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(54) **Sole for a shoe**

Sohle für einen Schuh

Semelle pour chaussure

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Description

1. Technical field

[0001] The present invention relates to a sole for a shoe, in particular a sports shoe.

2. Prior art

[0002] By means of soles, shoes are provided with a plethora of properties which can be pronounced in various strengths, depending on the specific type of shoe. Primarily, shoe soles typically have a protective function. They protect the foot of the respective wearer, due to their increased stiffness compared to the shoe shaft, against injuries caused by, e.g., sharp objects on which the wearer may tread. Furthermore, the shoe sole, due to an increased abrasion resistance, usually protects the shoe against excessive wear. In addition, shoe soles can improve the grip of the shoe on the respective ground and thus enable faster movements. A further function of a shoe sole can consist in its providing certain stability. Furthermore, a shoe sole can have a cushioning effect, for example, by absorbing the forces occurring during contact of the shoe with the ground. Finally, a shoe sole can protect the foot from dirt and spray water or provide a plurality of other functionalities.

[0003] In order to satisfy this plethora of functionalities, different materials are known from the prior art from which shoe soles can be manufactured. Exemplarily, shoe soles made from ethylene-vinyl-acetate (EVA), thermoplastic polyurethane (TPU), rubber, polypropylene (PP) or polystyrene (PS) are mentioned here. Each of these various materials provides a special combination of different properties which are more or less well-suited for the specific requirements of the respective shoe type. TPU, for example, is very abrasion-resistant and tear-proof. Furthermore, EVA distinguishes itself by a high stability and a relatively good cushioning effect. In addition, the use of expanded materials, in particular of expanded thermoplastic urethane (eTPU), was taken into consideration for the manufacture of a shoe sole. Thus, for example, WO 2005/066250 A1 describes methods for the manufacture of shoes whose shoe shaft is adhesively connected to a sole on the basis of foamed thermoplastic urethane. Expanded thermoplastic urethane distinguishes itself by a low weight and particularly good elasticity and cushioning properties.

[0004] In addition to cushioning and absorbing the shock energy produced when the foot treads on the ground, i.e. a cushioning in vertical direction, it is further known from prior art that during running, also shear forces occur in horizontal direction, in particular on grounds where a shoe has a good grip and the shoe is hence stopped abruptly together with the foot when contacting the ground. In case these shear forces cannot be absorbed at least partially by the ground and/or the sole of the shoe, the shear forces are transmitted with undimin-

ished effect to the movement apparatus, in particular the knee. This easily leads to an excessive burdening of the movement apparatus and promotes injuries. On the other hand, excessive shear capacity of the shoe sole would mean a loss of stability, in particular during faster running, which would lead to an increased risk of injuries. The increased shear capacity can also be undesired in specific regions of the sole, since these regions precisely serve to stabilize the foot. Furthermore, an increased shear capacity, e.g. in the area of the toes or of the mid-foot, can give the wearer a sensation of slipping of the shoe during running, which can reduce the wear comfort.

[0005] In order to solve this problem, sole constructions are known from the prior art, e.g. from DE 102 44 433 B4 and DE 102 44 435 B4, which can absorb in a way that does not strain the joints a part of the shear forces occurring during running. However, a disadvantage of these constructions consists in the fact that such soles are composed of several independent individual parts, have a fairly high weight and are expensive and complex in manufacture.

[0006] Moreover, US 2005/0150132 A1 discloses footwear (e.g., shoes, sandals, boots, etc.) that is constructed with small beads stuffed into the footbed, so that the beads can shift about due to pressure on the footbed by the user's foot during normal use. US 7,673,397 B2 discloses an article of footwear with support assembly having a plate and indentations formed therein. US 8,082,684 B2 discloses a sole unit for a shoe having at least one decoupling track between regions of sole unit allowing for the decoupling of the regions in response to forces from foot-ground contact. DE 10 2011 108 744 A1 discloses a method for the manufacture of a sole or part of a sole for a shoe. WO 2007/082838 A1 discloses foams based on thermoplastic polyurethanes. US 2011/0047720 A1 discloses a method of manufacturing a sole assembly for an article of footwear. Finally, WO 2006/015440 A1 discloses a method of forming a composite material.

[0007] Starting from the prior art, it is therefore an objective of the present invention to provide better soles for shoes, in particular for sports shoes. A further objective is to provide improved possibilities by means of which the shear capacity of shoe soles can be selectively influenced in specific regions of the sole.

3. Summary of the invention

[0008] The invention relates to a sole for a shoe according to claim 1 and to a shoe according to claim 13. Preferred embodiments are specified in the dependent claims. According to a first aspect of the present invention, this problem is solved by a sole for a shoe, in particular a sports shoe, comprising a cushioning element which comprises randomly arranged particles of an expanded material. The sole further comprises a control element free from expanded material, wherein the control element reduces shearing motions in a first region of the

cushioning element compared to shearing motions in a second region of the cushioning element.

[0009] The use of a cushioning element comprising expanded material is particularly advantageous for the construction of a shoe sole, since this material is very light, but is able, at the same time, to absorb the shock energy when the foot treads on the ground and to restore it to the runner. This increases the running efficiency and reduces the (vertical) impact burden upon the movement apparatus. A further advantage is provided by the use of randomly arranged particles of the expanded material. These considerably facilitate the manufacture of such a sole, since the particles are particularly easy to handle and, due to their random arrangement, no orientation is necessary during manufacture.

[0010] The use of a control element allowing for selectively controlling the shear capacity of the cushioning element furthermore allows for constructing soles that can also absorb and/or cushion horizontal shear forces which otherwise would have a direct impact on the movement apparatus, in particular the joints. This further increases the wear comfort of the shoe and the efficiency of the runner and prevents at the same time from injuries and wear of the joints. Since this control element is preferably free from expanded material, it has sufficient strength for complying with its control function.

[0011] In a preferred embodiment, the particles of expanded material comprise one or more of the following materials: expanded ethylene-vinyl-acetate (eEVA), expanded thermoplastic urethane (eTPU), expanded polypropylene (ePP), expanded polyamide (ePA), expanded polyether block amide (ePEBA), expanded polyoxymethylene (ePOM), expanded polystyrene (PS), expanded polyethylene (ePE), expanded polyoxyethylene (ePOE), expanded ethylene propylene diene monomer (eEPDM). According to the requirement profile of the sole, one or more of these materials can be advantageously used for the manufacture of the sole due to their substance-specific properties.

[0012] In a further preferred embodiment, the control element comprises one or more of the following materials: rubber, non-expanded thermoplastic urethane, textile materials, PEBA as well as foils and foil-like materials.

[0013] In a further preferred embodiment, the first region of the cushioning element comprises a higher intrinsic shear resistance than the second region of the cushioning element. The use of such a cushioning element with regions of different intrinsic shear resistance in combination with a control element, which locally influences the shear capacity of the cushioning element, offers great freedom and various adaption possibilities in the construction of a shoe sole.

[0014] In an embodiment, the control element has, in a first control region which influences the shearing motion of the cushioning element in the first region, a greater thickness and/or fewer holes than in a second control region which influences the shearing motion of the cushioning element in the second region. Based on the thick-

ness and the number and size of the holes, etc., the bending and deformation resistance of the control element can be determined, for example. These properties of the control element can, for their part, influence the shear and the bending capacity of the different regions of the cushioning element.

[0015] In a preferred embodiment, the cushioning element is provided as a component of a midsole. In a further preferred embodiment, the control element is provided as a part of an outsole.

[0016] By means of the construction of the cushioning element as a part of a midsole and/or of the control element as a part of an outsole, the number of different functional components of the sole and the shoe can be minimized and, at the same time, the adaption and control possibilities of the sole properties can be increased. This simplifies, e.g., the construction of the shoe and can reduce its weight considerably. Furthermore, additional composite materials such as adhesives for bonding the different elements of the sole and the shoe are not required. Consequently, the manufacture of the shoe is eventually more cost-effective together with improved functionality and furthermore offers improved recycling possibilities, since materials of common material classes are preferably used.

[0017] In a further embodiment, the outsole comprises a decoupling region that is not directly attached to the second region of the cushioning element of the midsole. As explained in detail further below, this enables to further influence and/or increase the shear capacity of the sole. So, for example, a control element provided as a part of an outsole can be bonded by a gel or the like to a cushioning element provided as a part of a midsole. The gel allows a further shearing effect between the control element and the cushioning element and thus allows absorbing higher shear forces.

[0018] According to a further aspect of the invention, the control element and the cushioning element can be manufactured from materials of a common material class, in particular from thermoplastic urethane. This allows a simplified manufacture of the sole and the shoe. In particular, materials from a common material class can often be bonded with each other and processed together in a significantly easier way than materials from different classes.

[0019] According to a further aspect of the invention, the first region is located in the medial region of the mid-foot and the second region in the lateral region of the heel. The shear forces occurring during running are especially produced when the foot contacts the ground. This happens typically with the lateral region of the heel. For this reason, a good shear capacity of the sole for absorbing the shear forces is desirable there. In the medial region of the foot, however, a supporting effect and increased stability are often desired. This allows a better pushing the foot off the ground and can furthermore prevent a pronation of the foot which can lead to irritations and injuries.

[0020] According to a further aspect of the invention, the control element further increases the bending resistance of the cushioning element in the first region compared to the second region. In particular, a control element designed as a part of an outsole can provide this functionality.

[0021] According to a further aspect of the invention, the sole comprises a frame made from non-expanded material, in particular from ethylene-vinyl-acetate, which surrounds at least a part of the cushioning element. Such a frame enables, for example, a further control of the shear capacity and can also be used to increase the stability of the sole.

[0022] In a preferred embodiment, the cushioning element allows a shearing motion of a lower sole surface relative to an upper sole surface in longitudinal direction of more than 1 mm, preferably more than 1.5 mm and particularly preferably more than 2 mm. These values offer a good balance between a sufficient stability of the shoe sole and a high absorption capacity for horizontal shear forces.

[0023] Preferably, the control element is laser-cut from a blank. For example, the control element can be provided in form as an outsole, or part of an outsole, which is laser-cut from a blank.

[0024] In the simplest form, the blank may be provided as a material layer comprising, for example, one or more of the materials suitable for the manufacture of a control element/outsole mentioned above. It is also possible, for example, that the blanks are provided in different sizes, thickness, with predefined holes, bulges, etc. and they may also comprise the general outline of a foot or sole.

[0025] Laser-cutting the control element can provide for a large freedom in design for the control element. It can also provide for the opportunity of an individual customization of the control element, sole and shoe. It may, for example, allow for numerous fashion designs, an individualization of each sole or shoe. The customization may be sport specific or according to typical movements of a customer or otherwise customer related. Furthermore, the laser-cutting may be automated to a large degree and may be based on, e.g., online tools or other ordering methods.

[0026] The above mentioned customization features and online ordering may, however, also be used in connection with other embodiments of inventive soles and shoes described herein or otherwise conceivable, without the control element necessarily being laser-cut from a blank.

[0027] A further aspect of the present invention relates to a shoe, in particular a sports shoe, with a sole according to one or more of the preceding embodiments of the invention. Here, individual aspects of the mentioned embodiments of the invention can be advantageously combined with one another, depending on the requirement profile for the sole and the shoe. Furthermore, it is possible to leave single aspects aside, if these should be irrelevant for the respective purpose of the shoe.

4. Brief description of the figures

[0028] In the following detailed description, currently preferred examples of implementations and embodiments of the sole according to the invention are described with reference to the following figures:

Fig. 1 Embodiment of a shoe sole with a midsole and an outsole which selectively influences the shear capacity and the bending capacity of the midsole. The sole further comprises a reinforcing element which is partially embedded in the midsole, as well as a heel clip;

Fig. 2 Shoes with different soles which were used for the measurements of **Figs. 3a - 9**;

Figs. 3a-b Comparison of the vertical compression of a midsole made from eTPU and a midsole made from EVA when the foot touches the ground;

Fig. 4 Measurements of the vertical compression of a midsole made from eTPU and a midsole made from EVA during an entire step cycle;

Figs. 5a-b Comparison of local material stretch in the lateral side wall of a midsole made from eTPU and a sole made from EVA during a rolling motion of the foot from the heel region to the forefoot region during a step;

Figs. 6a-c Measurements of the relative displacement of two measurement points at the opposite ends of the measurement sections represented in **Figs. 7a - 7c** during a complete step cycle for three different soles;

Figs. 7a-c The measurement points used for the measurements in **Figs. 6a - 6c** are each located at the ends of the measurement sections delineated in **Figs. 7a - 7c**;

Figs. 8a-c Comparison of the horizontal shear effect exerted on the sole material of three different midsoles when touching the ground with the lateral heel region;

Fig. 9 Measurements of the shear effects in the heel region of the sole material of different midsoles in longitudinal direction (AP direction) during an entire step cycle;

- Figs. 10a-d** Further measurements of the shear effects in the heel region of the sole material of various midsoles in longitudinal direction (AP direction) and in medial direction (ML direction) during an entire step cycle;
- Fig. 11** Average values of several measurements of the shear effects in the heel region of the sole material of respective different midsoles in longitudinal direction (AP direction) during an entire step cycle;
- Fig. 12** Average values of several measurements of the shear effects in the heel region of the sole material of respective different midsoles in medial-lateral direction (ML direction) during an entire step cycle;
- Figs. 13a-e** Representation of the plantar shearing effect on the sole material of different midsoles, at the end of a step, when the foot is pushed off the ground in the fore-foot region (cf. **Fig. 13e**);
- Figs. 14a-c** Preferred embodiment of a shoe with a sole according to an aspect of the present invention;
- Figs. 15a-c** Further preferred embodiment of a shoe with a sole according to an aspect of the present invention;
- Figs. 16a-b** Preferred embodiment of a shoe sole with a midsole and an outsole which selectively influences the shear capacity and the bending capacity of the midsole;
- Fig. 17** Particularly preferred embodiments of a shoe sole with a midsole and an outsole which selectively influences the shear capacity and the bending capacity of the midsole;
- Fig. 18** Schematic representation of possible embodiments for outsoles which selectively influence the shear and bending capacity of a midsole;
- Figs. 19,20** Schematic cross-section in ML direction through two embodiments of a midsole which comprises a first and a second plate element which can perform a sliding movement relative to each other;
- Figs. 21a-b** Embodiment of a shoe according to the invention with an embodiment of a sole according to the invention comprising a

control element laser-cut from a blank; and

- Figs. 22a-d** Further currently preferred embodiments of shoes according to the invention with embodiments of shoe soles according to the invention.

5. Detailed description of preferred embodiments

[0029] In the following detailed description, currently preferred embodiments of the invention relating to sports shoes are described. It is, however, emphasized that the present invention is not limited to these embodiments. The present invention can, for example, also be used for safety shoes, casual shoes, trekking shoes, golf shoes, winter shoes or other shoes as well as for protective clothing and paddings in sports apparel and sports equipment.

[0030] **Fig. 1** shows a sole **100** according to an aspect of the present invention. The sole **100** comprises a cushioning element **110** which comprises randomly arranged particles of an expanded material, as well as a control element **130** which selectively influences the shear capacity of the cushioning element.

[0031] In a preferred embodiment, the cushioning element **110** is provided, as shown in **Fig. i**, as a midsole or a part of the midsole, respectively. The cushioning element **110** comprises randomly arranged particles of an expanded material. In an embodiment, the whole cushioning element **110** consists of expanded material. Here, however, different expanded materials, or mixtures of several different expanded materials, can be used in various partial regions of the cushioning element **110**. In a further embodiment, only one or more partial regions of the cushioning element **110** consist of expanded material, while the rest of the cushioning element **110** consists of non-expanded material. For example, a cushioning element **110** can comprise a central region of particles of one or more expanded materials, said central region being surrounded by a frame of non-expanded material in order to increase the form stability of the sole. By means of an appropriate combination of expanded and/or non-expanded materials, a cushioning element **110** with the desired cushioning and stability properties can be manufactured.

[0032] The particles of the expanded material can, in particular, comprise one or more of the following materials: expanded ethylene-vinyl-acetate (eEVA), expanded thermoplastic urethane (eTPU), expanded polypropylene (ePP), expanded polyamide (ePA), expanded polyether block amide (ePEBA), expanded polyoxymethylene (ePOM), expanded polystyrene (PS), expanded polyethylene (ePE), expanded polyoxyethylene (ePOE), expanded ethylene propylene diene monomer (eEPDM). Each of these materials has specific characteristic properties which, depending on the requirement profile for the sole, can be advantageously used for the manufacture of the shoe sole. In particular eTPU has excellent

cushioning properties which remain unchanged also at lower or higher temperatures. Furthermore, eTPU is very elastic and restores the energy stored during compression, e.g. when treading on the ground, almost entirely to the foot during subsequent expansion. On the other hand, EVA, for example, distinguishes itself by great strength and is therefore suitable, e.g., for the construction of a frame which surrounds regions of expanded material or the whole cushioning element **110**, so as to give the cushioning element **110** high form stability.

[0033] The use of various materials or mixtures of different materials for the manufacture of the cushioning element **110** further allows for providing cushioning elements **110** comprising regions with different intrinsic shear resistances. In connection with a control element **130**, as described herein, this significantly increases the freedom of design in the construction of shoe soles **100** and thereby the possibilities of selectively influencing the shear behavior of the shoe sole **100**.

[0034] In a preferred embodiment, the control element **130**, as shown in **Fig. 1**, is provided as an outsole or as a part of an outsole. The control element **130** here preferably comprises one or more of the following materials: rubber, non-expanded thermoplastic urethane, textile materials, PEBA as well as foils or foil-like materials. In a particularly advantageous embodiment, the cushioning element **110** and the control element **130** are manufactured from materials of a common material class, in particular expanded and/or non-expanded thermoplastic urethane. This significantly simplifies the manufacturing process, as, for example, the cushioning element **110** and the control element **130** can be provided as one integral piece in a single mold without additional use of adhesives.

[0035] In order to selectively influence the shear behavior of the cushioning element **110**, the control element has a number of protrusions **132** which are different in size, hardness and expansion, elevations or bulges **135** of different lengths, thicknesses and structures, as well as openings and recesses **138** with different diameters. By varying these design possibilities, the influence exerted by the control element **130** on the shear behavior of the cushioning element **110** can be selectively controlled.

[0036] **Figs. 16a-b**, for example, show an embodiment **1600** of a sole **1610** according to the invention for a shoe which comprises a cushioning element **1630** provided as a midsole and which comprises randomly arranged particles **1635** of an expanded material. **Fig. 16a** shows the unloaded state and **Fig. 16b** shows the loaded state after touching **1650** the ground. The sole **1610** further comprises a control element **1620** provided as an outsole and which comprises a number of protrusions **1622** as well as a number of recesses/depressions **1628**. Here, the material of the control element **1620** preferably has a higher strength/stiffness than the material of the midsole **1630**. For example, the control element **1620** can be provided as a foil onto which the protrusions **1622** can be

selectively applied. For example, the control element **1620** can be a foil from TPU onto which protrusions **1622** also made from TPU can be applied. Such a preferred embodiment has the advantage that the foil and the protrusions, for example, can enter into a chemical bond without using additional bonding agents and which is extremely stable and resistant. In other embodiments, the control element comprises other/additional materials.

