A footwear sole structure may include a plurality of discrete sole elements defined by a plurality of sipes. The sipes may include a plurality of sipes that extend in a direction extending from a medial side of the sole structure to a lateral side of the sole structure and be rearwardly angled. Those sipes may be located in a midfoot region. The sole structure may include a plurality of additional sipes having longitudinal, transverse and other orientations.
FIG. 4F
ARTICULATED SOLE STRUCTURE WITH REARWARDLY ANGLED MEDIA LATERAL MIDFOOT SIPES

CROSS REFERENCE TO RELATED APPLICATION


BACKGROUND

[0002] Conventional articles of footwear often include two primary components: an upper and a sole structure. The upper provides a covering for the foot and securely positions the foot relative to the sole structure. The sole structure is secured to a lower surface of the upper and configured so as to be positioned between the foot and the ground when a wearer is standing, walking or running. Sole structures are often designed so as to cushion, protect and support the foot. Sole structures may also be designed so as to increase traction and to help control potentially harmful foot motion such as overpronation.

[0003] Many types of athletic footwear have a sole structure that includes a deformable midsole. A primary element of many conventional midsoles is a resilient polymer foam material that extends throughout the length of the footwear. The physical characteristics a midsole largely depend on the density and other properties of the polymer foam material and on the dimensional configuration of the midsole. By varying these factors throughout the midsole, the relative stiffness, degree of ground reaction force attenuation, and energy absorption properties may be altered to meet the specific demands of the activity for which the footwear is intended to be used.

[0004] Commonly-owned U.S. Pat. No. 6,990,755 describes an article of footwear having an articulated sole structure in which multiple sipes separate discrete sole elements of the midsole. The resulting sole structure helps to simulate a sensation of barefoot running while at the same time providing a degree of cushioning and protection to the wearer foot. The motion of a human foot during running and other activities can be quite complex, however. Accordingly, there remains an ongoing need for improved articulated sole structures that better accommodate natural tendencies and kinematics of the human foot.

SUMMARY

[0005] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the invention.

[0006] In at least some embodiments, a footwear sole structure may include a plurality of discrete sole elements defined by a plurality of sipes. The sipes may include a plurality of sipes that extend in a direction extending from a medial side of the sole structure to a lateral side of the sole structure (i.e., a mediolateral direction) and be rearwardly angled. The rearwardly-angled mediolateral sipes may be located in a midfoot region. The sole structure may include a plurality of additional sipes having longitudinal, transverse and/or other orientations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Some embodiments are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements.

[0008] FIG. 1 shows outlines of human foot bones from a plantar (bottom) view.

[0009] FIGS. 2A through 2D are lateral side, medial side, front and rear views, respectively, of a shoe according to some embodiments.

[0010] FIGS. 2E and 2F are area cross-sectional views taken from the locations indicated in FIG. 2A.

[0011] FIG. 2G is a bottom view of the shoe of FIGS. 2A through 2D.

[0012] FIG. 2H is a bottom view of the shoe of FIGS. 2A through 2D with a superimposed plantar view foot bone outline from FIG. 1.

[0013] FIGS. 3A through 3D are lateral side, medial side, front and rear views, respectively, of a shoe according to some additional embodiments.

[0014] FIG. 3E is a bottom view of the shoe of FIGS. 3A through 3D.

[0015] FIG. 3F is a bottom view of the shoe of FIGS. 3A through 3D with a superimposed plantar view foot bone outline from FIG. 1.

[0016] FIGS. 4A through 4D are lateral side, medial side, front and rear views, respectively, of a shoe according to some further embodiments.

[0017] FIG. 4E is a bottom view of the shoe of FIGS. 4A through 4D.

[0018] FIG. 4F is a bottom view of the shoe of FIGS. 4A through 4D with a superimposed plantar view foot bone outline from FIG. 1.

[0019] FIGS. 5A through 5D are lateral side, medial side, front and rear views, respectively, of a shoe according to some further embodiments.

[0020] FIG. 5E is a bottom view of the shoe of FIGS. 5A through 5D.

[0021] FIG. 5F is a bottom view of the shoe of FIGS. 5A through 5D with a superimposed plantar view foot bone outline from FIG. 1.

DETAILED DESCRIPTION

[0022] The following discussion and accompanying figures describe sole structures in accordance with several embodiments, as well as articles of footwear incorporating such sole structures. The sole structures depicted in the figures and discussed below have configurations that are suitable for athletic activities such as running. Other embodiments include sole structures and footwear having one or more features of the herein-described sole structures and adapted for basketball, baseball, football, soccer, walking, hiking and other athletic and nonathletic activities. Persons skilled in the relevant art will thus recognize that concepts disclosed herein may be applied to a wide range of footwear styles and are not limited to the specific embodiments discussed below and depicted in the figures.

[0023] To assist and clarify subsequent description of various embodiments, various terms are defined herein. Unless
context indicates otherwise, the following definitions apply throughout this specification (including the claims). “Shoe” and “article of footwear” are used interchangeably to refer to articles intended for wear on a human foot. A shoe may or may not enclose the entire foot of a wearer. For example, a shoe could include a sandal or other article that exposes large portions of a wearing foot. The “interior” of a shoe refers to space that is occupied by a wearer’s foot when the shoe is worn. An “interior side” (or surface) of a shoe element refers to a face of that element that is (or will be) oriented toward the shoe interior in a completed shoe. An “interior side” (or surface) of an element refers to a face of that element that is (or will be) oriented away from the shoe interior in the completed shoe. In some cases, the interior side of an element may have other elements between that interior side and the interior in the completed shoe. Similarly, an exterior side of an element may have other elements between that exterior side and the space external to the completed shoe.

