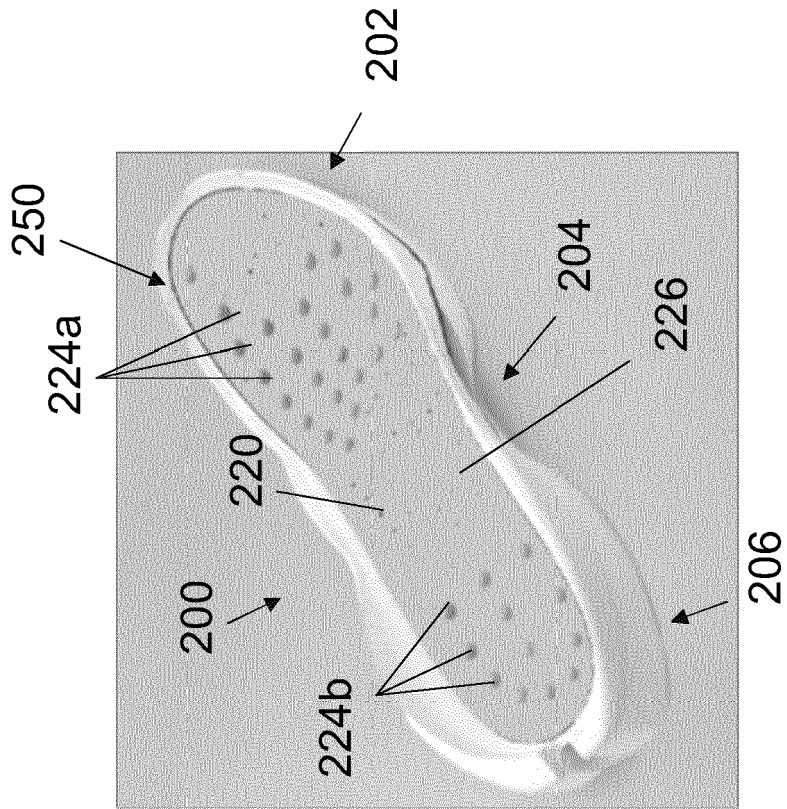


Fig. 14B

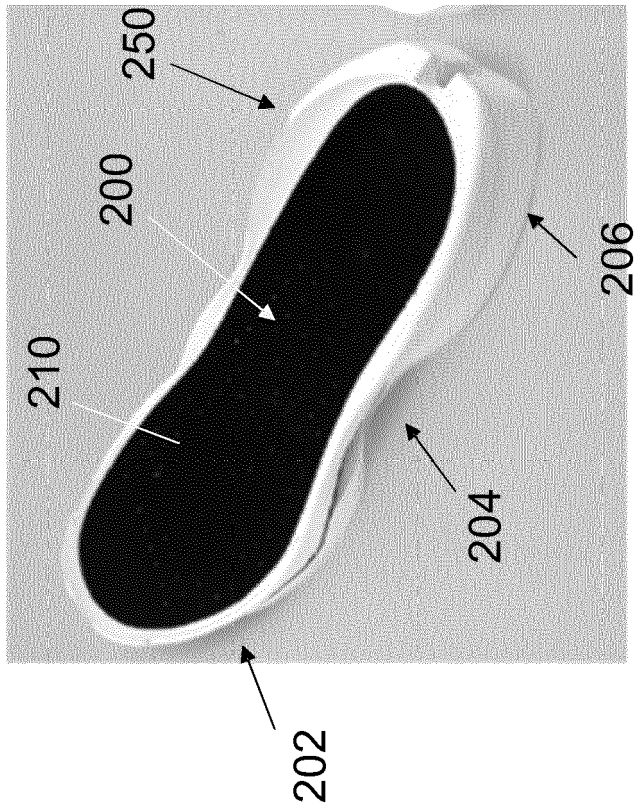