[0037] As shown in **Fig. 16b**, after touching **1650** the ground, the protrusions **1622** press into the material of the midsole **1630**, since the material of the control element **1620**, as already mentioned, is preferably of a higher stiffness/strength than the material of the midsole **1630**. Thereby, regions **1660** and **1670** are formed in which the material of the midsole **1630** is compressed to varying degrees.

[0038] In particular the material of the midsole in the regions **1670**, in which the protrusions **1622** press under load into the midsole **1630**, is compressed to a higher degree than in the regions **1660**, in which the control element comprises recesses/depressions **1628**. The different compressions of the midsole material caused thereby selectively influence the stretching and/or shear capacity of the midsole material in the corresponding regions **1660** and **1670**. For example, the stretching capacity of the midsole material decreases in the further compressed regions **1670** compared to the less compressed regions **1660**. Furthermore, this leads to an anchoring of the midsole **1630** at the outsole **1620** and hence to an increased ground grip.

[0039] Thus, the stretching and/or shear capacity of the midsole **1630** can be selectively activated or suppressed in individual partial regions by means of different designs of the control element **1620** with varied protrusions **1622**.

[0040] The protrusions **1622** can be of varied design. For example, the protrusions **1622** can be pointed, cone-shaped or pyramid-shaped, the protrusions **1622** can be cylindrical, they can be hemispherical, the control element **1620** can be wave-like and so forth. The protrusions **1622** here serve as a kind of anchor points which allow for a targeted local compression of the midsole material. Widely spaced protrusions **1622** here allow, for example, for greater stretching movements of the midsole materials than closer spaced protrusions **1622**. The shear capacity of the midsole **1630** can also be selectively influenced thereby.

[0041] **Fig. 17** shows a particularly preferred embodiment **1700** of a sole **1710** according to the invention that comprises a cushioning element **1730** provided as a midsole and which comprises randomly arranged particles **1735** of an expanded material, in unloaded state. The sole **1710** further comprises a control element **1720** provided as an outsole, said control element comprising a number of protrusions **1722** and a number of recesses/depressions **1728**. The material of the control element **1720** here preferably has a higher strength/stiffness than the material of the midsole **1730**. The symmetrical, wave-

like design of the control element shown in **Fig. 17** allows, on the one hand, a particularly good anchoring of the midsole **1730** to the outsole **1720** under load, as described above, and thus a particularly good ground grip. Furthermore, a control element **1720** designed in such a way can be introduced without any problem into a mold used for manufacture, during the manufacturing process.

[0042] **Fig. 18** schematically shows further embodiments of control elements **1800a**, **1800b**, **1800c** and **1800d** according to the invention. The embodiments **1800a**, **1800b**, **1800c** and **1800d**, preferably provided as an outsole or parts thereof, comprise a number of protrusions **1810** as well as depressions and/or reinforcing elevations **1820** which can, for example, connect two protrusions to each other. Here, the protrusions **1810** can comprise a number of different shapes, sizes, heights, etc., as already discussed above. The same applies to the depressions and/or reinforcing elevations **1820**. For example, their width/thickness and/or depth/height as well as their position and orientation on the control elements **1800a**, **1800b**, **1800c** and **1800d** can be adapted to the sole according to the respective requirements in order to selectively influence the properties of the sole. Here, too, it is explicitly emphasized that the depressions and/or reinforcing elevations **1820** need not perforce be arranged between two protrusions **1810**, but serve as stand-alone possibilities to design control elements according to the invention. In particular, such a reinforcing elevation can be advantageously used in the medial mid-foot region (cf. **1455**) in order to increase the stability of the sole there and to reduce the shear and stretching capacity of the midsole material in this region.

[0043] Furthermore, a control element can, according to a further aspect of the invention, comprise additional functional elements, such as, e.g., a torsion- and/or reinforcing element and the like, as a component and be manufactured as one integral piece therewith.

[0044] In addition, a control element can be provided as a complete outsole. In a further embodiment, however, an outsole comprises a number of individual independent control elements which may also be connected to each other.

[0045] In a preferred embodiment, the first region, which has a reduced shear capacity as compared to the second region, is located in the medial region of the mid-foot, while the second region is located in the lateral region of the heel. In a particularly preferred embodiment, the control element **130** comprises in particular a stabilizing bulge **135** at the medial edge of the midfoot region, as well as a number of openings with a diameter increasing towards the heel and the tip of the foot. The shear behavior of the cushioning element **110** adjusted in this way advantageously supports the natural physiological processes in the movement apparatus of a runner and increases the wear comfort and the efficiency of the runner, along with a minimization of the risk of injuries.

[0046] Besides influencing the shear behavior of the cushioning element **110**, the control element can also

influence the bending resistance of the cushioning element. For example, if the control element **130** is firmly attached to the cushioning element **130** in a region, the bending resistance of the control element **130** also influences the bending resistance of the cushioning element **110**. The bending resistance of the control element **130**, for its part, depends, for example, on the above-mentioned design options of the control element **130**. So, in the preferred embodiment shown in **Fig. 1**, the bending resistance in the heel and toe region is lower than in the midfoot region which is stabilized by means of the reinforcing bulge **135**.

[0047] In a further preferred embodiment, the sole **100** further comprises a decoupling region **160**. In this region, the cushioning element **110** and the control element **130** are not directly connected to each other. In one embodiment, there is no connection at all between the cushioning element **110** and the control element **130** in this region. In a preferred embodiment, the cushioning element **110** and the control element **130** are bonded in this region by means of a material which has a shear capacity. In a particularly preferred embodiment, this material with shear capacity comprises, for example, one or more of the following materials: eTPU, foamed material or a gel. This enables a further shearing motion of the cushioning element **110** with respect to the control element **130** and thus an additional possibility of influencing the shear behavior of the sole **100**. Such a decoupling region **160** is preferably located in the lateral heel region, since here, as will be shown further below in greater detail, the strongest shear forces occur during running.

[0048] **Fig. 19** shows a cross-section in medial-lateral direction through an embodiment of a midsole **1900** according to the present invention comprising randomly arranged particles **1910** of an expanded material and which can be advantageously combined with the other aspects of the present invention described herein. In the embodiment shown in **Fig. 19**, the whole midsole **1900** consists of expanded material. It is, however, clear to the skilled person that this is merely a specific example of a midsole **1900** according to the invention, and that in other embodiments only one or more partial regions of the midsole **1900** can comprise particles **1910** of expanded material. The midsole further comprises a first plate element **1920** and a second plate element **1930** that can slide relative to each other. Particularly preferred is a design in which the plate elements **1920** and **1930** can perform a sliding movement in several directions. In a preferred embodiment, the two plate elements **1920** and **1930** are completely surrounded by the material of the midsole **1900**, particularly preferred by the expanded material **1910** of the midsole **1900**. In other embodiments, however, the plate elements **1920** and **1930** are only partially surrounded by the material of the midsole **1900**.

[0049] Preferably, the two plate elements **1920** and **1930** are arranged, as shown in **Fig. 19**, in the heel region of the midsole **1900** such that they are located directly opposite each other. In a further embodiment, there is a

lubricant or a gel or the like between the two plate elements **1920** and **1930**, which counteracts wear of the plate elements **1920**, **1930** caused by the sliding movement and facilitates sliding.

[0050] By the sliding movement of the two plate elements **1920** and **1930**, such an arrangement can, for example, absorb or reduce, respectively, the horizontal shear forces acting on the movement apparatus of the wearer when he treads on the ground. This prevents wear of the joints and injuries of the wearer, in particular when he/she is running/walking fast. In other embodiments, the arrangement shown can also be located in a different region of the midsole **1900**, for example, in order to further support the rolling of the foot during a step.

[0051] In a further embodiment (not shown), the two plate elements **1920** and **1930** each comprise, in addition, a curved sliding surface. In a preferred embodiment, the curvature of the two sliding surfaces is chosen such that the two sliding surfaces match positively. By an appropriate selection of the degree and orientation of the curvature, it is possible to influence in which direction the sliding movement of the first plate element **1920** relative to the second plate element **1930** preferably takes place, for example, when treading on the ground. This, again, exerts an influence on the shear forces which are absorbed by the midsole or passed on to the wearer, respectively.

[0052] Further preferred embodiments of such plate elements which can slide relative to each other and which can be advantageously combined with one or more of the embodiments described herein that belong to the invention are to be found in DE 102 44 433 B4 and DE 102 44 435 B4.

[0053] For the functionality described just now it is further advantageous if the material of the midsole **1900** counteracts the sliding movement of the two plate elements **1920** and **1930** by a restoring force. Preferably, this restoring force is due to the fact that the two plate elements **1920** and **1930** are surrounded by the material of the midsole **1900**, in particular the expanded material **1910** of the midsole **1900**, and that the material of the midsole **1900** is compressed by the movement of the first and the second plate element **1920** and **1930**, respectively, in the regions which are adjacent to the two plate elements **1920** and **1930** in the direction of the sliding movement. Due to the elastic properties of the material, in particular of the expanded material **1910** of the midsole **1900**, a restoring force is produced which counteracts the sliding movement of the first and the second plate element **1920**, **1930**, respectively, with no need for complicated mechanics to this effect.

[0054] **Fig. 20** shows a cross-section in medial-lateral direction of a variation of the embodiment discussed just now with a midsole **2000**, which comprises randomly arranged particles **2010** of expanded material. The midsole comprises a plate element **2020** and a second, sled-shaped element **2030**. The two elements **2020**, **2030** can perform a sliding movement relative to each other. Due

to the sled-shaped design of the second element **2030**, a preferred direction for such a sliding movement is predetermined. In a preferred embodiment, however, there are voids **2040** between the first element **2020** and the second, sled-shaped element **2030** which also allow for small sliding movements of the two elements **2030** and **2040** relative to each other and which do not lie in the preferred direction mentioned above. By adapting the size of the voids **2030**, the extent of such sliding movements which do not lie in the preferred direction can be individually adapted to the needs and requirements of the sole. So, very small voids **2040** allow for sliding movements of the two elements **2020** and **2030** almost exclusively in the preferred direction, which can lead to an increased stability of the sole. Larger voids **2040**, however, facilitate noticeable sliding movements also in a non-preferred direction. This enables, for example, a better absorption of the horizontal shear forces by the sole when contacting the ground.

[0055] In the preferred embodiment shown in **Fig. 1**, the cushioning element **110** further surrounds an element **120** at least partially, for example, a torsion or reinforcing element. In a preferred embodiment, the element **120** has higher deformation stiffness than the expanded material of the cushioning element **110**. The element **120** hence can serve to further influence the elasticity- and also shear properties of the sole **100**. In a further embodiment, the element **120** can, for example, also be an element serving the optical design and/or an element for receiving an electronic component and/or an electronic component or any other functional element. In case the element **120** serves to receive a further element, such as, e.g., an electronic component, then it has preferably a hollow region which is accessible from the outside. In the embodiment shown in **Fig. 1**, such a cavity could, e.g., be located in the region of the recess **140**. In a preferred embodiment, the element **120** is not bonded, for example by an adhesive bond, with the cushioning element **110**. In particular, the element does not comprise, in a preferred embodiment, a bond with the expanded material of the cushioning material **110**. Since the cushioning element **110** partially surrounds the element, such a bond for fixing the element **120** is not required. Therefore, also non-glueable materials can be used for manufacturing the shoe. In a further embodiment, the element **120** can also be connected/bonded with the control element **130** in individual regions, for example by means of a bond such as, e.g., an adhesive bond, or be provided as one integral piece.

[0056] In the embodiment shown in **Fig. 1**, the sole **100** further comprises a heel clip **150**. Preferably, the heel clip **150** comprises a lateral finger and a medial finger which independent from each other encompass the lateral and the medial side of the heel. This allows a good fixation of the foot on the sole **100** without at the same time excessively restraining the room to move of the foot. In a further preferred embodiment, the heel clip **150** further comprises a recess in the region of the Achilles' ten-

don. This prevents a chafing or rubbing in particular of the upper edge of the heel clip **150** on the Achilles' tendon in the region above the heel. In a preferred embodiment, the heel clip **150** can further, be bonded, e.g. by a bond, to the control element **130** and/or the element **120** or be provided together with this as one integral piece.

[0057] Fig. 2 shows four different shoes **200**, **220**, **240** and **260** which were used for taking measurements of elasticity and shear properties of soles from various materials. The most important results of these measurements are summarized in the following Figs. 3a - 9.

[0058] The shoe **200** is a shoe with an upper **205** as well as a shoe sole **210** and a sliding element **212**, such as described, for example, in DE 102 44 433 B4 and DE 102 44 435 B4.

[0059] The shoe **220** comprises an upper **225** as well as a midsole **230** from eTPU which is surrounded by a frame from EVA. The EVA can, for example, be a compression molded 020 55C CMEVA which has a density of 0.2 g/cm³ and a hardness of 55 asker C.

[0060] The shoe **240** comprises an upper **245** as well as a midsole **250** of EVA.

[0061] Furthermore, the shoe **260** comprises an upper **265** as well as a midsole **270** of eTPU.

[0062] Figs. 3a, 3b and 4 show the vertical (i.e. the direction from foot to ground) compression of the soles of eTPU (shoe **260**) and EVA (shoe **240**).

[0063] For measuring these and further discussed properties of the various materials and sole designs, for each measurement a large number (>100) of pictures, referred to as "stages", were taken in the course of a step cycle. These are continuously numbered starting from 1. For each measurement there is hence a one-to-one correspondence between the number or "stage" of a take and the point in time of this take within the respective step. However, it has to be noted that between different measurements there may be a certain time offset for the individual stages, i.e. the stages with an identical number from various measurements do not perforce correspond to the same point in time during the step measured in the respective measurement.

[0064] Pictures **300a** and **300b** of Figs. 3a and 3b were taken during the heel touching the ground. Figs. 3a and 3b show the compression in percent of the respective midsole regions compared to the unloaded state of the sole. As expected, no compression occurs in the forefoot region (cf. **320a**, **320b**) while the ground is touched by the heel. In the heel region, however, noticeable compressions are visible on the sole of eTPU (cf. **310a**). The measurements therefore show that eTPU yields significantly more strongly under vertical load than EVA. Furthermore, the energy stored during compression of the eTPU sole is essentially restored to the runner in the course of the step. This increases the running efficiency significantly.

[0065] This is also confirmed by Fig. 4. On the horizontal axis, the number of the respective stage, i.e. the time, is shown, and on the vertical axis, the vertical com-

pression of the midsole is shown. The measured values **410** for a sole **270** from eTPU are shown as well as the measured values **420** for a sole **250** from EVA. At the time of the maximum vertical load, the EVA midsole **250** can be depressed only by about 1.3 mm, while the eTPU midsole **270** can be depressed by about 4.3 mm. Generally, the values of the vertical compression for eTPU compared to those of EVA range from 2:1 to 3:1, in some embodiments even above this.

[0066] Figs. 5a and 5b show the local material stretch of the midsole material compared to the unloaded state of the sole within the lateral side wall of the eTPU midsole **270** (measurement **500a**) and the EVA midsole **250** (measurement **500b**), also at a moment when the heel touches the ground. In addition to a percent indication of the material stretch compared to the unloaded state of the sole, the pictures of Figs. 5a and 5b indicate, however, also the direction of the material stretch in the form of stretch vectors. From the pictures, it can be seen that in the eTPU midsole **270**, significantly greater material stretches occur than in the EVA midsole **250**. This is due to the better shear capacity of eTPU compared to EVA. Therefore, eTPU is particularly appropriate for manufacturing a cushioning element for absorbing shear forces during running. In the example discussed here, the material stretch with eTPU is 2 - 3 times higher than with EVA. More precisely, the material stretch of eTPU is on average a stretch of 6-7%; the maximum stretch is 8-9%; the material stretch for EVA is on average a stretch of 2%; the maximum stretch is 3-4%.

[0067] Furthermore, the measurements reveal that the material stretch in the lateral side wall of the eTPU midsole **270** and of the EVA midsole **250** follow the natural shape of the metatarsal arch during running, i.e. the shoe follows the rolling movement of the foot. This is advantageous for the wear comfort and fit of the foot.

[0068] Figs. 6a-6c show the measurements **610a**, **610b** and **610c** of the relative offset of two measurement points in millimeters, which are each located at the opposite ends of the measurement sections **710a**, **710b** and **710c** shown in Figs. 7a - 7c. The measurements **610a**, **610b** and **610c** each comprise a complete step cycle. In Figs. 7a-c, the shoes used for the respective measurements are shown in a starting position.

[0069] Figs. 6a, 7a show the measurement results and the measurement points for a shoe **200** with a shoe sole **210** and a sliding element **212**, as described in DE 102 44 433 B4 and DE 102 44 435 B4.

[0070] Figs. 6b, 7b show the measurement results and the measurement points for a shoe **220** with a midsole **230** of eTPU and an EVA rim.

[0071] Figs. 6c, 7c show the measurement results and the measurement points for a shoe with an EVA sole **250**.

[0072] It is clearly visible that the sliding element **212** of the shoe **200** and the eTPU sole with EVA rim **230** allow significantly greater offsets between the two measurement points than the EVA midsole **250**. This means a better shear capacity of the lower midsole surface rel-

ative to the upper midsole surface and thus a better absorption capacity of the shear forces occurring during running. It is to be noticed that the shoe **220** which is simpler in construction allows offset values of up to 2.5 mm (cf. **Fig. 6b**), while the shoe **200** with the sliding element **212** allows only offset values of up to about 2 mm (cf. **Fig. 6a**). The shoe **240** with EVA midsole **250**, in contrast, allows only offset values of up to about 0.5 mm (cf. **Fig. 6c**).

[0073] The **Figs. 8a - 8c** show further measurements of the shear behavior of the shoe **200** with the sliding element **212** (measurement **800a**), of the shoe **220** with eTPU midsole with EVA rim **230** (measurement **800b**), and of the shoe **240** with EVA midsole **250** (measurement **800c**). What is shown is the local offset of the sole material compared to the unloaded state at a moment when the heel touches the ground.

[0074] It is clearly visible that the shoe **200** with the sliding element **212** and the shoe **220** with eTPU midsole with EVA rim **230** have a substantially higher shear capacity in the region of the heel than the shoe **240** with EVA midsole **250**.

[0075] **Fig. 9** again shows measurement results of measurements of the shearing in the midsole material in longitudinal direction (AP direction) during a complete step cycle for four different shoes.

[0076] The curve **910** shows again the measurement results of **Fig. 6a** for the shoe **200** with the sliding element **212**, with a maximum shearing of about 2 mm when the heel touches the ground. The curve **930** again shows the measurement results of **Fig. 6b** for the shoe **220** with eTPU midsole with EVA rim **230** with a maximum shearing of about 2.5 mm during the touching of the ground by the heel. The curve **940** again shows the measurement results of **Fig. 6c** for the shoe **240** with EVA midsole **250** with a maximum shearing of about 0.5 mm during the impacting on the ground with the heel. The curve **920**, finally, shows the measurement results of a measurement carried out in the same way for the shoe **260** with eTPU midsole **270** with a maximum shearing of about 1.8 mm during the touching of the ground by the heel.

[0077] One can thus recognize that the shoe **260** with the eTPU midsole **270** and in particular the shoe **220** with eTPU midsole with the EVA rim **230** have a very good shear capacity and thus are principally well-suited for the construction of midsoles.

[0078] **Figs. 10a - 13d** show further measurements of the shear capacity of differently designed soles.