Shoe elements can be described based on regions and/or anatomical structures of a human foot wearing that shoe, and by assuming that shoe is properly sized for the wearing foot. Fig. 1 shows outlines of human foot bones from a plantar (bottom) view. Those bones are the first distal phalanx 1, the first proximal phalanx 2, the first metatarsal 3, the second distal phalanx 4, the second middle phalanx 5, the second proximal phalanx 6, the second metatarsal 7, the third distal phalanx 8, the third middle phalanx 9, the third proximal phalanx 10, the third metatarsal 11, the fourth distal phalanx 12, the fourth middle phalanx 13, the fourth proximal phalanx 14, the fourth metatarsal 15, the fifth distal phalanx 16, the fifth middle phalanx 17, the fifth proximal phalanx 18, the fifth metatarsal 19, the medial cuneiform 20, the intermediate cuneiform 21, the lateral cuneiform 22, the navicular 23, the cuboid 24, the talus 25 and the calcaneus 26. The exact shape and size of the bones in a foot will vary from individual to individual, and Fig. 1 is merely intended as a convenient general reference.

A forefoot region of a foot includes the metatarsals 3, 7, 11, 15 and 19 and the phalanges 1, 2, 4-6, 8-10, 12-14 and 16-18. A forefoot element of a sole structure is an element having one or more portions located under, to the lateral and/or medial side of, and/or in front of a wearer’s forefoot (or portion thereof) when the shoe is worn. A midfoot region of a foot includes the cuboid 24, navicular 23 and cuneiforms 20-22, as well as the heads of the metatarsals 3, 7, 11, 15 and 19. A midfoot element of a sole structure is an element having one or more portions located under, to the lateral and/or medial side of, and/or behind a wearer’s hindfoot (or portion thereof) when the shoe is worn. The forefoot region may overlap with the midfoot region, as may the midfoot and hindfoot regions.

Unless indicated otherwise, a longitudinal axis refers to a horizontal heel-toe axis along the center of the foot, while that foot is resting on a horizontal surface, that is roughly parallel to a line along the second metatarsal and second phalanges. A transverse axis refers to a horizontal axis across the foot that is generally perpendicular to a longitudinal axis. A longitudinal direction is parallel (or roughly parallel) to a longitudinal axis. A transverse direction is parallel (or roughly parallel) to a transverse axis.

Fig. 2A is a lateral side view of a shoe 200 according to some embodiments. FIGS. 2B, 2C and 2D are medial side, front and rear views, respectively, of shoe 200. FIGS. 2E and 2F are area cross-sectional views taken from the locations indicated in FIG. 2A. FIG. 2G is a bottom view of shoe 200.

Shoe 200 includes an upper 201. Upper 201 creates an interior 215 (FIGS. 2E and 2F) configured to receive a foot of a shoe 200 wearer. In some embodiments, upper 201 can be similar to uppers described in commonly-owned U.S. Pat. No. 6,990,755, titled “Article of Footwear with a Stretchable Upper and an Articulated Sole Structure,” which patent is incorporated by reference herein. Shoes according to various embodiments can include sole structures such as those described herein in combination with any of various types of uppers. Because the details of such uppers are not pertinent to understanding sole structures disclosed herein, upper 201 is shown generically in FIGS. 2A-2F using a broken line or stippling.

As seen in FIGS. 2E and 2F, upper 201 may include a lasting element (e.g., a Strobel) 203. Lasting element 203 may be stitched to edges of upper 201 along a seam 204, with seam 204 located near a periphery of a footbed. An insole 205 can be positioned adjacent to the top surface of lasting element 203 within interior 215. Insole 205 may contact the bare or socked plantar surface of the wearer foot along the entire length of the foot. Insole 205 may be compressible and/or have an orthotic shape to conform to a wearer foot.

In the embodiment of shoe 200, sole structure 202 primarily comprises a single-piece midsole 206. A top surface 207 of midsole 206 is bonded to the underside of lasting element 203 and to border portions 214 of upper 201 located outside of seam 204. Midsole 206 protects the foot of a shoe 200 wearer from ground surface material that might puncture or otherwise injure the skin on the underside of the foot. Midsole 206 also provides cushioning by attenuating ground reaction forces and absorbing energy when a wearer of shoe 200 walks or runs. Suitable materials for midsole 206 can include any of various polymer foams utilized in conventional footwear midsoles, including but not limited to ethylvinylacetate (EVA), thermoplastic polyurethane (TPU) and polyurethane foams. Midsole 206 may also be formed from a relatively lightweight polyurethane foam having a specific gravity of approximately 0.22, as manufactured by Bayer AG under the BAYFLEX trademark.

Midsole 206 has an articulated structure that imparts relatively high flexibility and articulation. The flexible structure of midsole 206 is configured to complement the natural motion of the foot during running or other activities, and may impart a feeling or sensation of barefoot running. In contrast with barefoot running, however, midsole 206 attenuates ground reaction forces and absorbs energy to cushion the foot and decrease the overall stress upon the foot. Moreover, and as described in further detail below, midsole 206 includes a plurality of midsole sipes that accommodate transtalar foot motion.

Referring to FIGS. 2A and 2B, midsole 206 includes a spanning portion 209 and an articulated portion 210. The precise boundaries of spanning portion 209 and articulated portion 210 are only approximately indicated in FIGS. 2A and 2B. Spanning portion 209 includes the portion of midsole 206 above sipes 212. Articulated portion 210 includes a plurality of discrete sole elements 211 defined by sipes 212. Sole elements 211 are connected to and extend downward from
spanning portion 209. Only the ends of certain sipes 212 and a portion of sole elements 211 can be seen in FIGS. 2A through 2D).