Fig. 14A

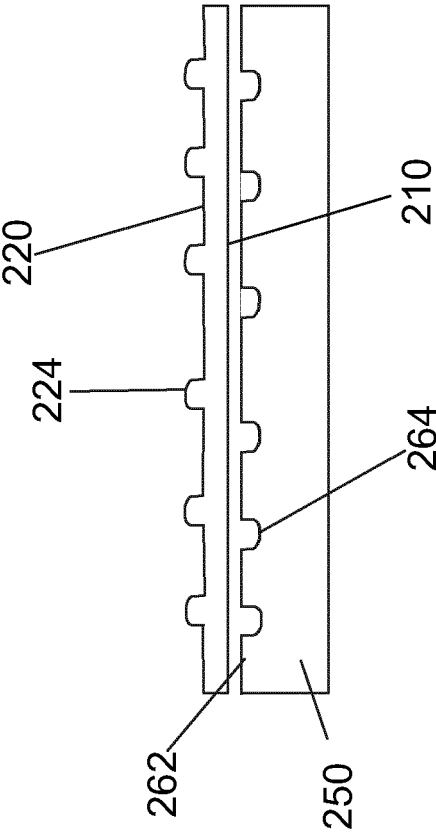


Fig. 15B

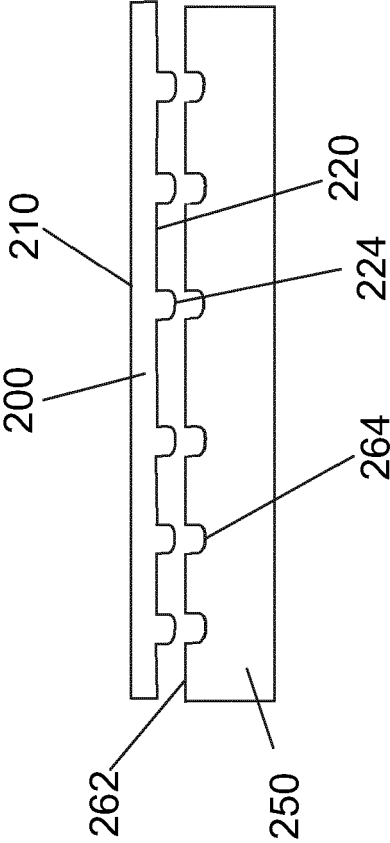