[0079] **Figs. 10a - 10d** show measurements of the changes in length of measurement sections of which one is arranged in longitudinal direction (AP direction) and one in medial-lateral direction (ML direction) in the heel region of the sole during a step cycle. These changes in length provide information on the plantar shear capacity of the respective sole.

[0080] **Fig. 10a** shows the change in length **1010a** of the measurement section **1015a** extending in AP direction, and the change in length **1020a** of the measurement

section **1025a**, which extends in ML direction, for a shoe with an EVA midsole without outsole, as, e.g., the shoe **240**. The measurements indicate a maximum change in length of about 1.2 mm in AP direction and of about 0.3 mm in ML direction.

[0081] **Fig. 10b** shows the change in length **1010b** of the measurement section **1015b** extending in AP direction and the change in length **1020b** of the measurement section **1025b** extending in ML direction for a shoe with an eTPU midsole without outsole, as, e.g., the shoe **260**. The measurements show a maximum change in length of about 3.5 mm in AP direction and of about 1.5 mm in ML direction.

[0082] **Fig. 10c** shows the change in length **1010c** of the measurement section **1015c** extending in AP direction and the change in length **1020c** of the measurement section **1025c** extending in ML direction for a shoe with a sliding element, as for instance the shoe **200**. The measurements show a maximum change in length of about 3.2 mm in AP direction and of about 0.7 mm in ML direction.

[0083] **Fig. 10d** shows the change in length **1010d** of the measurement section **1015d** extending in AP direction and the change in length **1020d** of the measurement section **1025d** extending in ML direction for the preferred embodiment of a shoe **1400** according to **Figs. 1** and **14a - 14c** comprising a midsole, which comprises eTPU, as well as a control element **1450** (cf. below) provided as an outsole. The measurement show a maximum change in length of about 3.4 mm in AP direction and a negative change in length of about 0.5 mm in ML direction. In particular the negative change in length in ML direction means a very good stability of the shoe in the midfoot region which reflects the influence of the medial reinforcement **1455** of the control element **1450**.

[0084] **Figs. 11** and **12** show the average values of a series of measurements conducted analogously to the measurements shown in **Figs. 10a - 10d**.

[0085] **Fig. 11** shows the average change in length of the measurement section extending in AP direction during a complete step cycle for a shoe with a sliding element, as, for example, the shoe **200** (cf. curve **1110**), for a shoe with an eTPU midsole, as, for example, the shoe **260** (cf. curve **1120**), for a shoe with an EVA midsole, as, for example, the shoe **240** (cf. curve **1130**) and for the shoe **1400** according to **Figs. 14a - 14c** (cf. curve **1140**).

[0086] **Fig. 12** shows the average change in length of the measurement section extending in ML direction during a complete step cycle for a shoe with a sliding element, as, for example, the shoe **200** (cf. curve **1210**), for a shoe with an eTPU midsole, as, for example, the shoe **260** (cf. curve **1220**), for a shoe with an EVA midsole, as, for example, the shoe **240** (cf. curve **1230**), and for the shoe **1400** according to **Figs. 14a - 14c** (cf. curve **1240**).

[0087] As can be inferred from **Figs. 11** and **12**, the shoe **1400** according to a particularly preferred embodiment has, with a maximum change in length in AP direction of more than 3 mm, the best shear capacity of all

four tested shoe types. At the same time, the shoe **1400** shows a sufficient stability in ML direction, as can be seen from **Fig. 12**. As shear forces occur during running mainly in AP direction, and since a bending/slipping of the foot in ML direction is to be avoided as far as possible, this combination of properties of the shoe is particularly advantageous.

[0088] In further preferred embodiments, the cushioning element enables a shearing motion in AP direction of a lower sole surface relative to an upper sole surface of more than 1 mm, preferably more than 1.5 mm and particularly preferably more than 2 mm. A selection between different values of the shear capacity of the cushioning element enables to adapt the shoe sole individually to the needs and physiological conditions of a runner. The values discussed here serve the skilled person only as a guideline in order to obtain an impression of typical preferred values of the shear capacity of a cushioning element. In individual cases, these values ideally have to be specifically adapted to the wishes and needs of the wearer.

[0089] **Figs. 13a - 13d** show the plantar material stretch in the sole of various shoes in percentages, compared to the unloaded state of the shoe, at the moment when the foot is pushed off the ground via the forefoot, as schematically shown in **Fig. 13e**. **Figs. 13a - 13d** furthermore show the stretch vectors which locally indicate the direction of the material stretch. **Fig. 13a** shows a measurement **1300a** for a shoe **240** with an EVA midsole, **Fig. 13b** shows a measurement **1300b** for a shoe **260** with an eTPU midsole. **Fig. 13c** shows a measurement **1300c** for a shoe with a sliding element, as, for example, the shoe **200**, and **Fig. 13d** shows a measurement **1300d** for the preferred embodiment of a shoe **1400** according to **Figs. 1** and **14a - 14c**, which comprises a midsole comprising eTPU, as well as a control element **1450** provided as an outsole (cf. below).

[0090] As can clearly be seen from the figures, in this position of the foot/shoe (i.e. when pushing the foot off the ground over the forefoot region, cf. **Fig. 13e**) the main load and deformation of the material of the shoes **240** and **260** occurs locally in the middle of the forefoot region (cf. **Fig. 13a** and **Fig. 13b**) (in other positions of the foot, the main load and deformation can also be observed in the heel region). In the case of the shoe with the sliding element and the shoe **1400**, however, the material stretches follow the shape of the outsole. In **Fig. 13d**, in particular, the structure of the outsole **1450** with its openings **1452**, elevations **1458** and protrusions **1459** can be seen. Furthermore, **Fig. 13d** shows that almost all of the stretch vectors in the forefoot region extend parallel in AP direction, i.e. the material stretches almost exclusively in AP direction, while it shows a good stability in ML direction. This is desirable for a dynamic push-off of the foot without losing stability. In case of insufficient stability of the sole in ML direction, the foot would otherwise be in danger of slipping sideways or bending, in particular at a higher running speed and, for instance, in a curve

or on uneven terrain.

[0091] The control element **1450**, e.g. in the form of an outsole, contributes to forming predefined zones where a specific shearing- and/or stretching behavior or a specific stability is required. The design of the control element **1450** can be adapted to the requirements of each sport. Linear sports have different requirements concerning the shearing behavior and stability of the sole than, for example, lateral sports. Therefore, the control elements **1450** and sole concepts can be individually designed for specific sports. For example, for sports like (indoor) football, basketball, or running sports, the best/most important shearing and stability zones can be determined and individually adapted. For example, in many fields of application, such preferred shearing and/or stretching zones are located beneath the big toe and in the heel region. Furthermore, by means of the aspects pertaining to the invention which are described herein, soles can be manufactured which can ideally imitate the rolling of the foot like when walking barefoot.

[0092] **Figs. 14a - 14c** show a preferred embodiment of a shoe **1400** with a cushioning element **1410** provided partially as a part of a midsole or as a midsole, said cushioning element comprising randomly arranged particles of expanded material, in particular particles of eTPU, and a control element **1450** provided as part of an outsole or as an outsole, which reduces the shear capacity of the midsole **1410** in the medial region of the midfoot compared to the lateral region of the heel. In addition, the shoe shown in **Figs. 14a - 14c** comprises an upper **1420**. In a preferred embodiment, the shoe **1400** further comprises a heel clip **1430** as well as an additional torsion or stiffening element **1440**, as already discussed above in connection with **Fig. 1** and the corresponding embodiments.

[0093] In one preferred embodiment, the control element **1450** which is provided as an outsole does not comprise expanded material. Particularly preferred is the control element made from rubber, thermoplastic urethane, textile materials, PEBA or foils and foil-like materials or a combination of such materials, respectively. It is furthermore advantageous if the control element **1450** and the cushioning element **1410** are manufactured from materials from a common class of materials, as already mentioned above. Furthermore, the control element **1450** preferably comprises a number of openings **1452** of different sizes, a bulge **1455** in the medial region of the midfoot as well as a number of elevations **1458** and protrusions **1459**. These elements serve, as already discussed, to influence the flexibility and stiffness properties of the control element **1450**, which, for their part, influence the shear capacity and the bending stiffness of the sole and particularly the midsole **1410**. The protrusions **1459** and the elevations **1458** can, furthermore, increase the ground grip, in particular, since the control element **1450** in the present preferred embodiment is provided as a part of an outsole.

[0094] The preferred embodiment shown in **Figs. 14a**

- **14c**, with a bulge **1455** in the medial region of the midfoot as well as a number of openings **1452** of varying diameter, enables a particularly good shear capacity in the heel region, especially in the lateral heel region, as well as a good stability in the medial midfoot region. As already mentioned several times, this combination of properties is particularly advantageous for use in case of running shoes. Other combinations of properties are, however, also possible, and the design options and embodiments presented herein enable the skilled person to manufacture a shoe having the desired properties.

[0095] Figs. **15a - 15c** show a further preferred embodiment of a shoe **1500** according to an aspect of the present invention. The shoe **1500** comprises a cushioning element **1510** provided as a part of a midsole or as a midsole which comprises randomly arranged particles of expanded material, for example eTPU. Furthermore, the shoe **1500** comprises a control element **1540** provided as a part of an outsole or as an outsole which can selectively influence the shear capacity and the bending stiffness of the cushioning element **1510** in the way which was already repeatedly discussed. The shoe further comprises an upper **1520** as well as a heel clip **1530**.

[0096] Figs. **21a-b** show another preferred embodiment of a shoe **2100** according to the invention. The shoe **2100** comprises a sole comprising a cushioning element **2110** with randomly arranged particles of an expanded material. In the exemplary embodiment shown here, the cushioning element **2110** is provided as a midsole **2110**. It may, however, also be merely a part thereof, for example.

[0097] The shoe **2100** furthermore comprises an upper **2120**. The upper **2120** may be made from a large variety of materials and by a large variety of manufacturing methods. The upper **2120** can, in particular, be warp-knitted, weft-knitted, woven or braided, and it can comprise natural or synthetic materials, it may comprise fibers or yarns, multilaminate materials, compound materials and so on.

[0098] The sole of the shoe **2100** furthermore comprises a control element **2150**, provided in the case at hand as an outsole **2150**. In other cases it may only be part of an outsole or it may be part of the midsole. The control element **2150** is free from expanded material. Suitable materials for the control element/outsole **2150** may include rubber, non-expanded thermoplastic urethane, textile materials, PEBA as well as foils and foil-like materials.

[0099] The control element **2150** reduces shearing motions within a first region of the cushioning element **2110** compared to shearing motions within a second region of the cushioning element **2110**. Reduced shearing may, for example, occur in regions **2160**, **2165** where the control element **2150** comprises continuous regions of material. It may also occur in the regions of the "material webs" **2170**, **2175**, which are interspersed by holes **2152**, **2155**, **2158** in the control element **2150**. In the regions of these holes **2152**, **2155**, **2158**, for example, the shear-

ing motion may be increased in comparison.

[0100] Taking account of the explanations regarding the inventive concept of controlling the shearing motion of a cushioning element as described in this document, it is clear to a skilled person that by choosing different designs and arrangements of the continuous material regions (like regions **2160**, **2165**), the "material webs" (like web **2170**) and the holes (like holes **2152**, **2155**, **2158**), the shearing and other properties, like e.g. the bending stiffness, torsional stiffness or the general roll-off behavior, of the midsole **2110** of the shoe **2100** can be influenced as desired in a large number of ways. The influence can be fine-tuned even further with the potential inclusion of bulges, elevations, protrusions in the control element **2150**, as already described before.

[0101] In the present case, the control element **2150** is laser-cut from a blank (not shown). This may be done before the control element **2150** is affixed to the remaining parts of the sole of the shoe **2100**, in particular the midsole **2110**, and is preferably done in an automated manner, at least to a large degree. In principle, however, the blank may also be arranged at, e.g., the midsole **2110** first, then the blank is cut and finally the cut-out sections of the blank are removed. To this end, a bonding agent may be applied between the midsole **2110** and the blank, which does not immediately harden completely but still provides enough adhesion that the blank is secured on the midsole **2110** (or other parts of the shoe **2100**) for it to be cut. For cutting, the shoe **2100** including the blank may e.g. be arranged on a last to allow three-dimensional positioning within a cutting device. After removal of the cut-out pieces of the blank, which is still possible since the agent has not completely hardened, the bonding agent may then be left to harden completely or this may be facilitated by heating, cooling, energizing or other means.

[0102] In the simplest form, the blank may be provided as a material layer comprising, for example, one or more of the materials suitable for the manufacture of a control element/outsole mentioned above. It is also possible, for example, that the blanks are provided in different sizes, thickness, with predefined holes, bulges, elevations, protrusions and so forth, which may already provide a basic pattern that may then be fine-tuned by the laser-cutting process. Such a basic pattern may, e.g., be adapted to specific movement patterns occurring during, say, a specific sporting activity and different blanks may be used for the manufacture of shoes **2100** for the different sporting activities. Examples may include blanks for running shoes, tennis shoes, basketball shoes, football shoes, etc. This approach can have the advantage that the blanks can be produced quickly and in a large number beforehand and the individual customization can then be carried out more efficiently and more quickly. To this end, the blanks may also already comprise the general outline of a foot or sole.

[0103] This can, in particular, become important, if the customization, particularly by laser-cutting, is done on

the spot, for example in a sales room, a sales stand at a sporting event or the like, where there is only limited room for a cutting device and manufacturing apparatus.

[0104] Laser-cutting the control element **2150** can provide for a large freedom in design for the control element **2150**. It can also provide for the opportunity of an individual customization of the control element **2150**, sole and shoe **2100**, as already mentioned. It may, for example, allow for numerous fashion designs and a corresponding individualization of each sole or shoe **2100**. The customization may be sport specific or according to typical movements of a customer or otherwise customer related. Furthermore, the laser-cutting may be automated to a large degree and may be based on, e.g., online tools or other ordering methods.

[0105] While reference has been made to laser cutting throughout the description of **Figs. 21a-b**, other techniques are in principle also possible. Examples are CNC cutting, die cutting, water jet cutting.

[0106] Finally, **Figs. 22a-d** show further currently preferred embodiments of shoes **2200a**, **2200b**, **2200c**, and **2200d** according to the invention.

[0107] The main purpose of **Figs. 22a-d** is to give the skilled person a better understanding of the scope and further possible embodiments of the present invention. Therefore, the embodiments **2200a**, **2200b**, **2200c**, and **2200d** will only be discussed briefly. For a more detailed discussion of individual aspects, reference is made to the discussion of the embodiments of shoes, soles, midsoles, cushioning elements and control elements according to the invention already put forth herein, in particular the discussion of the embodiments **100**, **1400**, **1500**, **1600**, **1700**, **1800a-d**, **1900**, **2000** and **2100**. The features, options and functionality discussed in relation to these embodiments also apply to the embodiments **2200a**, **2200b**, **2200c**, and **2200d**, as far as applicable.

[0108] The shoes **2200a**, **2200b**, **2200c**, **2200d** each have a sole comprising a respective cushioning element **2210a**, **2210b**, **2210c** and **2210d** comprising randomly arranged particles of an expanded material. Whereas the cushioning elements **2210a** and **2210b** of the shoes **2200a** and **2200b** only extend throughout the forefoot regions, the cushioning elements **2210c** and **2210d** of the shoes **2200c** and **2200d** extend throughout the entire soles of the shoes **2200c**, **2200d**. The cushioning elements **2210a**, **2210b**, **2210c** and **2210d** shown here are provided as part of a respective midsole. Other arrangements of the cushioning elements are, however, also conceivable.

[0109] The soles of the shoes **2200a**, **2200b**, **2200c** and **2200d** furthermore each comprise a control element **2250a**, **2250b**, **2250c** and **2250d** free from expanded material. The control elements **2250a**, **2250b**, **2250c** and **2250d** each reduce shearing motions within a first region of the respective cushioning element **2210a**, **2210b**, **2210c** and **2210d** compared to shearing motions within a second region of the respective cushioning element **2210a**, **2210b**, **2210c** and **2210d**. In the embodiments

2200a, **2200b**, **2200c** and **2200d** shown here, the control elements **2250a**, **2250b**, **2250c** and **2250d** are provided as part of a respective outsole.

[0110] The control elements **2250a**, **2250b**, **2250c** and **2250d** may further serve the purpose to selectively increase the bending resistance of the respective cushioning element **2210a**, **2210b**, **2210c** and **2210d**.

[0111] To influence the shearing motions and bending stiffness of the respective cushioning elements **2210a**, **2210b**, **2210c**, **2210d** or soles, the control elements **2250a**, **2250b**, **2250c** and **2250d** comprise a number of holes or openings **2252a**, **2252b**, **2252c**, **2252d** in different arrangements, shapes, sizes, sole regions, etc.. The control elements **2250a**, **2250b**, **2250c** and **2250d** further comprise a "web" or material mesh **2258a**, **2258b**, **2258c**, **2258d** between the individual openings **2252a**, **2252b**, **2252c**, **2252d**.

[0112] Whereas the openings **2252a**, **2252b**, **2252c** and material meshes **2258a**, **2258b**, **2258c** are configured in a diamond shape in the embodiments **2200a**, **2200b** and **2200c**, the openings **2252d** and material mesh **2258d** roughly form parallelograms. Other configurations are, however, also possible, as already discussed at various times throughout this document and as shown, e.g., in the heel region of the shoe **2200d**. Moreover, the control elements **2250a**, **2250b**, **2250c** and **2250d** may also comprise further protrusions, elevations, etc.. For example, as shown in **Fig. 22a**, the control element **2250a** comprises a number of protrusions **2259a**.

[0113] The recurring arrangement of the openings **2252a**, **2252b**, **2252c**, **2252d** and material meshes **2258a**, **2258b**, **2258c**, **2258d** in diamond or parallelogram shape may in particular result in one or more preferred directions along which the soles may predominantly shear or bend. By the exact patterns and arrangement of the holes and material regions, these preferred directions can be adjusted to a given requirement profile for a particular sole or shoe.