[0033] All of sipes 212 and sole elements 211 can be seen in FIG. 2G, a bottom view of shoe 200 showing the exposed bottom surface of sole structure 202. In the embodiment of shoe 200, midsole 206 includes eighteen sipes 212 through 212r. Sipes 212a through 212r define numerous discrete sole elements 211 by exposing sides of those elements. This permits those discrete elements to move away from one another and allows midsole 206 to flex along sipes 212. For example, a medial side of sole element 211a is exposed by sipe 212a. A lateral side of sole element 211a is exposed by sipe 212b. Front and rear sides of sole element 211a are exposed by sipes 212b and 212c, respectively. The exposed sides of sole element 211a allow sole element 211a to separate from the sides of adjacent sole elements when a wearer steps on an uneven surface and/or when the wearer dorsiflexes, pronates, supinates or otherwise moves his or her foot. Other sole elements can similarly separate from adjacent sole elements. To avoid cluttering FIG. 2G with unnecessary details, only a few of sole elements 211 are marked or discussed.

[0034] As used herein, a sipe generally refers to a separation between sides of adjacent discrete sole elements. In some cases, a sipe may leave little or no space between the sides of adjacent sole elements when the siped sole structure is unloaded. For example, side faces of adjacent sole elements separated by a narrow sipe may actually be in contact with one another when the sole structure is unloaded, and there may only be space between those faces when the sole structure flexes along the sipe. In other cases, a wider sipe may create a larger gap between sides of adjacent sole elements, and there may be space between those sole element sides in the unloaded sole structure. In still other cases, a sipe may have a portion (e.g., the deepest part of the sipe) in which adjacent sole elements are in contact when the sole structure is unloaded and another portion (e.g., the portion of the sipe near the bottom surface of the sole structure) in which there is a groove or other space between adjacent sole element faces in the unloaded sole structure.

[0035] Sipes can be formed by molding, e.g., by including blades in a midsole mold corresponding to desired sipe locations. Sipes can also be formed by cutting sipes in a midsole or other sole structure using a knife or other tool. Sipes can also be formed using combinations of molding and cutting operations, as well as by other processes. In some embodiments, thinner sipes may be “knifed” (i.e., cutting with a blade), while wider sipes may be molded into a midsole. In some such embodiments, the molded-in sipes may be located in areas of a shoe where higher stresses may be expected (e.g., at the heel, where a step lands, and at the toe, where step-off occurs). Molded-in sipes may in some cases be more durable than knifed sipes, as all sides of the sipes are exposed to curing conditions and have an outer crust of cured polymer. Conversely, knifed sipes are cut into the midsole after curing. Thus, knifed sipes side edges and their junction with the spanning portion may constitute uncured polymer material that is less durable than cured polymer.

[0036] As seen in FIG. 2G, sipes 212a, 212b, 212c and 212d are longitudinally oriented and extend in generally longitudinal directions. Sipe 212a is located in the medial forefoot region and extends from forefoot sipe 212b to midfoot sipe 212c. Sipe 212b is curved and extends from a front edge of outsole 206 in the toe region to hindfoot sipe 212c. Sipe 212c is also curved and extends from the front edge of outsole 206 to a rear edge of outsole 206 in the hindfoot region. Sipe 212d is curved and extends from forefoot sipe 212b to hindfoot sipe 212c.

[0037] Sipes 212e through 212r are transversely oriented and extend in generally transverse directions. Sipe 212e extends from a lateral edge of outsole 206 to sipe 212b. Sipes 212f through 212k, sipe 212m, sipe 212n and sipe 212p extend from the lateral edge of midsole 206 to the medial edge of outsole 206. Sipe 212l extends from the midsole 206 lateral edge to the intersection of sipes 212r and 212k. Sipe 212m extends from the midsole 206 medial edge to sipe 212b. Sipe 212n extends from the midsole 206 lateral edge to sipe 212c. Sipe 212p extends from the midsole 206 medial edge to the intersection of sipes 212d and 212l. Although sipe 212e joins sipe 212f just short of reaching the midsole 206 medial edge, sipe 212g and the portion 212h of sipe 212k to the medial side of sipe 212a effectively form a single sipe that extends from the midsole 206 lateral edge to the midsole 206 medial edge.

[0038] In some embodiments, sipe depth (as a percentage of sole structure thickness) is maximized and the thickness of a spanning portion minimized so as to reduce the force needed to flex the sole structure along the sipe and to separate adjacent sole elements. For example, and as seen in the area cross-sectional view of FIG. 2E, the thickness t of spanning portion 209 over sipe 212a under the footbed is relatively small compared to the depth d of sipe 212a. To avoid confusing FIG. 2E with unneeded detail, longitudinally-oriented sipes 212k and 212l have not been shown in the rear face of transversely-oriented sipe 212a. Similarly, sipes 212c through 212f have been omitted from the area cross-sectional view of FIG. 2E.

[0039] Sipe depth d and under-footbed spanning portion thickness t may vary within a particular shoe and among various embodiments. In at least some embodiments, the portions of midsole 209 above sipes 212 and sole elements 211 and under the footbed have a thickness t of about 3 mm throughout the entire midsole. In some embodiments, this thickness t may be in a range between about 2.5 mm and about 10 mm. Other embodiments include, without limitation: embodiments in which this thickness t is in a range between about 3 mm and about 8 mm, embodiments in which this thickness t is in a range between about 3 mm and about 6 mm, embodiments in which this thickness t is in a range between about 3 mm and about 5 mm, embodiments in which this thickness t is in a range between about 3 mm and about 4 mm, and embodiments in which this thickness t is in a range between about 2.5 mm and about 3.5 mm.