Fig. 15A

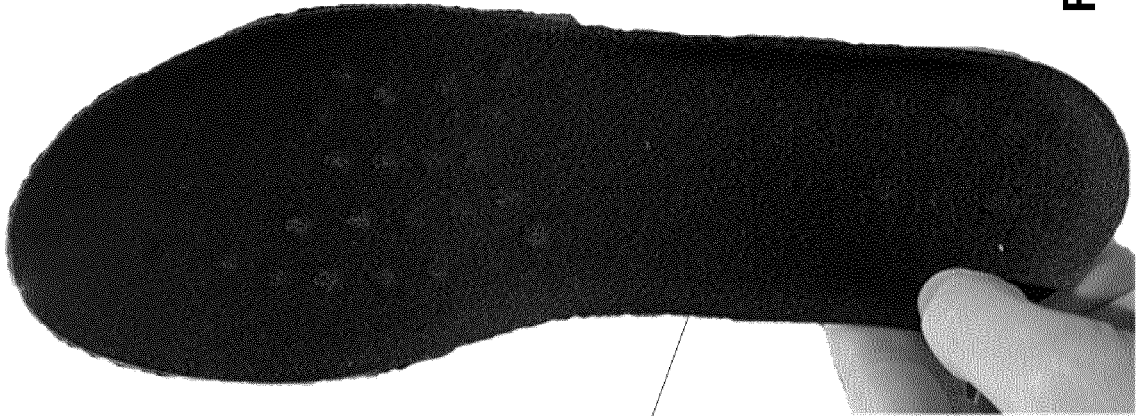


Fig. 16B

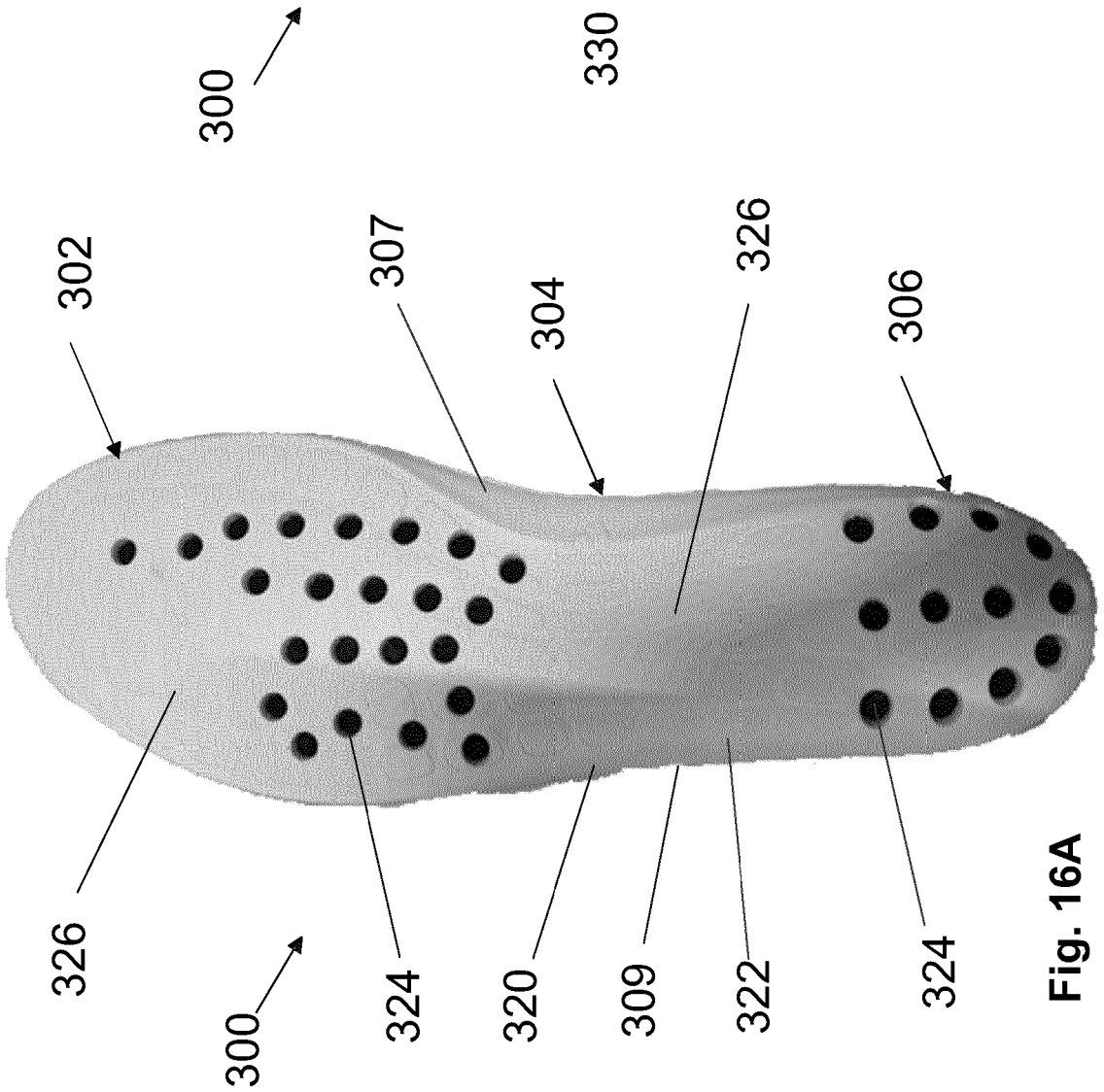