Claims

1. Sole (100; 1610; 1710) for a shoe (1400; 1500; 2100; 2200a-d), in particular a sports shoe, comprising:
 - a. a midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) comprising randomly arranged particles (1635; 1735) of an expanded material,
 - b. an outsole (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) free from expanded material,
 - c. wherein the outsole (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) reduces shearing motions within a first region (1670) of the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) compared to shearing motions within a second region (1660) of the midsole (110;

- 1410; 1510; 1630; 1730; 2110; 2210a-d), and d. wherein the outsole (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) comprises a plurality of protrusions (132; 1459; 1622; 1722; 1810; 2259a) that serve as anchor points to allow for a targeted local compression of the midsole material to selectively influence the shear capacity of the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d).
2. Sole according to claim 1, wherein the particles (1635; 1735) of expanded material comprise one or more of the following materials: expanded ethylene-vinyl-acetate, expanded thermoplastic urethane, expanded polypropylene, expanded polyamide, expanded polyether block amide, expanded polyoxymethylene, expanded polystyrene, expanded polyethylene, expanded polyoxyethylene, expanded ethylene propylene diene monomer.
3. Sole according to one of the preceding claims, wherein the outsole (130; 1450; 1540; 1620; 1800a-d; 2150; 2250a-d) comprises one or more of the following materials: rubber, thermoplastic urethane, textile materials, polyether block amide, foils or foil-like materials.
4. Sole according to one of the preceding claims, wherein the first region of the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) has a larger intrinsic shear resistance than the second region of the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d).
5. Sole according to one of the preceding claims, wherein the outsole further (130; 1450; 1540; 1620; 1800a-d; 2150; 2250a-d) has a larger thickness and/or fewer holes (138; 1452; 2152; 2155; 2158; 2252a-d) in a first control region controlling the shearing motion of the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) in the first region than in a second control region controlling the shearing motion of the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) in the second region.
6. Sole according to one of the preceding claims, wherein the outsole (1450; 1620; 1720) comprises a decoupling region (160) that is not directly attached to the second region of the midsole.
7. Sole according to one of the preceding claims, wherein the outsole (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) and the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) are manufactured from a common class of materials, in particular thermoplastic urethane.
8. Sole according to one of the preceding claims, wherein the first region is located in the medial mid-foot region and wherein the second region is located in the lateral heel region.
9. Sole according to one of the preceding claims, wherein the outsole (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) further increases the bending resistance of midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) in the first region compared to the second region.
10. Sole according to one of the preceding claims, further comprising a frame made from non-expanded material, in particular ethylene-vinyl-acetate, surrounding at least a part of the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d).
11. Sole according to one of the preceding claims, wherein the midsole (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) allows for a shearing motion in longitudinal direction of a lower sole surface relative to an upper sole surface of more than 1 mm, preferably more than 1.5 mm, and particularly preferably more than 2 mm.
12. Sole according to one of the preceding claims, wherein the outsole (2150; 2250a-d) is laser-cut from a blank.
13. Shoe (1400; 1500; 2100; 2200a-d), in particular a sports shoe, with a sole (100; 1610; 1710) according to one of the preceding claims.

Patentansprüche

1. Sohle (100; 1610; 1710) für einen Schuh (1400; 1500; 2100; 2200a-d), insbesondere einen Sportschuh, aufweisend:
- a. eine Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d), die zufällig angeordnete Partikel (1635; 1735) aus einem expandierten Material aufweist,
 - b. eine Außensohle (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) frei von expandiertem Material,
 - c. wobei die Außensohle (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) Scherbewegungen in einem ersten Bereich (1670) der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) gegenüber Scherbewegungen in einem zweiten Bereich (1660) der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) verringert, und
 - d. wobei die Außensohle (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) eine Mehrzahl von Vorsprüngen (132; 1459; 1622;

- 1722; 1810; 2259a) aufweist, welche als Ankerpunkte dienen, um eine gezielte lokale Kompression des Mittelsohlenmaterials zu erlauben, um die Scherfähigkeit der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) selektiv zu beeinflussen.
2. Sohle gemäß Anspruch 1, wobei die Partikel (1635; 1735) aus expandiertem Material eines oder mehrere der folgenden Materialien aufweisen: expandiertes Ethylen-Vinyl-Acetat, expandiertes thermoplastische Urethan, expandiertes Polypropylen, expandiertes Polyamid, expandiertes Polyetherblockamid, expandiertes Polyoxymethylen, expandiertes Polystyrol, expandiertes Polyethylen, expandiertes Polyoxyethylen, expandiertes Ethylen-Propylen-Dien-Monomer. 5 10
 3. Sohle gemäß einem der vorhergehenden Ansprüche, wobei die Außensohle (130; 1450; 1540; 1620; 1800a-d; 2150; 2250a-d) eines oder mehrere der folgenden Materialien aufweist: Gummi, thermoplastisches Urethan, textile Materialien, Polyetherblockamid, Folien oder folienartige Materialien. 15 20
 4. Sohle gemäß einem der vorhergehenden Ansprüche, wobei der erste Bereich der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) einen größeren intrinsischen Scherwiderstand hat als der zweite Bereich der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d). 25 30
 5. Sohle gemäß einem der vorhergehenden Ansprüche, wobei die Außensohle (130; 1450; 1540; 1620; 1800a-d; 2150; 2250a-d) ferner in einem ersten Steuerbereich, der die Scherbewegung der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) in dem ersten Bereich steuert, eine größere Dicke und / oder weniger Löcher (138; 1452; 2152; 2155; 2158; 2252a-d) hat als in einem zweiten Steuerbereich, der die Scherbewegung der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) in dem zweiten Bereich steuert. 35 40
 6. Sohle gemäß einem der vorhergehenden Ansprüche, wobei die Außensohle (1450; 1620; 1720) einen Entkopplungsbereich (160) aufweist, der nicht direkt an dem zweiten Bereich der Mittelsohle befestigt ist. 45
 7. Sohle gemäß einem der vorhergehenden Ansprüche, wobei die Außensohle (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) und die Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) aus Materialien derselben Materialklasse, insbesondere aus thermoplastischem Urethan, hergestellt sind. 50 55
 8. Sohle gemäß einem der vorhergehenden Ansprüche, wobei der erste Bereich sich im medialen Mittelfußbereich befindet und wobei der zweite Bereich sich im lateralen Fersenbereich befindet.
 9. Sohle gemäß einem der vorhergehenden Ansprüche, wobei die Außensohle (130; 1450; 1540; 1620; 1720; 1800a-d; 2150; 2250a-d) ferner den Biege- 5 widerstand der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) in dem ersten Bereich gegenüber dem zweiten Bereich erhöht.
 10. Sohle gemäß einem der vorhergehenden Ansprüche, weiter aufweisend einen Rahmen hergestellt aus nicht-expandiertem Material, insbesondere Ethylen-Vinyl-Acetat, der zumindest einen Teil der Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) umgibt.
 11. Sohle gemäß einem der vorhergehenden Ansprüche, wobei die Mittelsohle (110; 1410; 1510; 1630; 1730; 2110; 2210a-d) eine Scherbewegung in Längsrichtung einer unteren Sohlenoberfläche relativ zu einer oberen Sohlenoberfläche von mehr als 1 mm, bevorzugt mehr als 1,5 mm und besonders bevorzugt mehr als 2 mm ermöglicht.
 12. Sohle gemäß einem der vorhergehenden Ansprüche, wobei die Außensohle (2150; 2250a-d) durch einen Laser aus einem Rohling geschnitten ist.
 13. Schuh (1400; 1500; 2100; 2200a-d), insbesondere ein Sportschuh, mit einer Sohle (100; 1610; 1710) gemäß einem der vorhergehenden Ansprüche.

Revendications

1. Semelle (100 ; 1610 ; 1710) pour une chaussure (1400 ; 1500 ; 2100 ; 2200a-d), en particulier une chaussure de sport, comprenant :
 - a. une semelle intermédiaire (110 ; 1410 ; 1510 ; 1630 ; 1730; 2110; 2110a-d) comprenant des particules agencées aléatoirement (1635 ; 1735) d'un matériau expansé,
 - b. une semelle extérieure (130; 1450; 1540; 1620, 1720; 1800a-d; 2150; 2250a-d) dépourvue de matériau expansé,
 - c. dans laquelle la semelle extérieure (130; 1450 ; 1540 ; 1620, 1720 ; 1800a-d ; 2150 ; 2250a-d) réduit les mouvements de cisaillement au sein d'une première région (1670) de la semelle intermédiaire (110 ; 1410; 1510; 1630; 1730; 2110; 2110a-d) par rapport aux mouvements de cisaillement au sein d'une seconde région (1660) de la semelle intermédiaire (110 ; 1410 ; 1510 ; 1630 ; 1730 ; 2110 ; 2110a-d), et
 - d. dans laquelle la semelle extérieure (130; 1450 ; 1540; 1620, 1720; 1800a-d; 2150;

- 2250a-d) comprend une pluralité de saillies (132; 1459 ; 1622; 1722; 1810; 2259a) qui servent de points d'ancrage pour permettre une compression locale ciblée du matériau de la semelle intermédiaire pour influencer sélectivement la capacité de cisaillement de la semelle intermédiaire (110; 1410; 1510 ; 1630 ; 1730 ; 2110 ; 2110a-d).
2. Semelle selon la revendication 1, dans laquelle les particules (1635 ; 1735) de matériau expansé comprennent un ou plusieurs des matériaux suivants : éthylène-acétate de vinyle expansé, uréthane thermoplastique expansé, polypropylène expansé, polyamide expansé, polyéther amide à blocs expansé, polyoxyméthylène expansé, polystyrène expansé, polyéthylène expansé, polyoxyéthylène expansé, monomère éthylène-propylène-diène expansé.
 3. Semelle selon l'une des revendications précédentes, dans laquelle la semelle extérieure (130 ; 1450 ; 1540 ; 1620, 1720; 1800a-d; 2150 ; 2250a-d) comprend un ou plusieurs des matériaux suivants : caoutchouc, uréthane thermoplastique, matériaux textiles, polyéther amide à blocs, feuilles ou matériaux semblables à des feuilles.
 4. Semelle selon l'une des revendications précédentes, dans laquelle la première région de la semelle intermédiaire (110 ; 1410 ; 1510 ; 1630 ; 1730 ; 2110 ; 2110a-d) présente une résistance intrinsèque au cisaillement plus élevée que la seconde région de la semelle intermédiaire (110 ; 1410 ; 1510 ; 1630 ; 1730 ; 2110 ; 2110a-d).
 5. Semelle selon l'une des revendications précédentes, dans laquelle en outre la semelle extérieure (130 ; 1450; 1540; 1620, 1720; 1800a-d; 2150; 2250a-d) présente une épaisseur plus élevée et/ou moins de trous (138; 1452; 2152; 2155; 2158; 2252a-b) dans une première région de contrôle contrôlant le mouvement de cisaillement de la semelle intermédiaire (110; 1410 ; 1510; 1630; 1730; 2110 ; 2110a-d) dans la première région que dans une seconde région de contrôle contrôlant le mouvement de cisaillement de la semelle intermédiaire (110 ; 1410 ; 1510 ; 1630 ; 1730 ; 2110 ; 2110a-d) dans la seconde région.
 6. Semelle selon l'une des revendications précédentes, dans laquelle la semelle extérieure (1450 ; 1620 ; 1720) comprend une région de découplage (160) qui n'est pas directement solidarisée à la seconde région de la semelle intermédiaire.
 7. Semelle selon l'une des revendications précédentes, dans laquelle la semelle extérieure (130 ; 1450 ; 1540 ; 1620, 1720; 1800a-d; 2150; 2250a-d) et la semelle intermédiaire (110 ; 1410 ; 1510 ; 1630 ; 1730 ; 2110 ; 2110a-d) sont fabriquées à partir d'une classe commune de matériaux, en particulier un uréthane thermoplastique.
 8. Semelle selon l'une des revendications précédentes, dans laquelle la première région est située dans la région médiale du milieu du pied et dans laquelle la seconde région est située dans la région latérale du talon.
 9. Semelle selon l'une des revendications précédentes, dans laquelle la semelle extérieure (130 ; 1450 ; 1540 ; 1620, 1720 ; 1800a-d ; 2150 ; 2250a-d) augmente en outre la résistance à la flexion de la semelle intermédiaire (110 ; 1410 ; 1510 ; 1630 ; 1730 ; 2110 ; 2110a-d) dans la première région par rapport à la seconde région.
 10. Semelle selon l'une des revendications précédentes, comprenant en outre un cadre réalisé en un matériau non expansé, en particulier en éthylène-acétate de vinyle, entourant au moins une partie de la semelle intermédiaire (110 ; 1410 ; 1510 ; 1630 ; 1730 ; 2110 ; 2110a-d).
 11. Semelle selon l'une des revendications précédentes, dans laquelle la semelle intermédiaire (110; 1410 ; 1510 ; 1630; 1730; 2110; 2110a-d) autorise un mouvement de cisaillement en direction longitudinale d'une surface inférieure de la semelle par rapport à une surface supérieure de la semelle de plus de 1 mm, de préférence de plus de 1,5 mm, et de façon particulièrement préférée de plus de 2 mm.
 12. Semelle selon l'une des revendications précédentes, dans laquelle la semelle extérieure (2150 ; 2250a-d) est découpée au laser à partir d'un flan.
 13. Chaussure (1400 ; 1500; 2100; 2200a-d), en particulier chaussure de sport, avec une semelle (100 ; 1610 ; 1710) selon l'une des revendications précédentes.