[0040] For men’s U.S. shoe sizes according to some embodiments, sipe depth d in the hindfoot region (near the midsole edge) is about 18 mm +/-3 mm, sipe depth d in the midfoot region (near the midsole edge) is about 14 mm +/-3 mm, and sipe depth d in the forefoot region (near the midsole edge) is about 10 mm +/-3 mm. Sipe depths d may decrease by, e.g., about 30% or more in the middle of the sipe. For men’s U.S. shoe sizes according to some additional embodiments, sipe depths d are similar, but may be within a different range (e.g., +/-2 mm). In any of these embodiments, the thickness t of the midsole under-footbed spanning portion above the sipes may have a value of about 3 mm, may have a value in one of the ranges previously indicated, or may have a different value.

[0041] For women’s U.S. shoe sizes according to some embodiments, sipe depth d in the hindfoot region (near the
midsole edge) is about 17 mm +/-3 mm, sipe depth d in the midfoot region (near the midsole edge) is about 13 mm +/-3 mm, and sipe depth d in the forefoot region (near the midsole edge) is about 9 mm +/-3 mm. Sipe depths d may decrease by, e.g., about 30% or more in the middle of the sipe. For women's U.S. shoe sizes according to some additional embodiments, sipe depths d are similar, but may be within a different range (e.g., +/-2 mm). In any of these embodiments, the thickness t of the midsole under-footbed spanning portion above the sipes may have a value of about 3 mm, may have a value in one of the ranges previously indicated, or may have a different value.

In some embodiments, and as to some or all of the sipes located in the hindfoot and midfoot regions, a ratio d/t is at least 1 over the majority of the length of those sipes. This may include, without limitation, sipes 212 through 212o. The ratio d/t over a majority of a sipe length may be greater (e.g., 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, etc.) for some or all sipes in the hindfoot and/or midfoot regions (including but not limited to sipes 212 through 212o). Additional embodiments can include, without limitation, one or more of the following features: the d/t ratio in some or all hindfoot region sipes can be anywhere in a range between about 8.4 to about 1.5 for men's U.S. sizes, the d/t ratio in some or all hindfoot region sipes can be anywhere in a range between about 6.8 to about 1.1 for men's U.S. sizes, the d/t ratio in some or all midfoot region sipes can be anywhere in a range between about 5.7 to about 4 for men's U.S. sizes, the d/t ratio in some or all midfoot region sipes can be anywhere in a range between about 4 to about 3.3 for men's U.S. sizes, the d/t ratio in some or all hindfoot region sipes can be anywhere in a range between about 8 to about 3.3 for women's U.S. sizes, the d/t ratio in some or all hindfoot region sipes can be anywhere in a range between about 6.4 to about 1 for women's U.S. sizes, the d/t ratio in some or all midfoot region sipes can be anywhere in a range between about 4.3 to about 3 for women's U.S. sizes, the d/t ratio in some or all hindfoot region sipes can be at least 2 over at least 50% of the length of those sipes, the d/t ratio in some or all hindfoot region sipes can be at least 2 over at least 75% of the length of those sipes, the d/t ratio in some or all hindfoot region sipes can be at least 2 over at least 90% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2.5 over at least 50% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2.5 over at least 75% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2.5 over at least 90% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 50% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 75% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 90% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 50% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 75% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 90% of the length of those sipes. The d/t ratio in some or all midfoot region sipes can be at least 2 over at least 50% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 75% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 90% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 50% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 75% of the length of those sipes, the d/t ratio in some or all midfoot region sipes can be at least 2 over at least 90% of the length of those sipes.

In the embodiment of shoe 200, sole structure 202 includes a spanning portion 209 and an articulated portion 210 as parts of a single integrally-formed midsole. Spanning portion 209 interconnects the discrete sole elements defined by the sipes of the articulated portion. This need not be the case, however. In some embodiments, for example, a lasting element or some other flexible member coupled to the underside of a lasting element may serve as a sole structure spanning portion. Individual sole elements could be cut or otherwise formed and then bonded to the bottom of that lasting element or other flexible member. In such an embodiment, the thickness t of the spanning portion could be the thickness of the flexible member bonded to the bottom of the lasting element. If the sole elements are bonded directly to the lasting element, t could equal zero.

As also seen in FIG. 2G, various tread patterns may be formed in the exposed surfaces of sole elements 212. Tread patterns other than those shown in FIG. 2G could be used. One or more discrete sole elements 211 may further include an outsole element 208 embedded in or otherwise secured to its lower surface. Such outsole elements may provide increased wear resistance and/or be included for aesthetic purposes. An outsole element 208 may be recessed within a sole element 211. In some embodiments, outsole elements 208 may extend throughout all or substantially all of the lower surface of midsole 206 (i.e., each sole element may have an attached outsole element). In the embodiment of shoe 200, outsole elements 208 are located on sole elements 211c, 211d, and 211e in the hindfoot region and in sole elements 211a, 211b, and 211f in the frontmost medial forefoot region. Suitable materials for outsole elements 208 can include any of various conventional rubber materials utilized in footwear outsoles (e.g., carbon black rubber compound).

FIG. 2H is another bottom view of shoe 206 showing the exposed bottom surface of sole structure 202. The foot bone outlines of FIG. 1 are superimposed in FIG. 2H so as to indicate the approximate locations, relative to sipes 212 and sole elements 211, of the bones in a wearer foot located within interior 215. For convenience, outsole elements 208 have been omitted. A longitudinal axis A2l, of sole structure 202 is generally parallel to a line that follows the second phalanges 4-6 and the second metatarsal 7. In the embodiment of outsole 206, transverse sipes 212a and 212p through 212t are roughly perpendicular to longitudinal axis A2l. Each of transverse sipes 212c through 212f is oriented in a medial-to-lateral (i.e., mediolateral) direction and is forwardly angled. Thus, the angles in the forward lateral quadrants of the intersections of sipes 212d through 212f with axis A3l (e.g., angle b22) are less than 90 degrees.