Fig. 16A



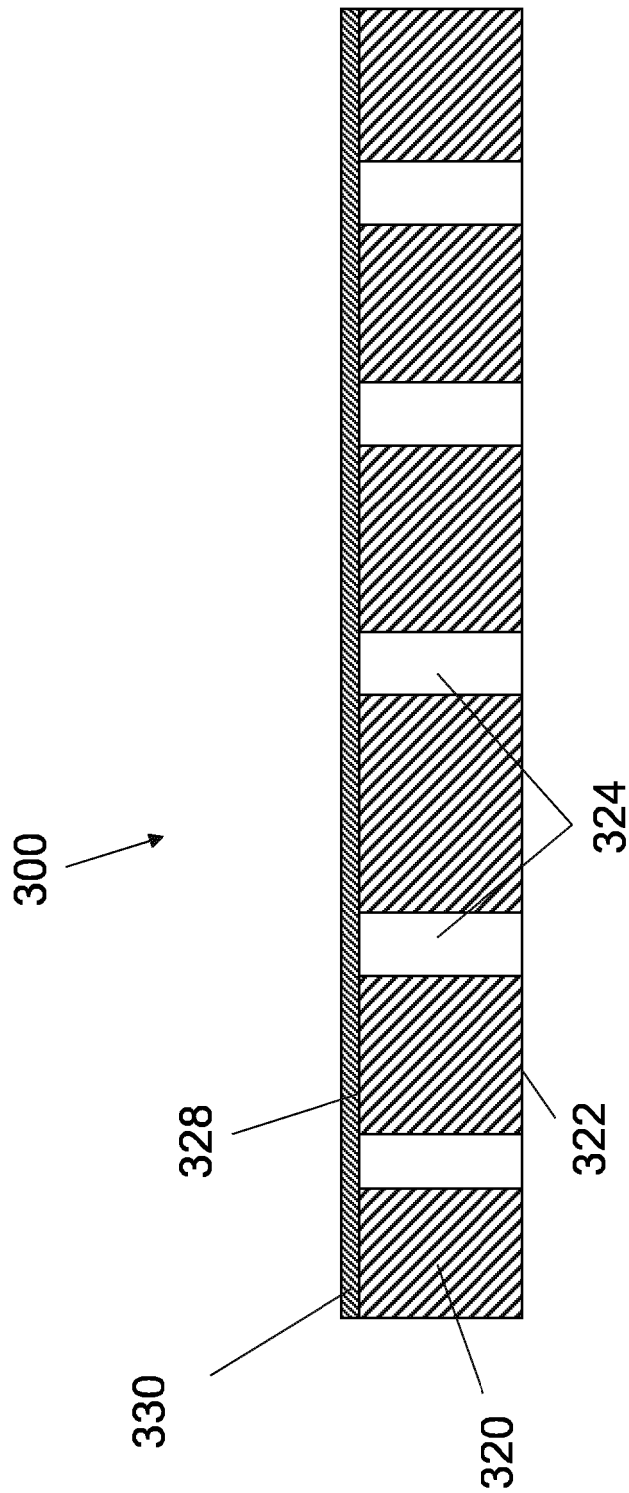
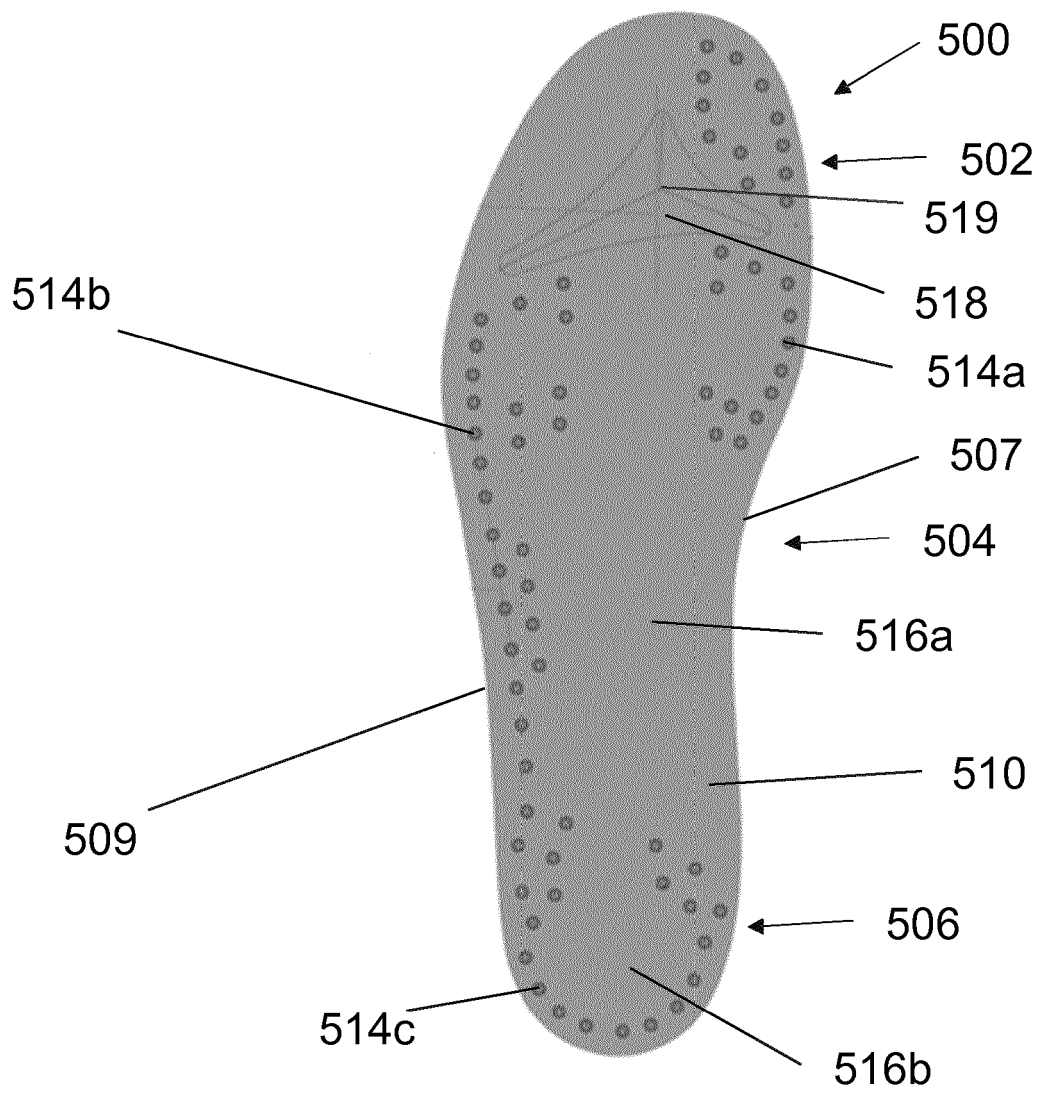