FIG 1

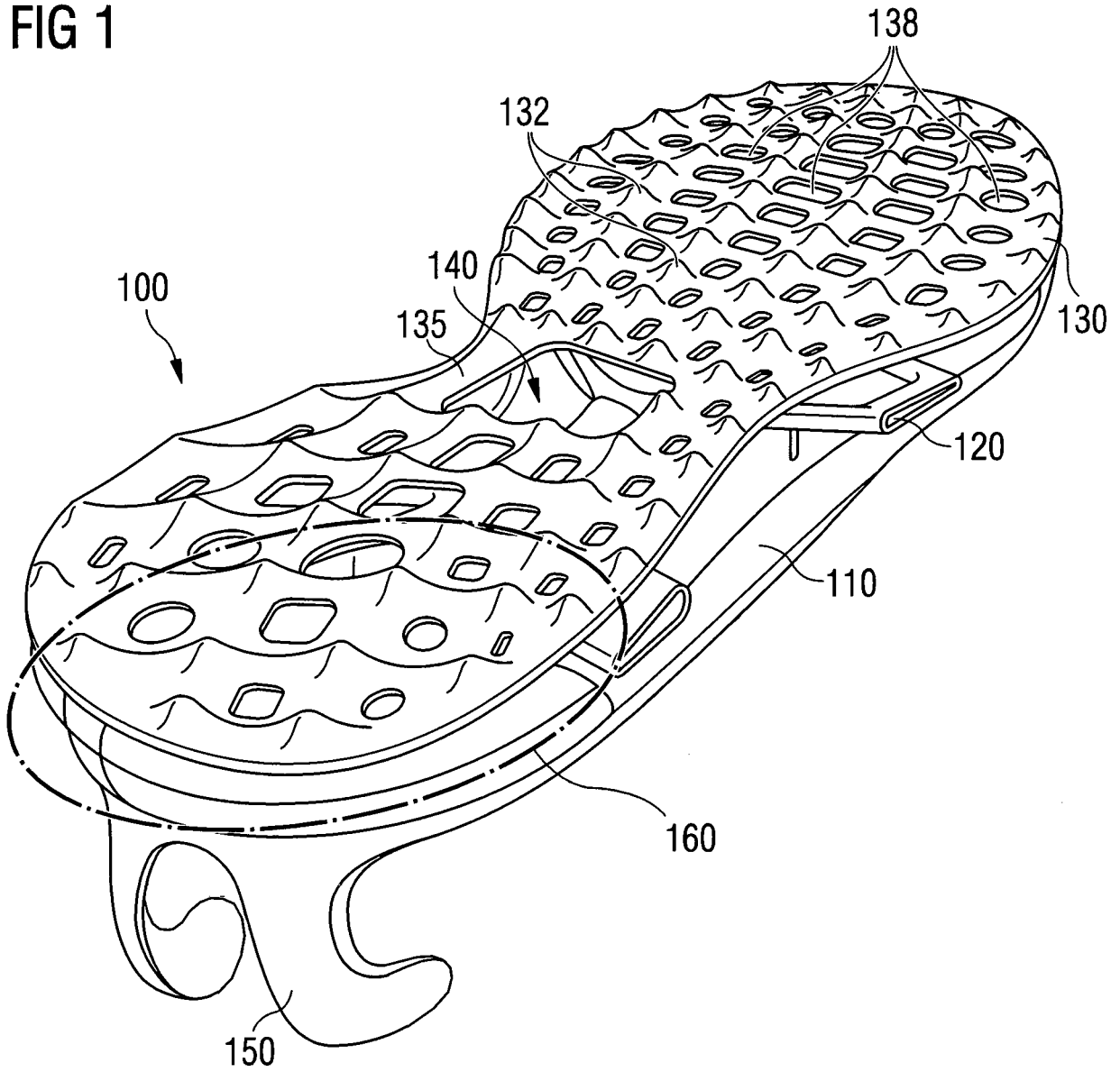


FIG 2

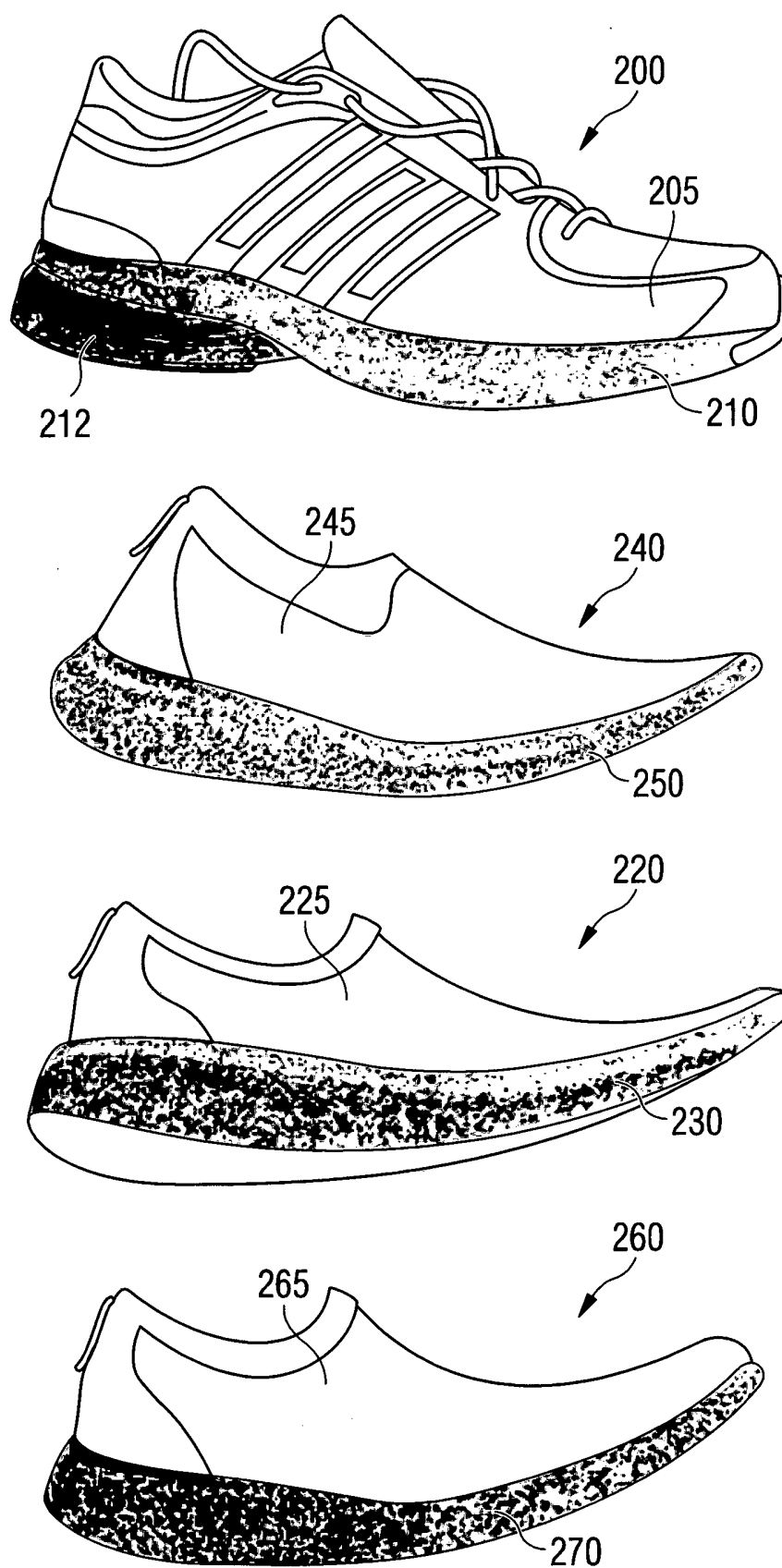


FIG 3a

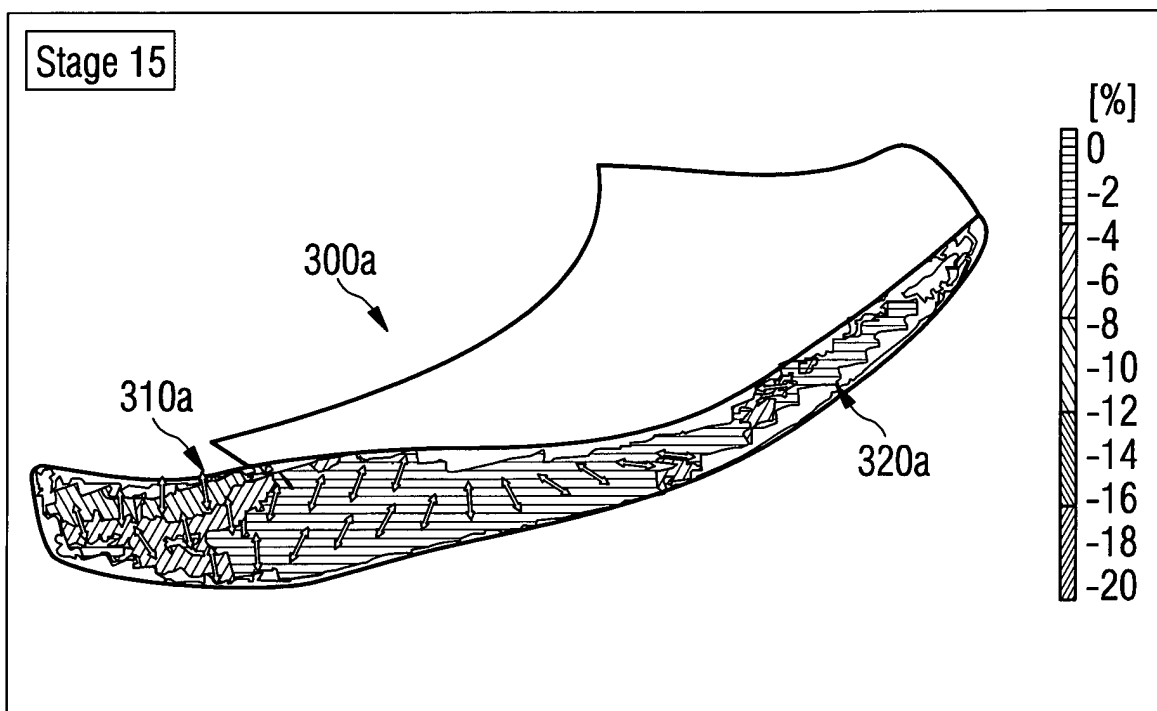


FIG 3b

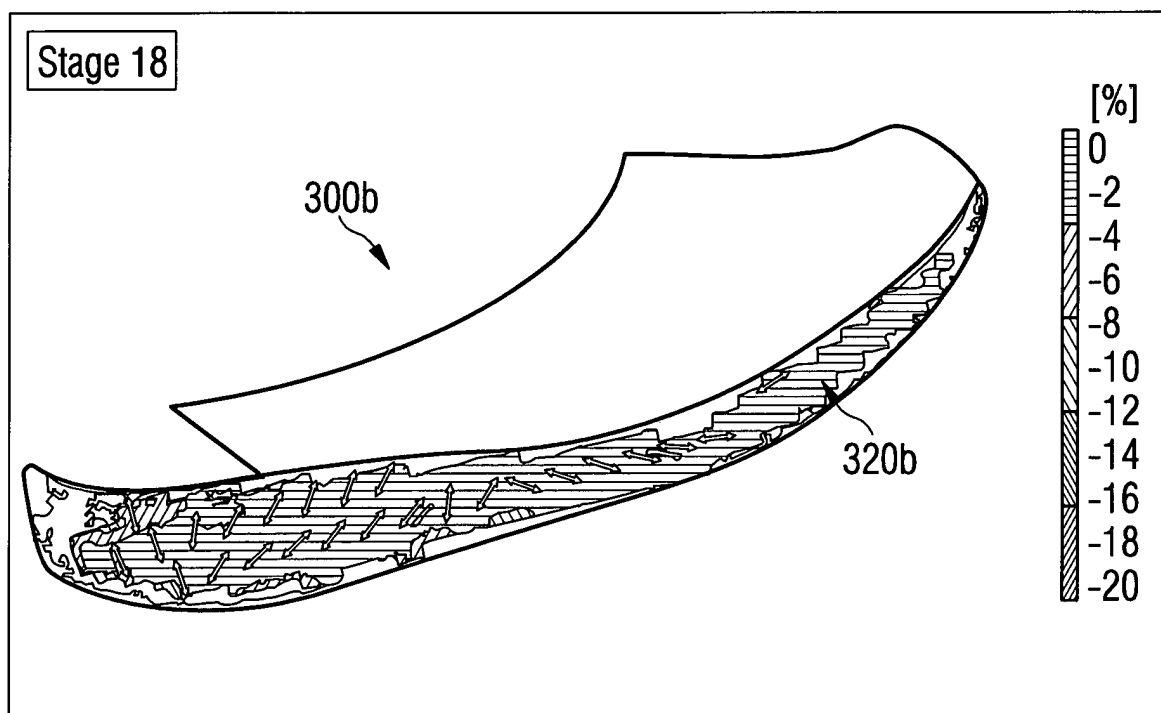


FIG 4

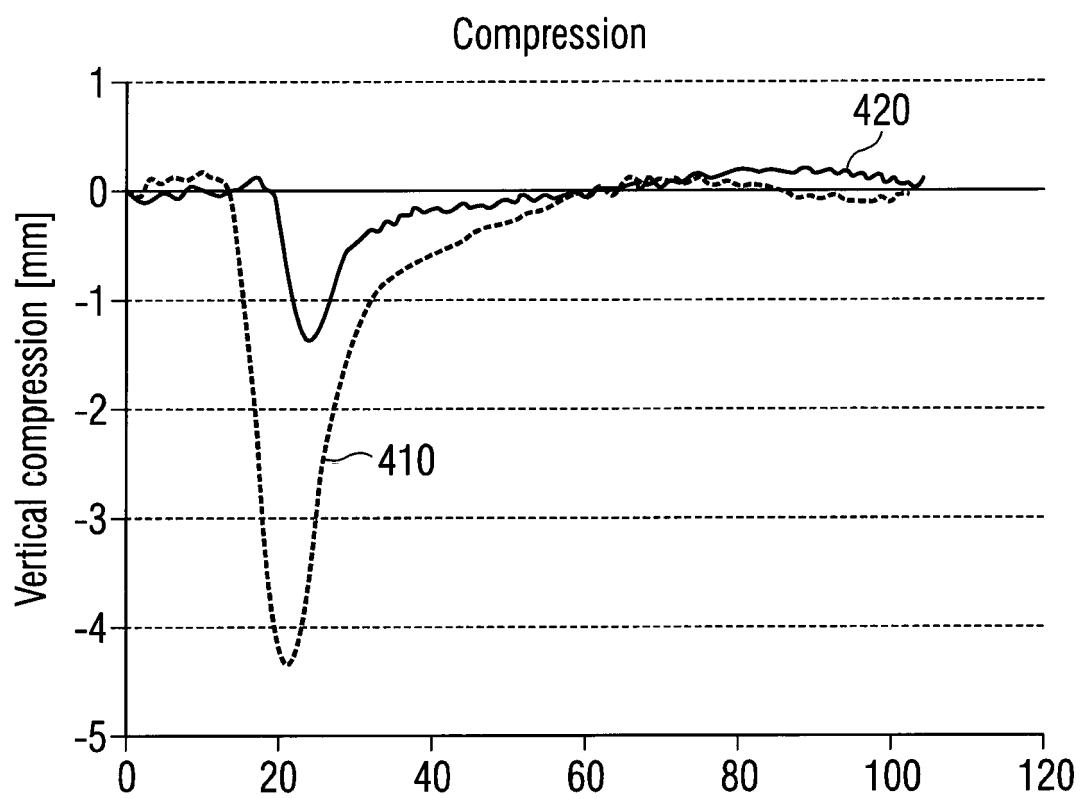


FIG 5a

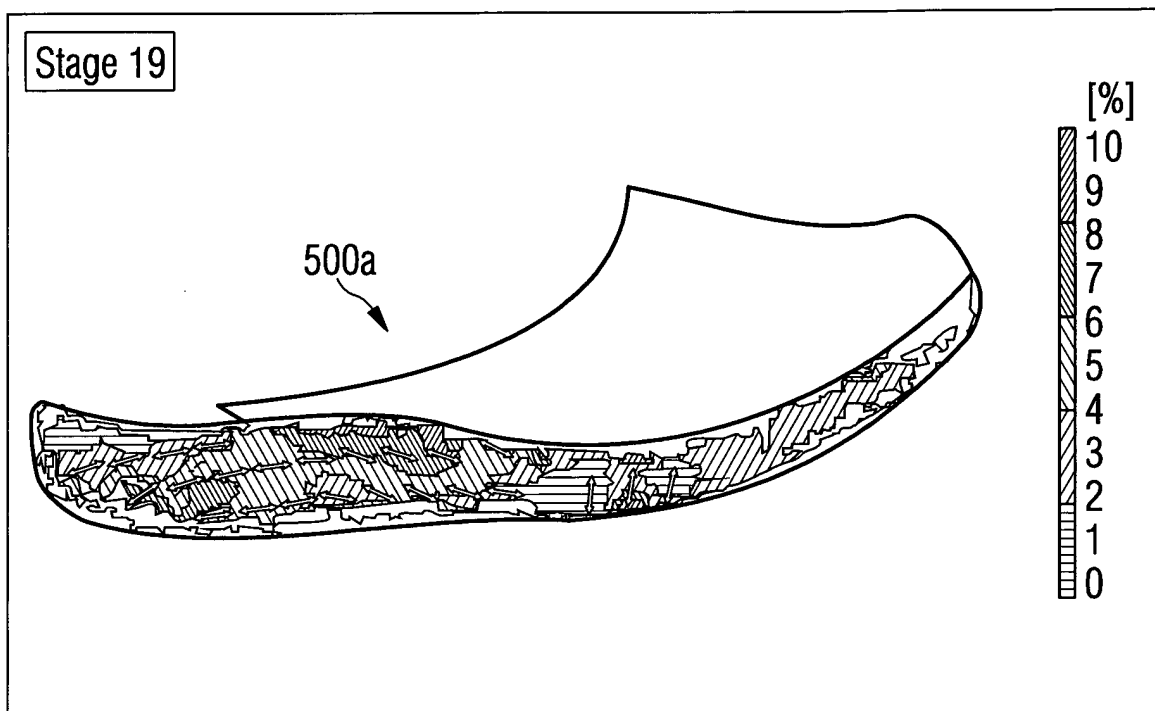


FIG 5b

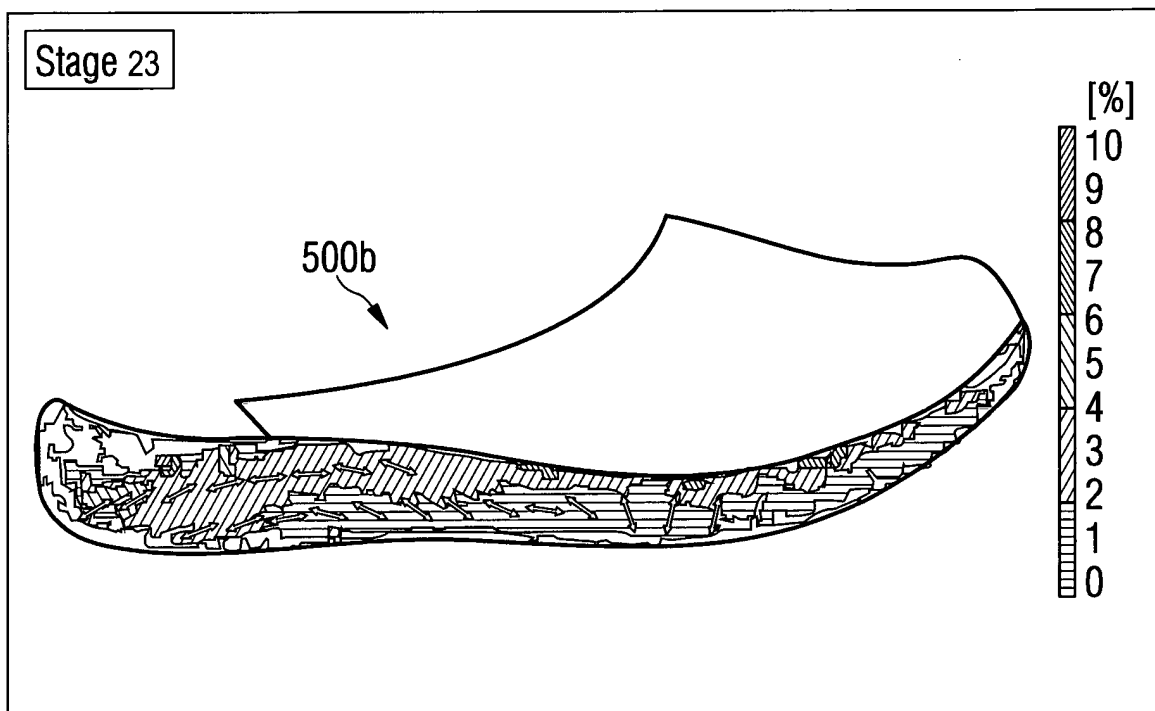


FIG 6a

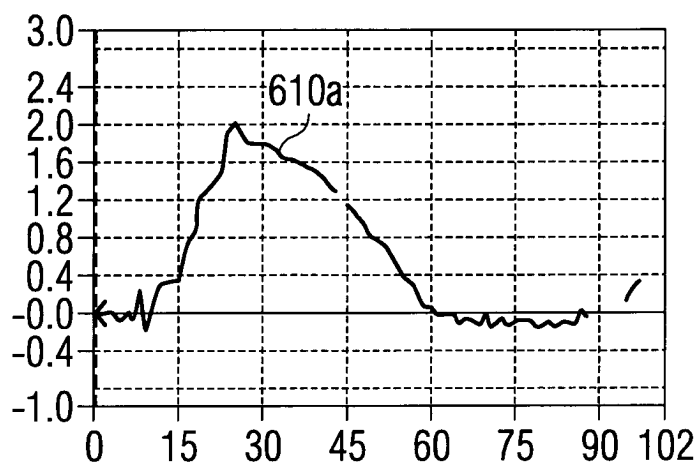


FIG 7a

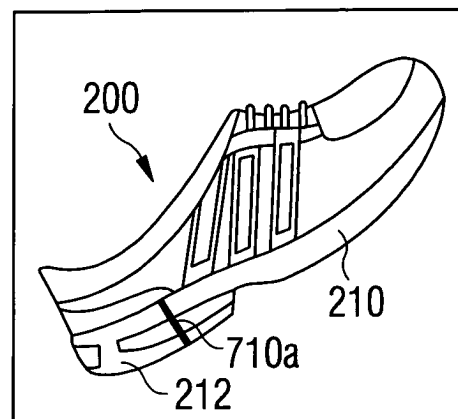


FIG 6b

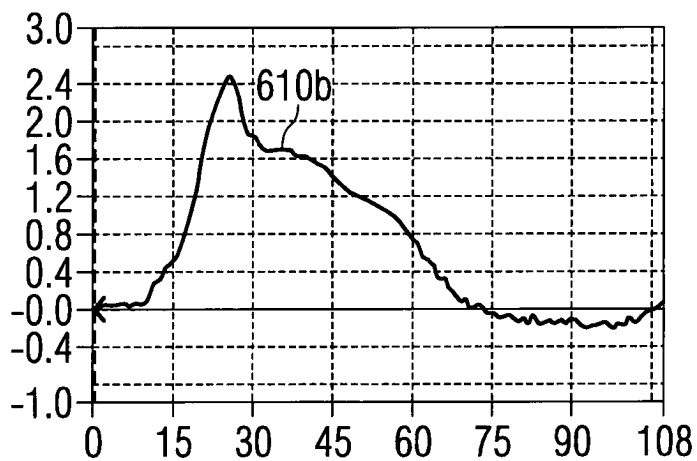


FIG 7b

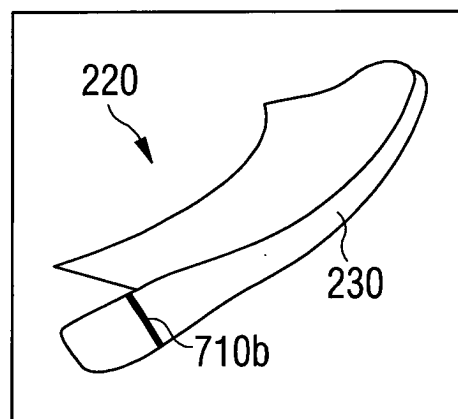


FIG 6c

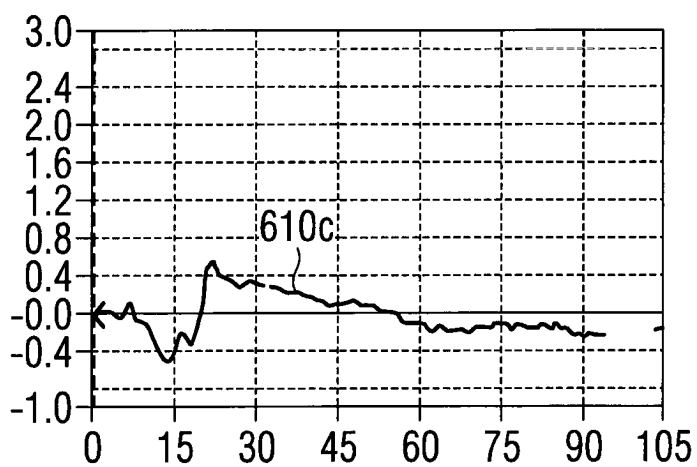


FIG 7c

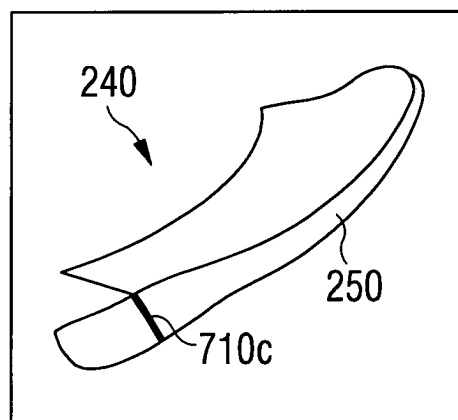