Conversely, each of sipes 212f through 212o is oriented in a mediolateral direction and is rearwardly angled. Angles in the forward medial quadrants of the intersections of sipes 212f through 212o with axis A3l (e.g., angle b22) are
thus less than 90 degrees, as are angles in the rear lateral quadrants of such intersections. As indicated above, sipe 212/ and sipe portion 212₂ effectively form a single sipe that extends from the midsole 206 lateral end to the midsole 206 medial edge. An average angle of sipe 212₋/212₂ relative to axis A₂ is defined by drawing a line between the sipe 212₋/212₂ endpoints and determining the angle of that line relative to axis A₂. This is also shown in FIG. 21, where line C₂ creates an angle b₂ in the rear lateral quadrant of the intersection with axis A₂. A similar average angle could be defined for sipe 212₋. Because sipe 212₋ is straight, however, that average angle would effectively be the same as the angle of sipe 212₋ itself relative to axis A₂.

As further seen in FIG. 21, rearwardly-angled mediolateral sipes 212₋ through 212₁₋ are located in a region that extends from the heads of metatarsals 3, 7, 11, 15 and 19 to medial cuneiform 20, navicular 23 and cuboid 24. The presence of mediolateral rearwardly-angled sipes in this region offers several advantages. For example, these sipes allow beneficial transfaternal motion during linear wearer motion (e.g., while running). In particular, these mediolateral rearwardly-angled sipes accommodate relative motion of the wearer tarsal bones (cuneiforms 19-21, navicular 22, cuboid 24, talus 25 and calcaneus 26) that naturally occurs during unshod running on grass. This in turn allows the foot to more easily rotate relative to the midfoot about axis A₂. The combination of sipes 212₋ through 212₁₋ with sipes having locations such as those of sipes 212₋ through 212₁₋ and 212₂ through 212₋ further improves the ability of sole structure 202 to facilitate natural foot motion.

In at least some embodiments, the average angles of one or more rearwardly-angled mediolateral sipes in a midfoot region, relative to a longitudinal axis such as A₂ and determined in a lateral rear quadrant (e.g., angle b₂), are between approximately 45 degrees and approximately 70 degrees. In some embodiments, rearwardly-angled mediolateral sipes are spaced approximately 10 mm apart. This spacing may vary in some embodiments by, e.g., 5 mm to 20 mm and need not be constant for a set of mediolateral midfoot sipes. The average angles of multiple rearwardly-angled mediolateral midfoot sipes relative to a longitudinal axis need not be the same. For example, one such sipe may form a first average angle relative to the longitudinal axis, a second such sipe may form a second average angle relative to the longitudinal axis, and a third such sipe may form a third average angle relative to a longitudinal axis, etc. The first, second and third average angles may all be different from one another, but each may be within the range of approximately 45 degrees to approximately 70 degrees.

FIG. 3A is a lateral side view of a shoe 300 according to at least some additional embodiments. FIGS. 3B, 3C and 3D are medial side, front and rear views, respectively, of shoe 300. FIG. 3E is a bottom view of shoe 300.

Shoe 300 includes an upper 301. As previously indicated, shoes according to various embodiments can include sole structures such as those described herein in combination with any of various types of uppers. Accordingly, upper 301 is also shown generically in FIGS. 3A-3D) using a broken line. Upper 301 may include a lasting element and have a construction similar to that described in connection with upper 201 and shown in FIGS. 2E and 2F.

Shoe 300 includes a sole structure 302, which sole structure primarily comprises a single-piece midsole 306. A top surface of midsole 306 may be bonded to the underside of the upper 301 lasting element and to border portions of upper 301. Midsole 306 protects the foot of a shoe 300 wearer from ground surface material. Midsole 306 also provides cushioning by attenuating ground reaction forces and absorbing energy when a wearer of shoe 300 walks or runs. Suitable materials for midsole 306 can include any of various materials described above in connection with midsole 206.

Midsole 306 also has an articulated structure. Referring to FIGS. 3A and 3B, midsole 306 includes a spanning portion 309 and an articulated portion 310. The precise boundaries of spanning portion 309 and articulated portion 310 are only approximately indicated in FIGS. 3A and 3B. Spanning portion 309 includes the under-footbed portion of midsole 306 above sipes 312. Articulated portion 310 includes a plurality of discrete sole elements defined by sipes 312. Those sole elements are connected to and extend downward from spanning portion 309. Only the ends of certain sipes 312 and certain sole elements can be seen in FIGS. 3A through 3D.

All of sipes 312 and all sole elements can be seen in FIG. 3E, a bottom view of shoe 300 showing the exposed bottom surface of sole structure 302. In the embodiment of shoe 300, outsole 306 includes eighteen sipes 312₂ through 312₋. Similar to midsole 206, sipes 312₋ through 312₋ define numerous discrete sole elements in midsole 306. Sipes 312₋, 312₋, 312₋ and 312₋ are longitudinally oriented and extend in generally longitudinal directions. Sipe 312₋ is located in the medial forefoot region and extends from forefoot sipe 312₋ to midfoot sipe 312₋. Sipe 312₋ is curved and extends from a front edge of outsole 306 in the toe region to a rear edge of outsole 306 in the hindfoot region. Sipe 312₋ is curved and extends from forefoot sipe 312₋ to hindfoot sipe 312₋. Sipe 312₋ is curved and extends from forefoot sipe 312₋ to the rear edge of outsole 306 in the hindfoot region. Sipes 312₋ through 312₋ are transversely oriented and extend from a medial edge of midsole 306 to a lateral edge of midsole 306.