Fig. 17



**Fig. 18A**

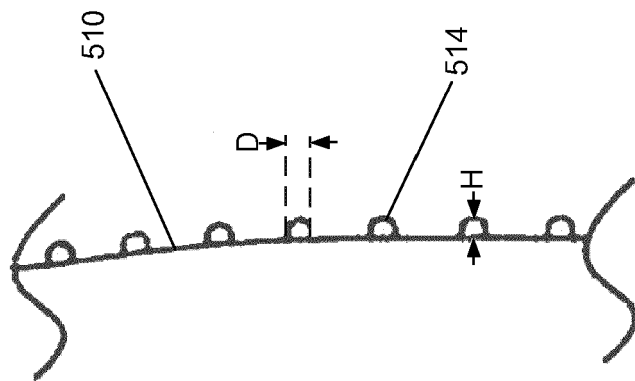


Fig. 18B

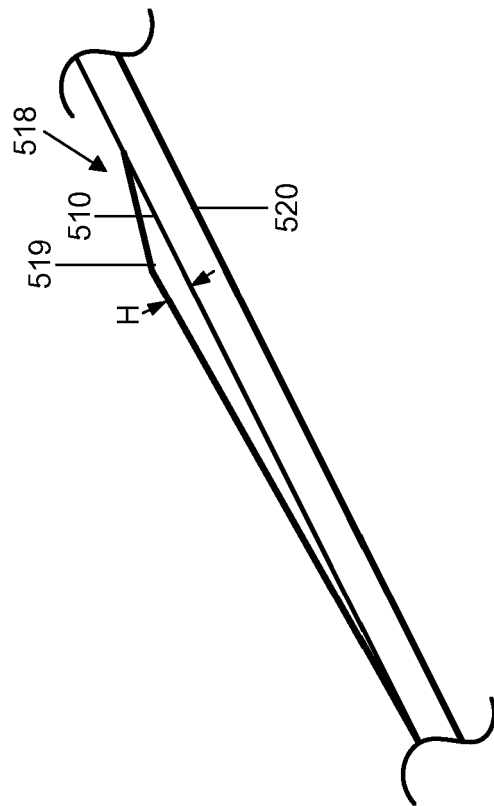
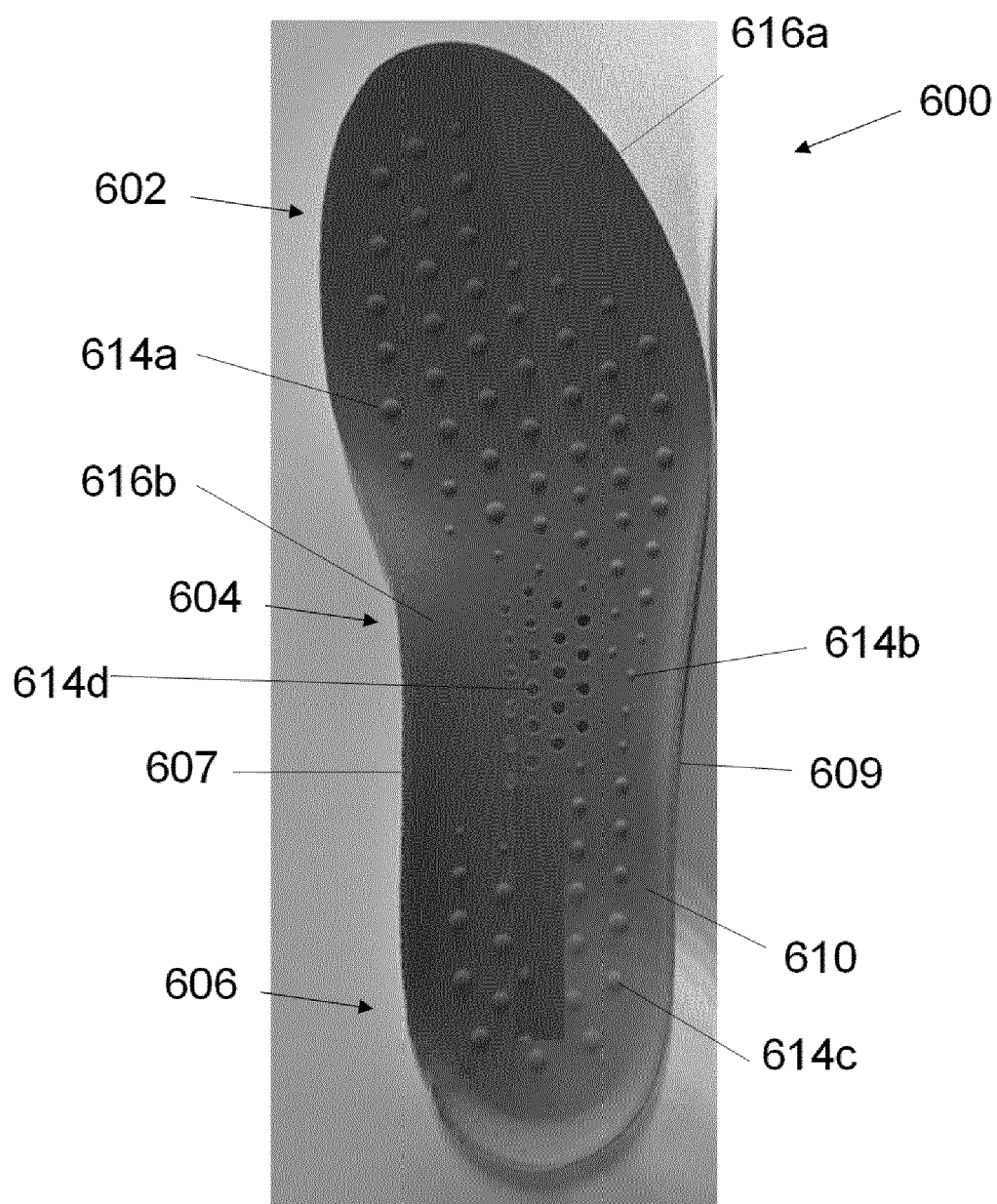


Fig. 18C



**Fig. 19**



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Application Number

EP 24 21 6427

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EPO FORM 1503 03.82 (P04C01)

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The present search report has been drawn up for all claims			
Place of search <b>The Hague</b>		Date of completion of the search <b>24 March 2025</b>	Examiner <b>Cianci, Sabino</b>
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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