FIG 8a

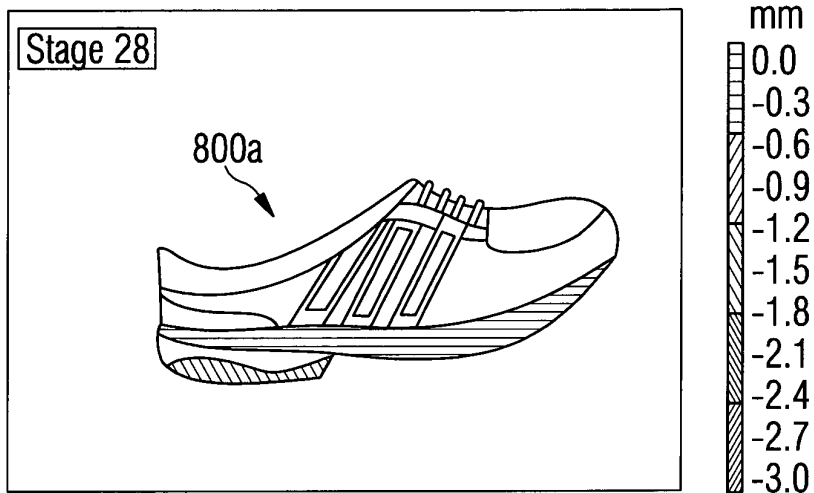


FIG 8b

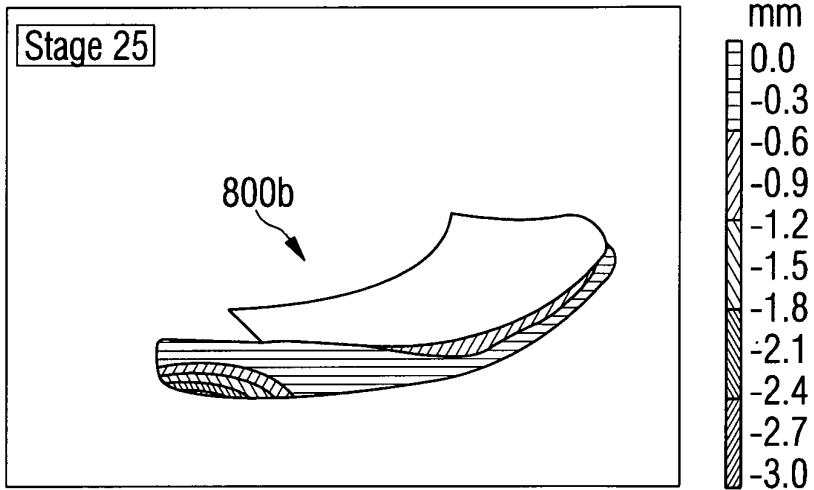


FIG 8c

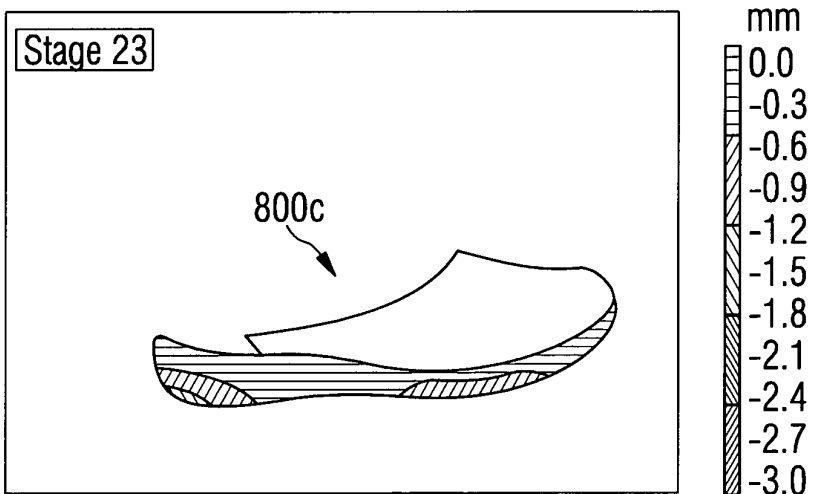


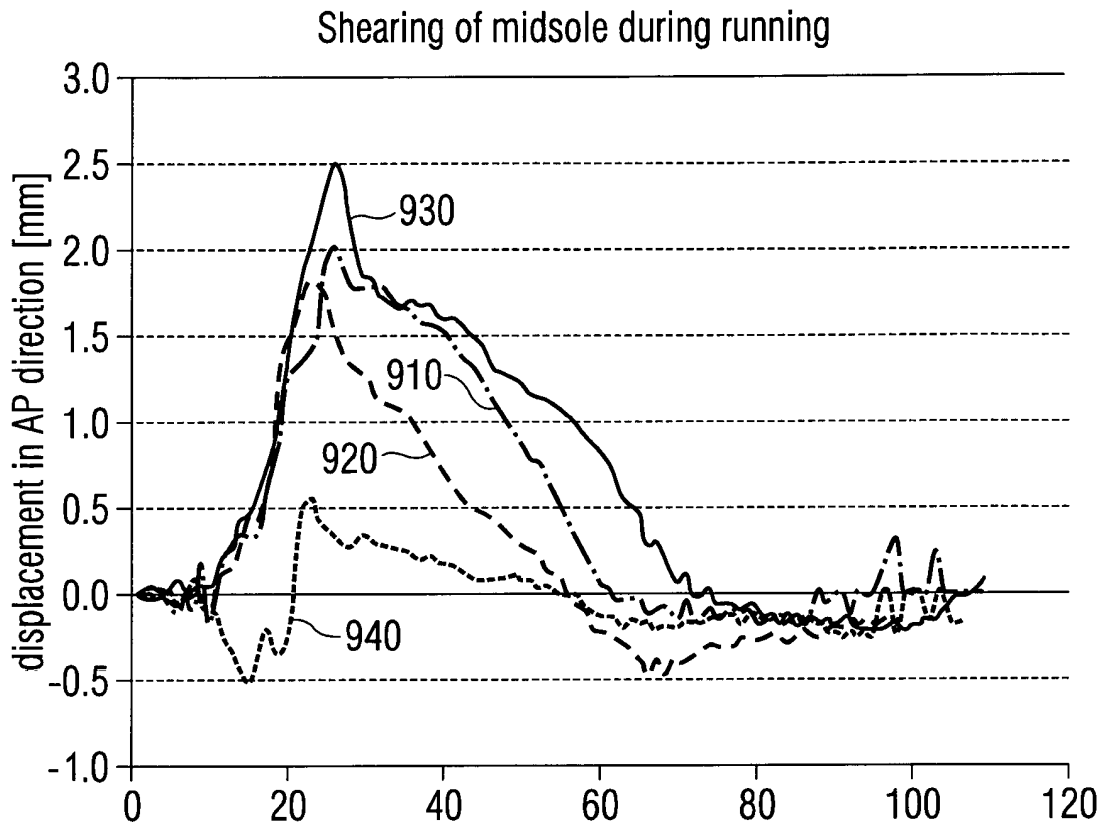
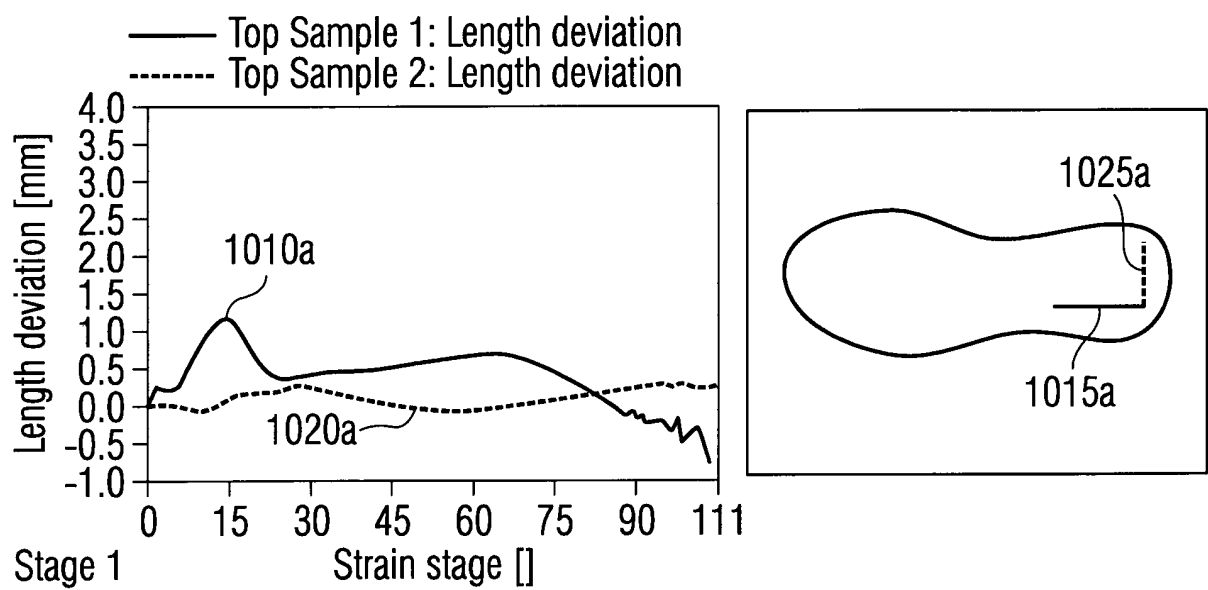
FIG 9**FIG 10a**

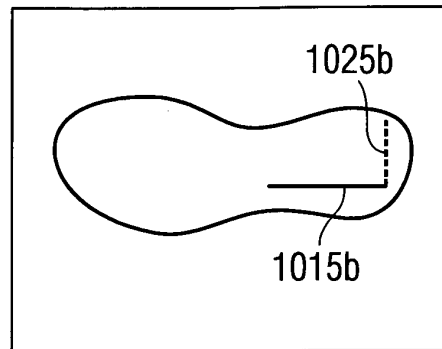
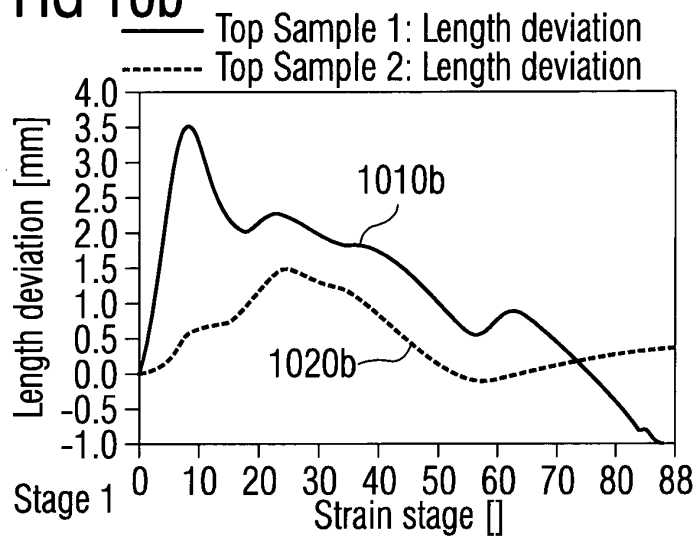
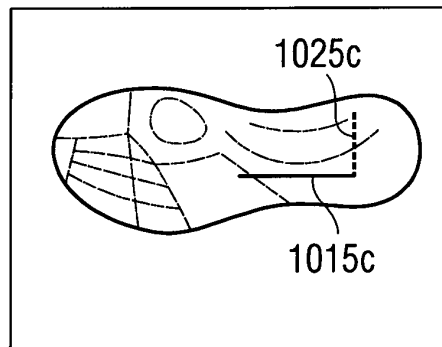
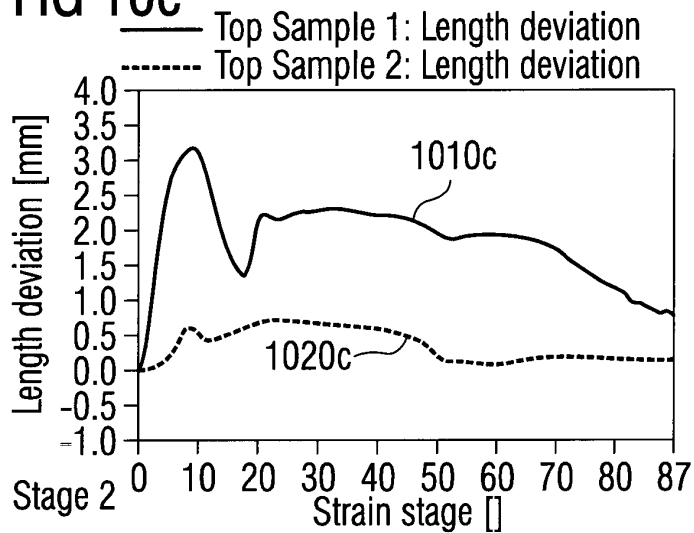
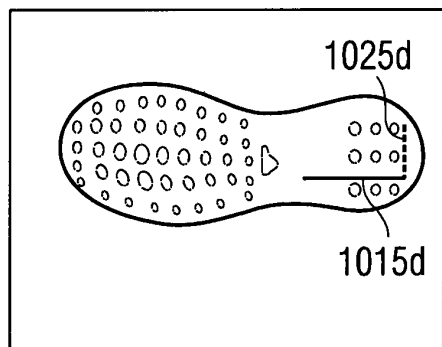
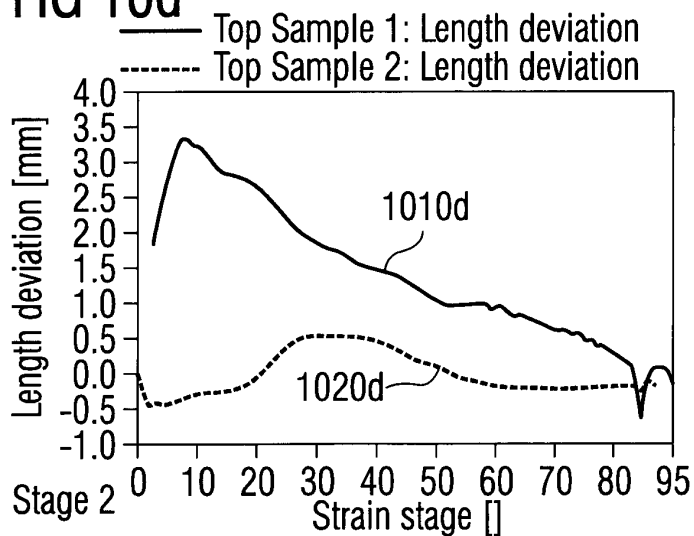
FIG 10b**FIG 10c****FIG 10d**

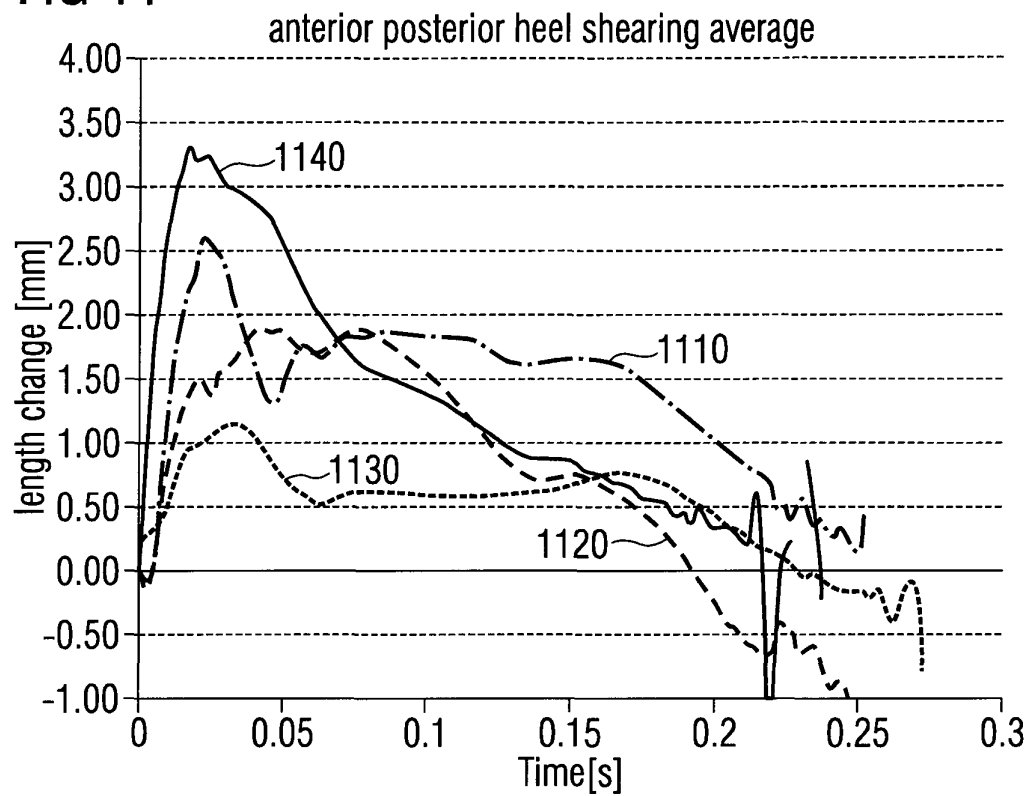
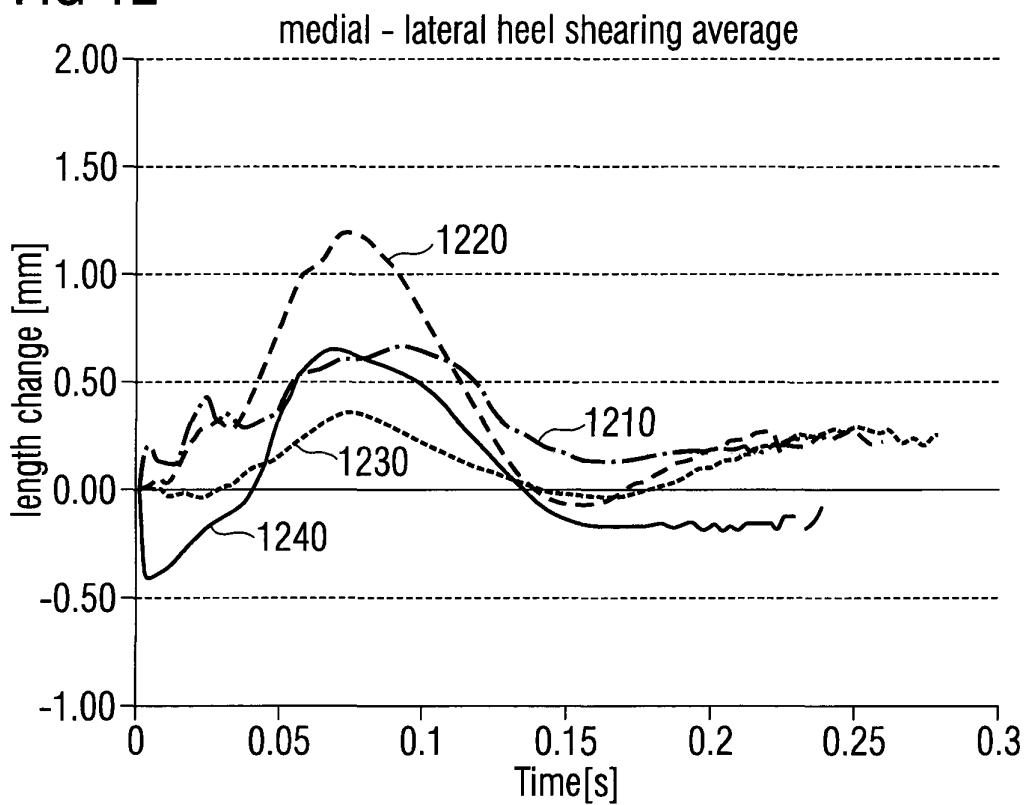
FIG 11**FIG 12**