Various tread patterns may be formed in the exposed surfaces of discrete sole elements in midsole 306. Tread patterns other than those shown in FIG. 3E could be used. One or more discrete sole elements may further include an outsole element 308 embedded in or otherwise secured to its lower surface. In the embodiment of shoe 300, outsole elements 308 are located on sole elements in the hindfoot region and in sole elements in the forefoot region. In some embodiments, outsole elements 308 may extend throughout all or substantially all of the lower surface of midsole 306 (i.e., each sole element may have an attached outsole element). Suitable materials for outsole elements 308 can include those indicated above for outsole elements 208.

FIG. 3F is another bottom view of shoe 300 showing the exposed bottom surface of sole structure 302. The foot bone outlines of FIG. 1 are superimposed in FIG. 3F so as to indicate the approximate locations, relative to sipes 312, of the bones in a wearer foot located within an interior of shoe 300. For convenience, outsole elements 308 have been omitted. A longitudinal axis A₃ of sole structure 302 is generally parallel to a line that follows the second phalanges 4-6 and the second metatarsal 7. In the embodiment of outsole 306, transverse sipes 312₋ and 312₋ are roughly perpendicular to longitudinal axis A₃. Each of transverse sipes 312₋ through 312₋ is oriented in a mediolateral direction and is forwardly angled.

Each of sipes 312₋ through 312₋ is curved and has two concave portions. Specifically, each of sipes 312₋ through...
312o has a rearwardly-facing concave portion on the medial side and a forwardly-facing concave portion on the lateral side (or conversely, a forwardly-facing convex portion on the medial side and a rearwardly-facing convex portion on the lateral side). Notwithstanding its curved shape, however, each of sipes 312/ through 312o is nonetheless oriented in a mediolateral direction and is rearwardly angled. FIG. 3F shows a broken line C₁, connecting the end of sipe 312₁ at the medial edge of midsole 306 with the end of sipe 312₁ at the lateral edge of midsole 306. Similar lines C₂₂, C₃₃ and C₄₄ are shown connecting the medial and lateral ends of sipes 312₂ through 312₉, respectively. As can be seen by comparing each of lines C₁₁ through C₉₉ with longitudinal axis A₁₁, the average angles of sipes 312/ through 312o relative to axis A₁₁ in the lateral rear quadrant (e.g., angle b₁₁) are all less than 90 degrees. In at least some embodiments, each of angle b₁₁, and the similarly defined angles of each of lines C₂₂ through C₉₉, relative to axis A₁₁, is between approximately 45 degrees and approximately 70 degrees. Sipes 312/ through 312o are, in at least some embodiments, approximately 10 mm apart.

[0057] In some embodiments, shoes such as or similar to those described in connection with FIGS. 3A-3F have d dimensions such as are described in connection with previous embodiments for some or all sipes, and/or t dimensions such as are described in connection with previous embodiments for some or all midsole portions, and/or d/t ratios such as are described in connection with previous embodiments for some or all midsole portions.

[0058] Similar to sipes 312/ through 312o discussed in connection with midsole 206, mediolateral rearwardly-angled sipes 312/ through 312o allow beneficial transaltoral motion during linear wearer movement. The combination of sipes 312/ through 312o with sipes having locations such as those of sipes 312₂ through 312₉ and 312p through 312r further improves the ability of sole structure 302 to facilitate natural foot motion.

[0059] FIG. 4A is a lateral side view of a shoe 400 according to at least some further embodiments. FIGS. 4B, 4C and 4D are medial side, front and rear views, respectively, of shoe 400. Shoe 400 is similar to and has a construction similar to that of shoe 300. Except as indicated below or as shown in the drawings, upper 401, sole structure 402, midsole 406, spanning portion 409, articulating portion 410 and sipes 412 are similar to upper 301, sole structure 302, midsole 306, spanning portion 309, articulating portion 310 and sipes 312 of shoe 300.

[0060] FIG. 4E is a bottom view of shoe 400 showing the exposed bottom surface of sole structure 402. Outsole 406 similarly includes eighteen sipes 412o through 412₂ that define numerous discrete sole elements in midsole 406. Various tread patterns may be formed in the exposed surfaces of discrete sole elements in midsole 406. Tread patterns other than those shown in FIG. 4E could be used. One or more discrete sole elements may further include an outsole element 408 embedded in or otherwise secured to its lower surface. In the embodiment of shoe 400, outsole elements 408 are located on sole elements in the hindfoot region and in sole elements in the forefoot region. In some embodiments, outsole elements 408 may extend throughout all or substantially all of the lower surface of midsole 406 (i.e., each sole element may have an attached outsole element). Suitable materials for outsole elements 408 can include those indicated above for outsole elements 208.

[0061] Midsole 406 includes a reverse flex groove 420 in the lower portion of sipe 412c. Groove 420 accommodates reverse flexing of the foot in the longitudinal direction. In some embodiments, groove 420 includes a wider outer portion and a deeper sipe that extends upward into the midsole beyond the bottom of the wider outer portion. In some embodiments, the wider outer portion has a curved (e.g., rounded) outer surface, is approximately 3 mm to 4 mm wide, and is approximately 2 mm to 4 mm deep.

[0062] FIG. 4F is another bottom view of shoe 400 showing the exposed bottom surface of sole structure 402. The foot bone outlines of FIG. 1 are superimposed in FIG. 4F so as to indicate the approximate locations, relative to sipes 412, of the bones in a wearer foot located within an interior of shoe 400. A longitudinal axis A₃₉ of sole structure 402 is generally parallel to a line that follows the second phalanges 4-6 and the second metatarsal 7. Outsole elements 408 have been omitted. Sipes 412/ through 412o are similar to sipes 312/ through 312o. Lines (e.g., line D₂₉) connecting the ends of sipes 412/ through 412o form angles with longitudinal axis A₃₉ in the lateral rear quadrant (e.g., angle b₂₉) of approximately 45 degrees to approximately 70 degrees. Sipes 412/ through 412o are curved in a manner similar to sipes 312/ through 312o, but are somewhat wider.

[0063] Similar to sipes 312/ through 312o discussed in connection with midsole 206, mediolateral rearwardly-angled sipes 412/ through 412o allow beneficial transaltoral motion during linear wearer movement. The combination of sipes 412/ through 412o with sipes having locations such as those of sipes 412o through 412₂ and 412p through 412r further improves the ability of sole structure 402 to facilitate natural foot motion.

[0064] In some embodiments, shoes such as or similar to those described in connection with FIGS. 4A-4F have d dimensions such as are described in connection with previous embodiments for some or all sipes, and/or t dimensions such as are described in connection with previous embodiments for some or all midsole portions, and/or d/t ratios such as are described in connection with previous embodiments for some or all midsole portions.

[0065] FIG. 5A is a lateral side view of a shoe 500 according to at least some further embodiments. FIGS. 5B, 5C and 5D are medial side, front and rear views, respectively, of shoe 500. Shoe 500 is similar to and has a construction similar to that of shoe 300. Except as indicated below or as shown in the drawings, upper 501, sole structure 502, midsole 506, spanning portion 509, articulating portion 510 and sipes 512 are similar to upper 301, sole structure 302, midsole 306, spanning portion 309, articulating portion 310 and sipes 312 of shoe 300.

[0066] FIG. 5E is a bottom view of shoe 500 showing the exposed bottom surface of sole structure 502. Outsole 506 includes eighteen sipes 512o through 512₂ that define numerous discrete sole elements in midsole 506. Various tread patterns may be formed in the exposed surfaces of discrete sole elements in midsole 506. Tread patterns other than those shown in FIG. 5E could be used. One or more discrete sole elements may further include an outsole element 508 embedded in or otherwise secured to its lower surface. In the embodiment of shoe 500, outsole elements 508 are located on sole elements in the hindfoot region and in sole elements in the forefoot region. In some embodiments, outsole elements 508 may extend throughout all or substantially all of the lower surface of midsole 506 (i.e., each sole element may have an
attached outsole element). Suitable materials for outsole elements 508 can include those indicated above for outsole elements 208.

[0067] Midsole 506 includes a reverse flex groove 520 as part of sipe 512c. Groove 520, which is wider and longer than groove 420 of midsole 406, can be as wide (or wider) and as deep (or deeper) than groove 420.

[0068] FIG. 5F is another bottom view of shoe 500 showing the exposed bottom surface of sole structure 502. The foot bone outlines of FIG. 1 are superimposed on FIG. 5F so as to indicate the approximate locations, relative to sipes 512, of the bones in a wearer foot located within an interior of shoe 500. For convenience, outsole elements 508 have been omitted. A longitudinal axis A 1 of sole structure 502 is generally parallel to a line that follows the second phalanges 4-6 and the second metatarsal 7. Sipes 512/ through 512m are curved similar to sipes 312/ through 312m. Lines (e.g., line E 1 ) connecting the ends of sipes 512/ through 512m form angles with longitudinal axis A 1 in the lateral rear quadrant (e.g., angle B 1 ) of approximately 45 degrees to approximately 70 degrees.

[0069] Similar to sipes 212/ through 212m discussed in connection with midsole 206, mediolateral rearwardly angled sipes 512/ through 512m allow beneficial transatorial motion during linear wearer motion. The combination of sipes 512/ through 512m with sipes having locations such as those of sipes 512 through 512p further improves the ability of sole structure 502 to facilitate natural foot motion.

[0070] In some embodiments, shoes such as or similar to those described in connection with FIGS. 5A-5F have d dimensions such as are described in connection with previous embodiments for some or all sipes, and/or d dimensions such as are described in connection with previous embodiments for some or all midsole portions, and/or d/t ratios such as are described in connection with previous embodiments for some or all midsole portions.

[0071] The number and configuration of rearwardly angled mediolateral midfoot sipes can be varied. As indicated above, the rearward angle of such sipes may range, e.g., between about 45 degrees and about 70 degrees, measured relative to a longitudinal axis and in a rear lateral quadrant of an intersection of the sipe with that axis. Some embodiments may include five or more rearwardly angled mediolateral midfoot sipes. Curvatures other than those shown in the drawings could be utilized, but with the sipe endpoints still achieving a rearward angle between about 45 degrees and about 70 degrees. The distances between sipes could vary and need not be uniform. Sipe angles need not be uniform. Sipe gap (e.g., whether the sipe is like sipe 312/ of FIG. 3E or like sipe 412/ of FIG. 4E) need not be uniform within a set of sipes in a single midsole.

[0072] In still further embodiments, a sole structure and/or article of footwear may include additional features. For example, in some embodiments a sole structure may include stiffening elements in one or more regions and/or additional padding in one or more regions. A lasting element could include an incorporated padding element. The depths, orientations and number of sipes may be varied.

[0073] The foregoing description of embodiments has been presented for purposes of illustration and description. The foregoing description is not intended to be exhaustive or to limit embodiments of the present invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of various embodiments. The embodiments discussed herein were chosen and described in order to explain the principles and the nature of various embodiments and their practical application to enable one skilled in the art to utilize the present invention in various embodiments and with various modifications as are suited to the particular use contemplated. Any and all combinations, subcombinations and permutations of features from above-described embodiments are within the scope of the invention. With regard to claims directed to an apparatus, an article of manufacture or some other physical component or combination of components, a reference in the claim to a potential or intended wearer or a user of a component does not require actual wearing or using of the component or the presence of the wearer or user as part of the claimed component or component combination.