FIG 13a

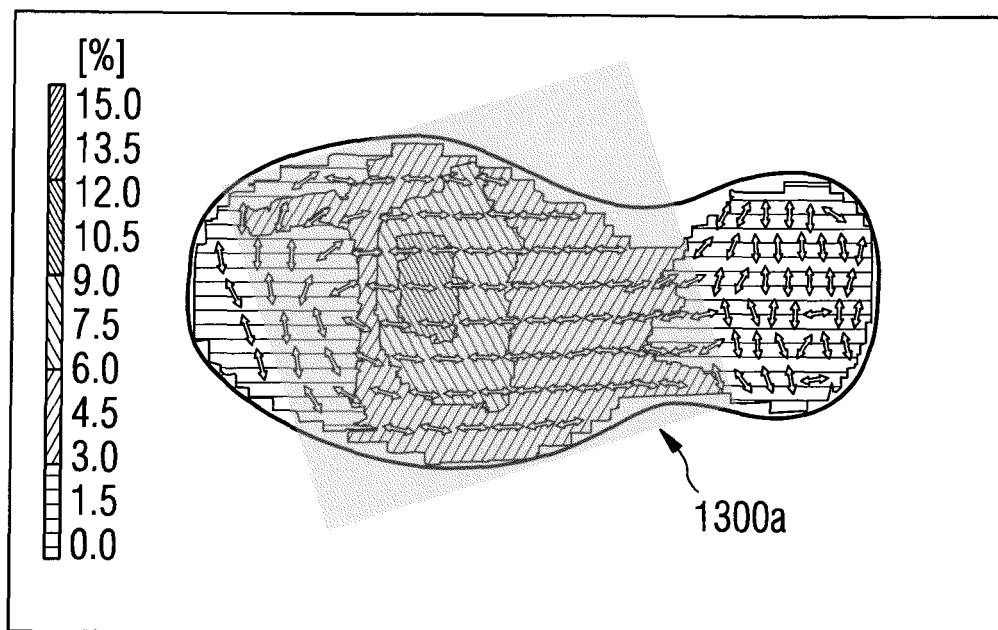


FIG 13b

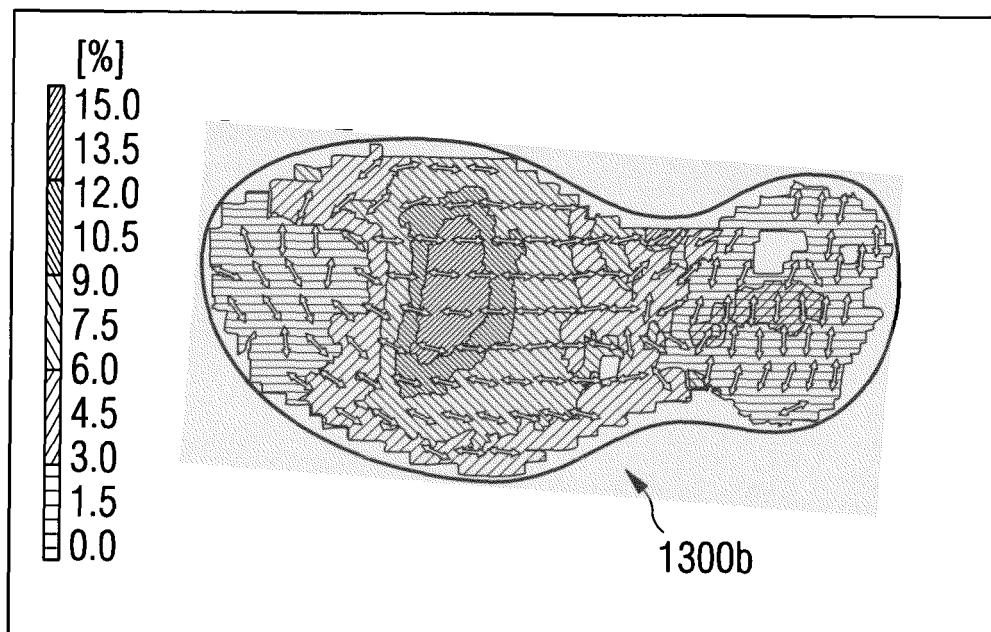


FIG 13c

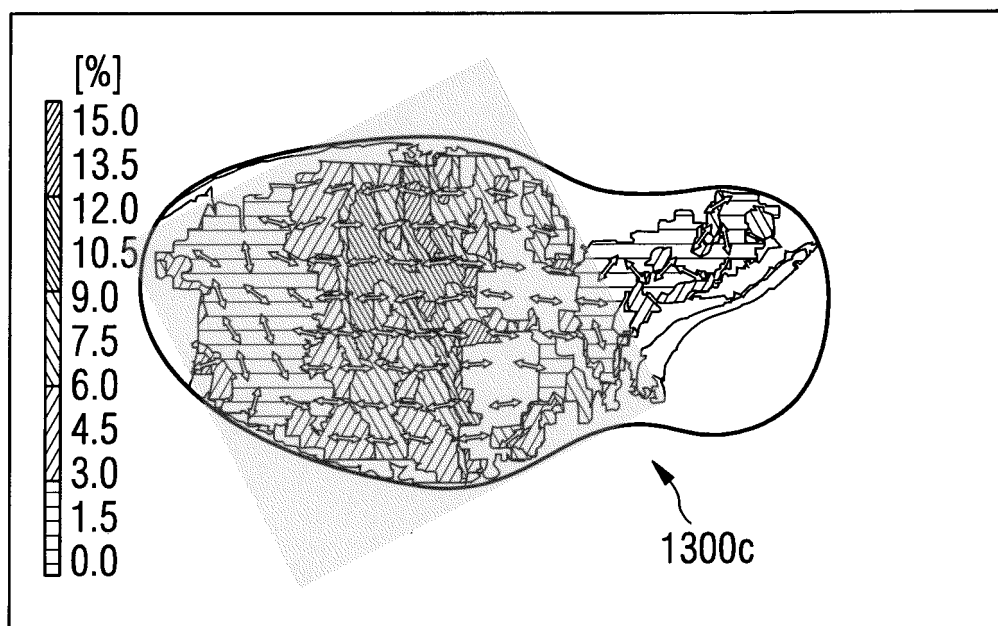


FIG 13d

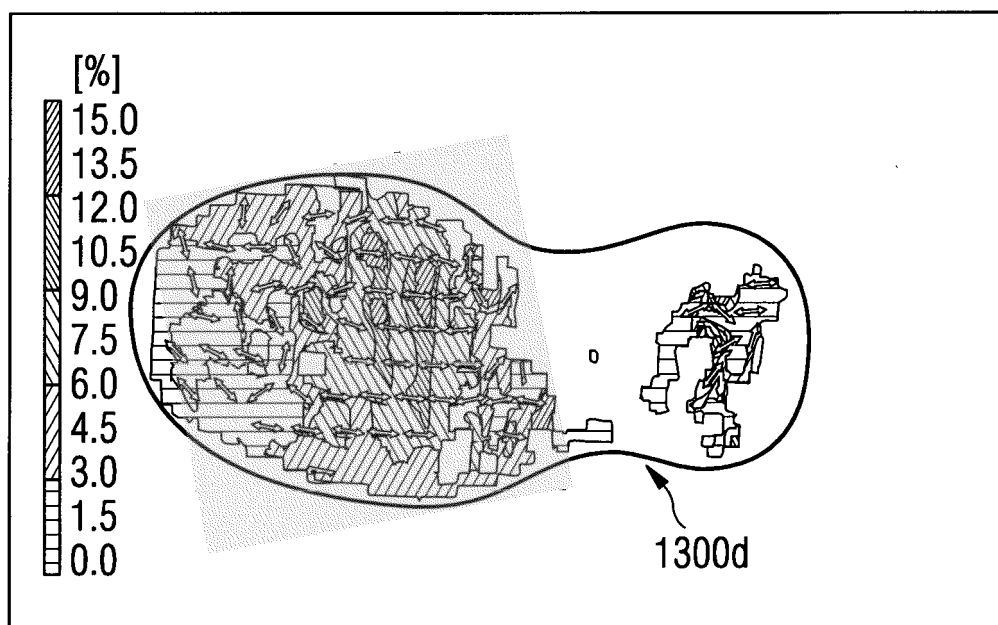


FIG 13e

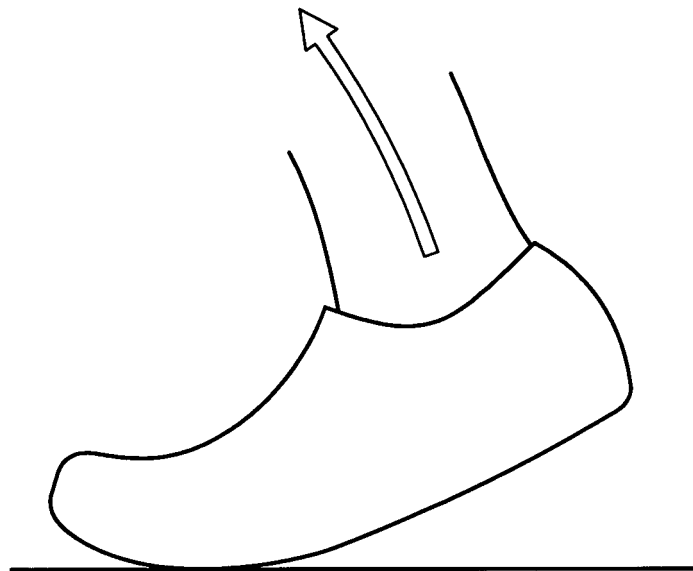


FIG 14a

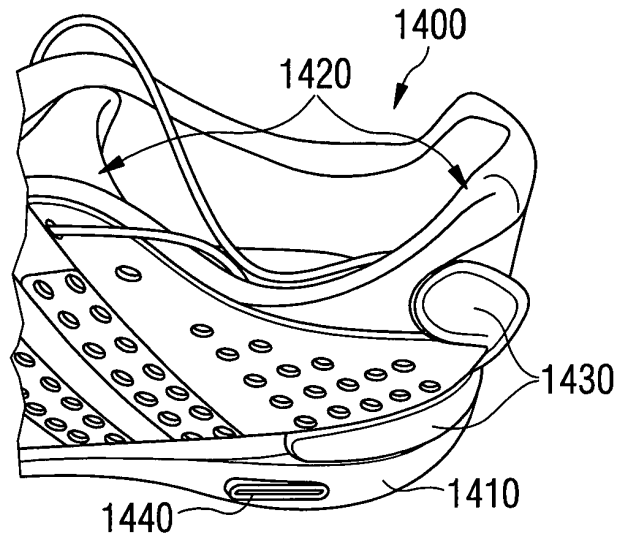


FIG 14b

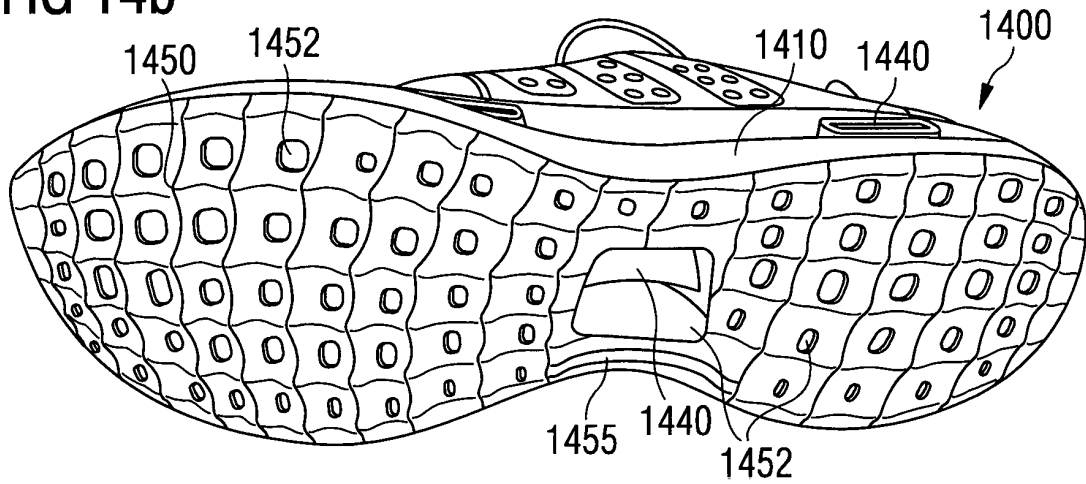


FIG 14c

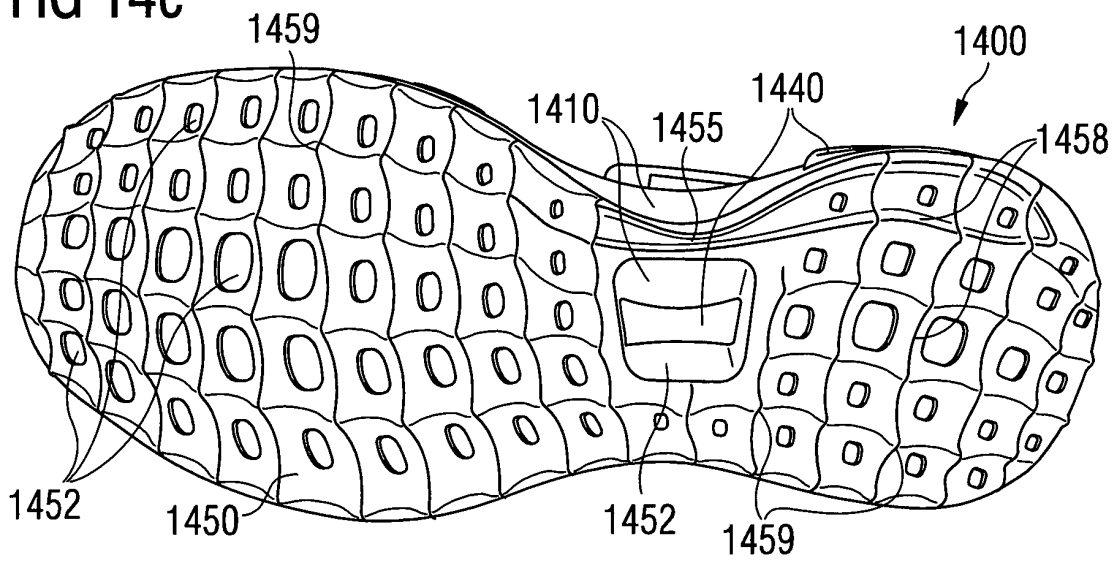


FIG 15a

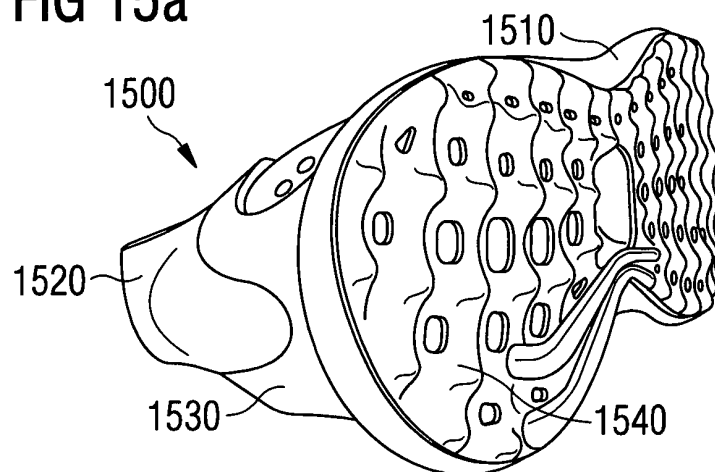


FIG 15b

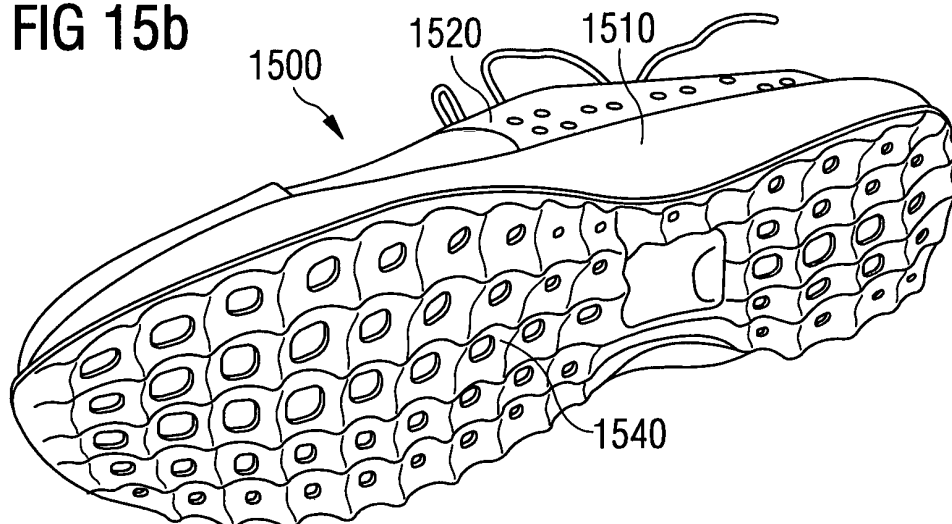


FIG 15c

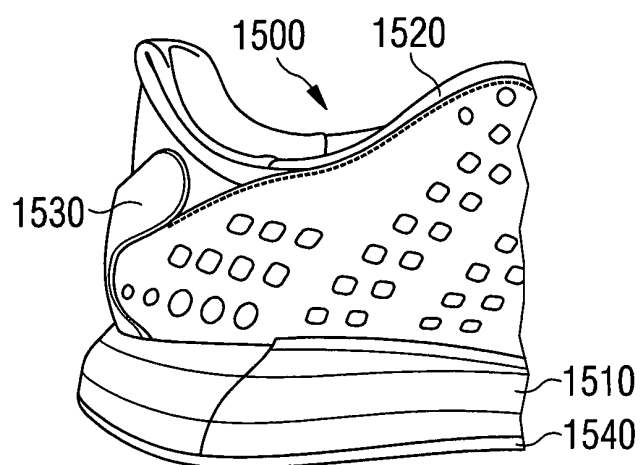


FIG 16a

FIG 16b

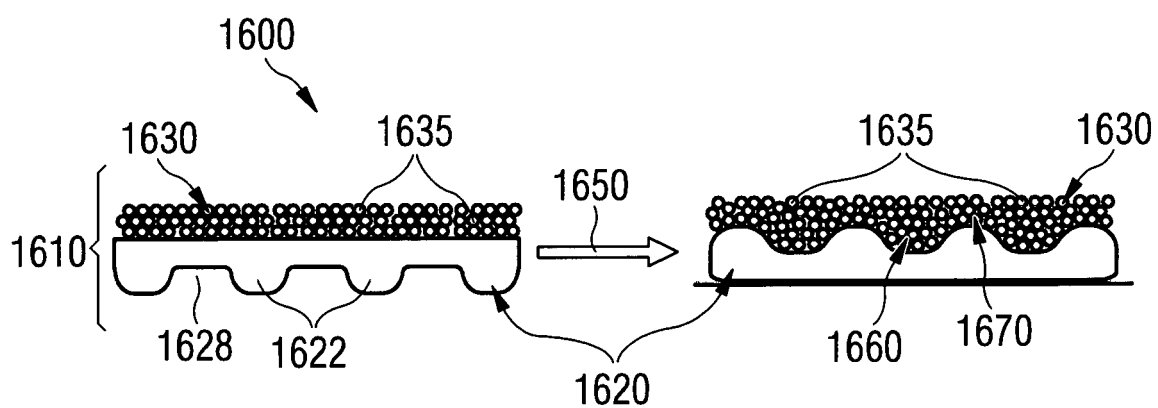