1. An articulated sole structure, comprising: a footwear sole structure spanning portion, the spanning portion extending longitudinally along the length of the sole structure and transversely between the medial and lateral sides of the sole structure; and an articulated portion comprising a plurality of discrete sole elements extending downward from the spanning portion and defined by a plurality of sipes extending upward into the articulated portion, wherein the plurality of sipes includes a plurality rearwardly angled mediolateral sipes in a midfoot region, each of the rearwardly angled mediolateral sipes extending across the entire width of the sole structure from a medial edge of the sole structure to a lateral edge of the sole structure, and regions of the spanning portion above the rearwardly angled mediolateral sipes have a thickness t of 10 millimeters or less.

2. The articulated sole structure of claim 1, wherein the plurality rearwardly angled mediolateral sipes includes at least three sipes.

3. The articulated sole structure of claim 2, wherein each of the rearwardly angled mediolateral sipes has a ratio of sipe depth d to spanning portion thickness t of at least 2 over a majority of the length of the sipe.

4. The articulated sole structure of claim 2, wherein each of the rearwardly angled mediolateral sipes is curved.

5. The articulated sole structure of claim 4, wherein each of the rearwardly angled mediolateral sipes has an average angle, relative to a longitudinal axis of the sole structure and in a rear lateral quadrant of an intersection with the longitudinal axis, between approximately 45 degrees and approximately 70 degrees.

6. The articulated sole structure of claim 5, wherein the longitudinal axis corresponds to the second metatarsal and second phalanged bones of a wearer foot when an article of footwear comprising the sole structure is worn.

7. The articulated sole structure of claim 2, wherein each of the rearwardly angled mediolateral sipes intersects at least a first and a second sipe, each of the first and second sipes being oriented in a substantially longitudinal direction.

8. The articulated sole structure of claim 1, wherein the spanning portion and discrete sole elements are parts of a single piece polymer foam element.

9. The articulated sole structure of claim 1, further comprising a reverse flex groove formed in an underside of the
sole structure, the reverse flex groove being oriented in a substantially longitudinal direction along the underside.

10. The articulated sole structure of claim 10, wherein the reverse flex groove extends from at least a portion of the sole structure corresponding to a wearer calcaneus to at least a portion of the sole structure corresponding to a wearer metatarsal-phalangeal joint.

11. The articulated sole structure of claim 1, wherein the rearwardly-angled mediolateral sipes are located in a portion of the sole structure corresponding, when an article of footwear comprising the sole structure is worn, to a region extending from the heads of the first through fifth metatarsals of a wearer foot to the medial cuneiform, the navicular and the cuboid of the wearer foot.

12. An article of footwear, comprising:
   an upper, and
   a flexible midsole coupled to the upper, the midsole including a plurality of downwardly extending sipes, wherein the plurality of sipes includes a plurality of rearwardly-angled mediolateral sipes in a midfoot region, each of the rearwardly-angled mediolateral sipes extending across the entire width of the midsole from a medial edge of the midsole to a lateral edge of the midsole, and
   regions of the midsole above the rearwardly-angled mediolateral sipes have a thickness between 0 and 10 millimeters.

13. The article of footwear of claim 12, wherein the plurality of rearwardly-angled mediolateral sipes includes at least three sipes.

14. The article of footwear of claim 13, wherein each of the rearwardly-angled mediolateral sipes has a ratio of sipe depth d to spanning portion thickness t of at least 2 over a majority of the length of the sipe.

15. The article of footwear of claim 13, wherein each of the rearwardly-angled mediolateral sipes is curved.

16. The article of footwear of claim 15, wherein each of the rearwardly-angled mediolateral sipes has an average angle, relative to a longitudinal axis of the midsole and in a rear lateral quadrant of an intersection with the longitudinal axis, between approximately 45 degrees and approximately 70 degrees.

17. The article of footwear of claim 16, wherein the longitudinal axis corresponds to the second metatarsal and second phalangeal bones of a wearer foot when the article of footwear is worn.

18. The article of footwear of claim 13, wherein each of the rearwardly-angled mediolateral sipes intersects at least a first and a second sipe, each of the first and second sipes being oriented in a substantially longitudinal direction.

19. The article of footwear of claim 12, wherein the rearwardly-angled mediolateral sipes are located in a portion of the midsole corresponding, when the article of footwear is worn, to a region extending from the heads of the first through fifth metatarsals of a wearer foot to the medial cuneiform, the navicular and the cuboid of the wearer foot.

20. An articulated sole structure, comprising:
   a midsole, wherein
   the midsole includes a spanning portion extending longitudinally along the length of the midsole and transversely between the medial and lateral sides of the midsole,
   the midsole includes an articulated portion comprising a plurality of discrete sole elements extending downward from the spanning portion and defined by a plurality of sipes extending upward into the articulated portion,
   the plurality of sipes includes a plurality of curved rearwardly-angled mediolateral sipes in a midfoot region, each of the curved rearwardly-angled mediolateral sipes extending across the entire width of the sole structure from a medial edge of the sole structure to a lateral edge of the sole structure, and
   wherein each of the curved rearwardly-angled mediolateral sipes has an average angle, relative to a longitudinal axis of the midsole and in a rear lateral quadrant of an intersection with the longitudinal axis, between approximately 45 degrees and approximately 70 degrees.

21. The articulated sole structure of claim 20, wherein the plurality of curved rearwardly-angled mediolateral sipes includes at least three sipes.

22. The articulated sole structure of claim 20, wherein each of the rearwardly-angled mediolateral sipes has a ratio of sipe depth d to spanning portion thickness t of at least 2 over at least 50% of the length of the sipe.

23. The articulated sole structure of claim 20, wherein each of the rearwardly-angled mediolateral sipes has a ratio of sipe depth d to spanning portion thickness t of at least 2 over at least 75% of the length of the sipe.

24. The articulated sole structure of claim 20, wherein each of the rearwardly-angled mediolateral sipes has a ratio of sipe depth d to spanning portion thickness t of at least 2 over at least 90% of the length of the sipe.

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