FIG 17

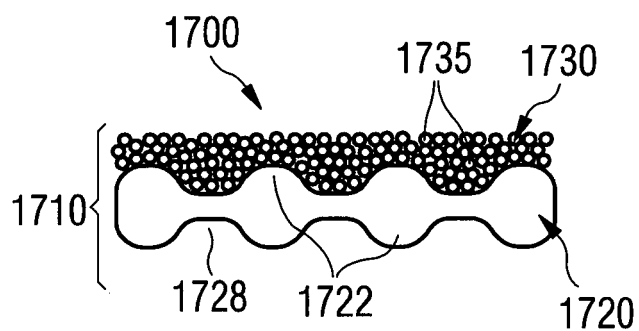


FIG 18

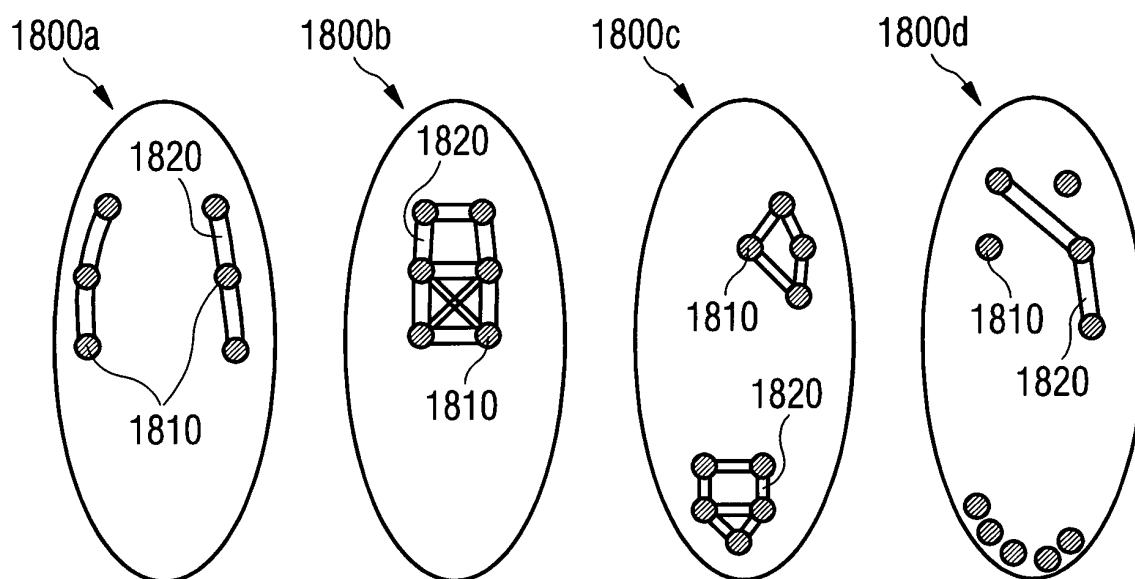


FIG 19

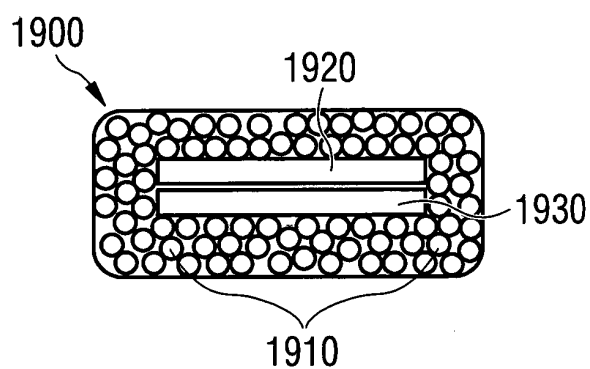


FIG 20

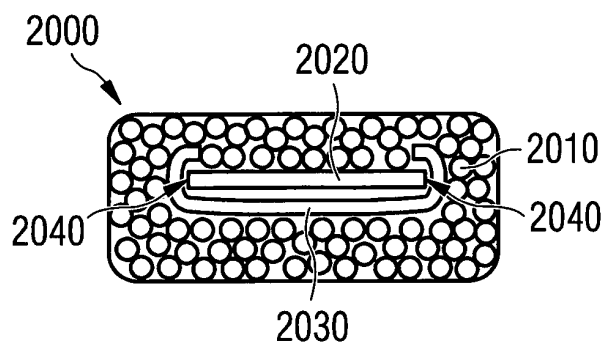


FIG 21a

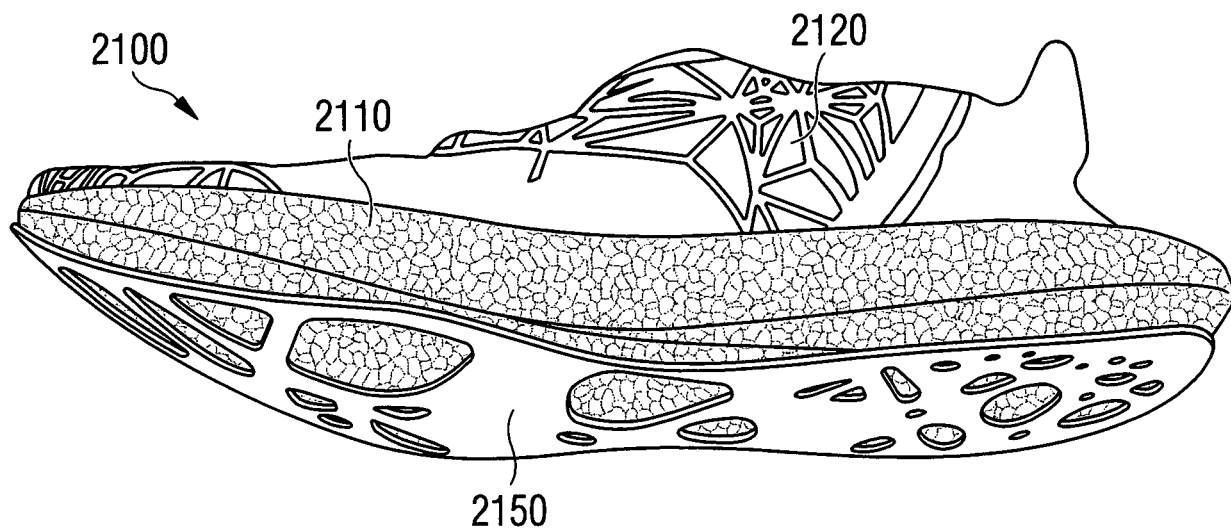


FIG 21b

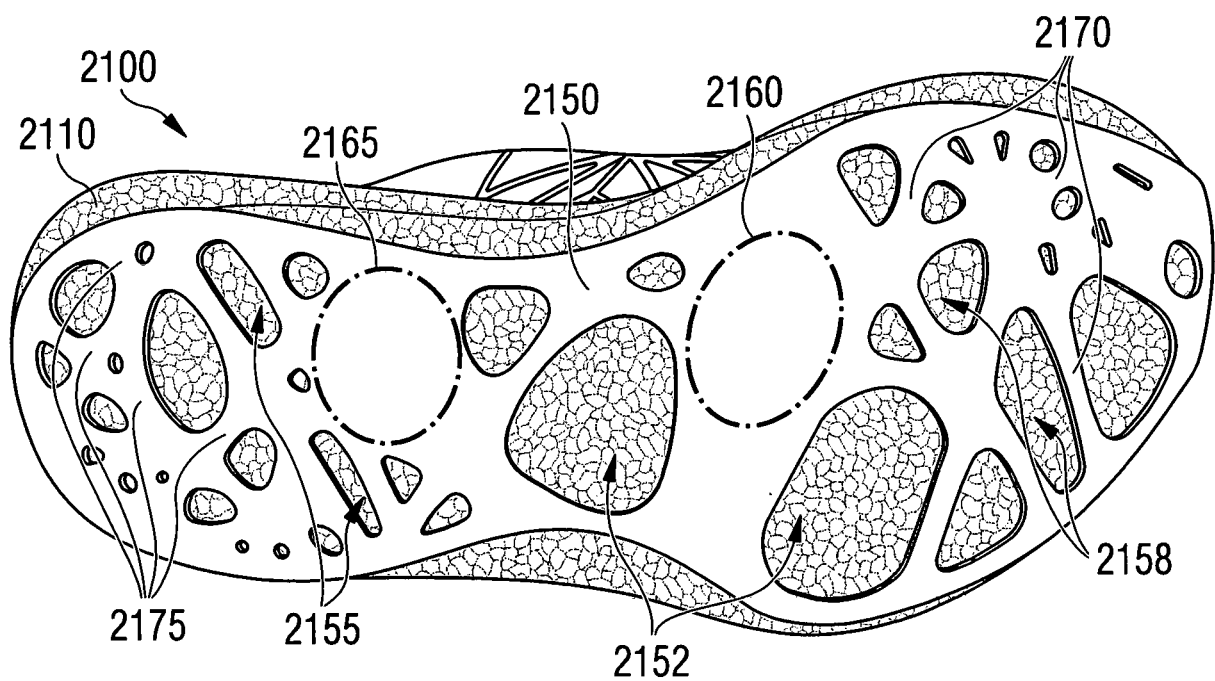


FIG 22a

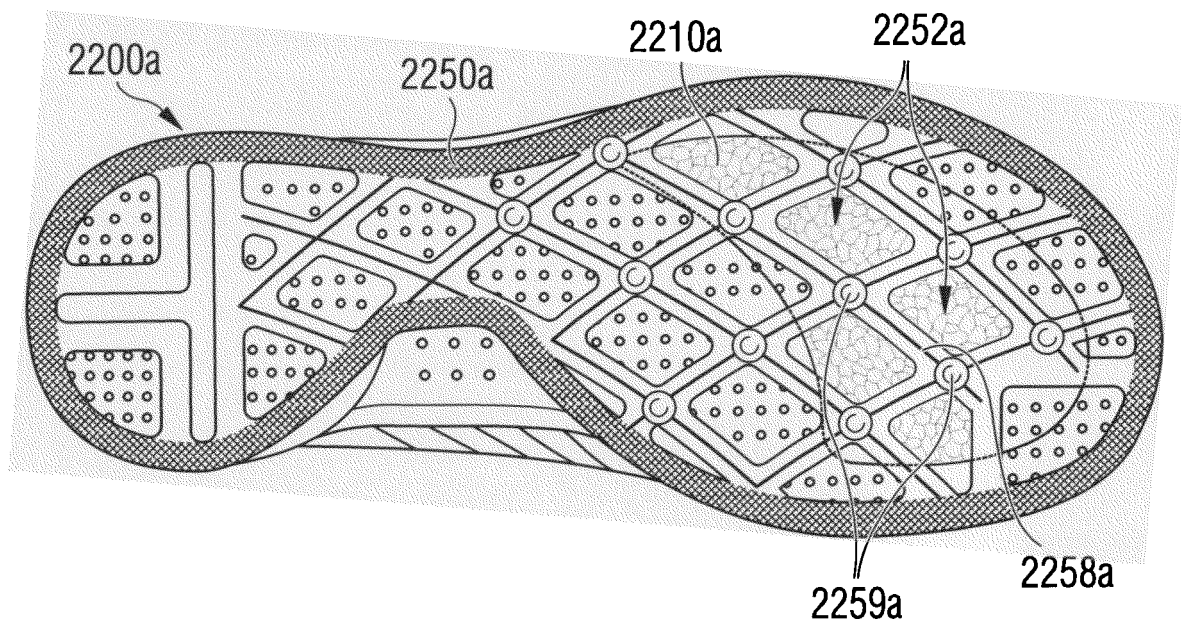


FIG 22b

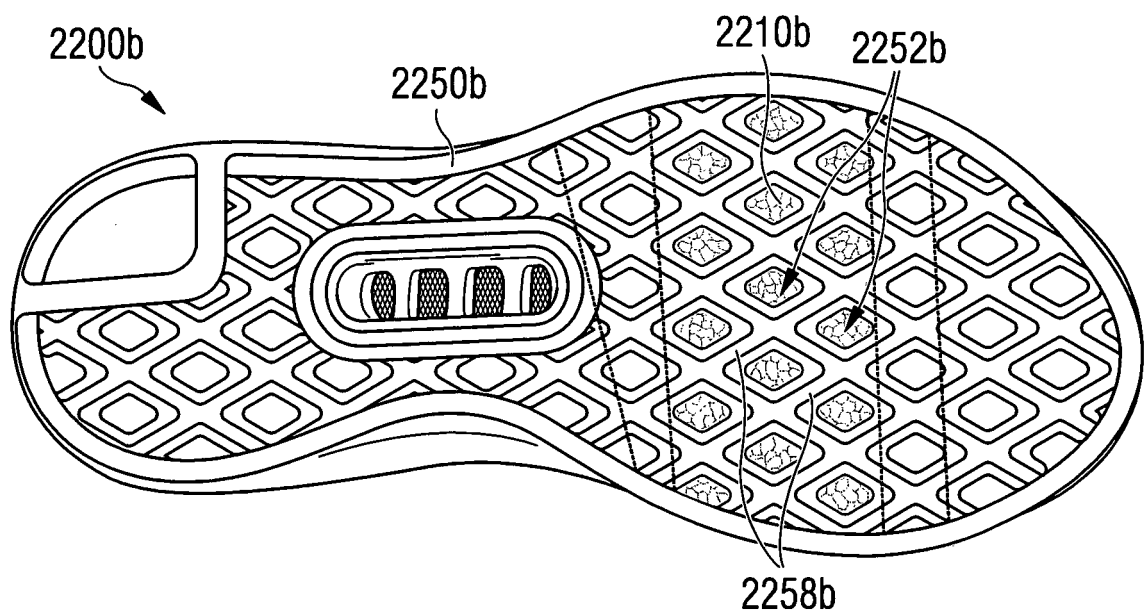


FIG 22c

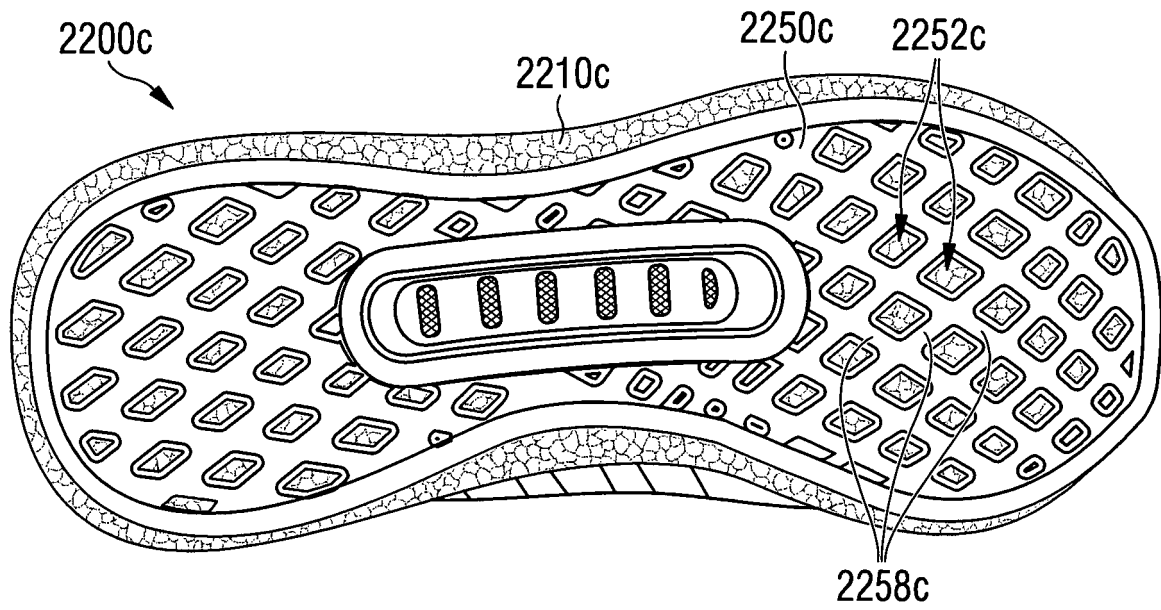
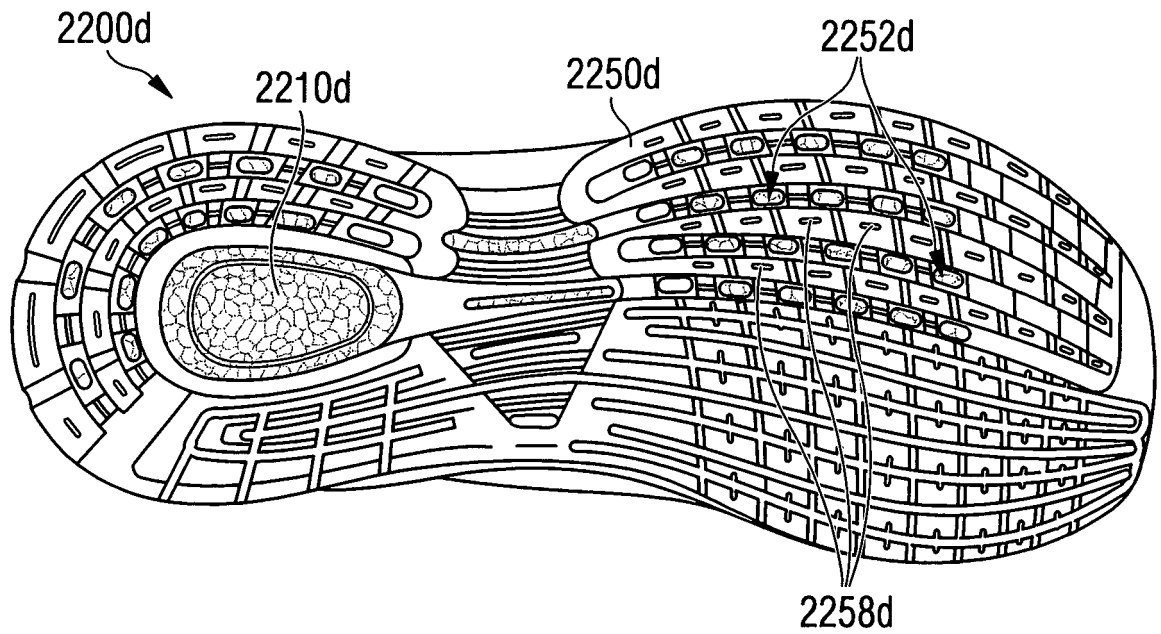


FIG 22d



REFERENCES CITED IN THE DESCRIPTION

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