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Inventor(s)	Engle; Courtney et al.

DIMPLE PATTERNS FOR GOLF BALLS

Abstract

Golf balls having a dimple pattern arranged in a tetrahedral layout are disclosed. The dimple pattern has four substantially identical dimple sections, where each dimple section is defined by a spherical triangle. The dimples in each of the four dimple sections have at least two different dimple diameters including a minimum dimple diameter and a maximum dimple diameter. The resulting dimple pattern has a low dimple surface coverage and high dimple diameter disparity which helps to reduce the flight of the golf ball while providing improved aerodynamic consistency.

Inventors: **Engle; Courtney (Fall River, MA), Dytko; John S. (Derby, CT), Madson; Michael (Easton, MA), Nardacci; Nicholas (Barrington, RI)**

Applicant: **Acushnet Company** (Fairhaven, MA)

Family ID: **1000007694448**

Assignee: **Acushnet Company (Fairhaven, MA)**

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Background/Summary

FIELD OF THE INVENTION

[0001] The present disclosure relates generally to golf balls. More particularly, the present disclosure relates to golf ball dimple patterns that are arranged in a tetrahedral layout having low surface coverages and high dimple diameter disparity.

BACKGROUND OF THE INVENTION

[0002] The flight performance of a golf ball is affected by a variety of factors including the weight, size, materials, dimple pattern, and external shape of the golf ball. Golf ball manufacturers seek to maximize aerodynamic efficiency and improve the performance of golf balls by adjusting the materials and construction of the ball as well as the dimple pattern and dimple shape.

[0003] The aerodynamic forces acting on a golf ball are typically resolved into orthogonal components of lift (F.sub.L) and drag (F.sub.D). Lift is defined as the aerodynamic force component acting perpendicular to the flight path. It results from a difference in pressure that is created by a distortion in the air flow that results from the back spin of the ball. Due to the back spin, the top of the ball moves with the air flow, which delays the separation to a point further aft. Conversely, the bottom of the ball moves against the air flow, moving the separation point forward. This asymmetrical separation creates an arch in the flow pattern, requiring the air over the top of the ball to move faster, and thus have lower pressure than the air underneath the ball.

[0004] Drag is defined as the aerodynamic force component acting parallel to the ball flight direction. As the ball travels through the air, the air surrounding the ball has different velocities and, thus, different pressures. The air exerts maximum pressure at the stagnation point on the front of the ball. The air then flows over the sides of the ball and has increased velocity and reduced pressure. The air separates from the surface of the ball, leaving a large turbulent flow area with low pressure, i.e., the wake. The difference between the high pressure in front of the ball and the low pressure behind the ball reduces the ball speed and acts as the primary source of drag.

[0005] Recently, there has been an increased desire to manipulate these aerodynamic forces to produce reduced-flight golf balls (i.e., golf balls that are designed to travel a distance that is shorter than the distance traveled by standard golf balls). Advances in golf ball compositions and dimple designs have caused high-performance golf balls to exceed the maximum distance allowed by the United States Golf Association (USGA). Some industry experts have called for the USGA to roll back the distance standard for golf balls to preserve the game.

[0006] Golf ball manufacturers have developed ways to reduce the distance traveled by the golf ball. For example, some manufacturers have created inefficient dimple patterns or have modified the compositions of the golf ball core to reduce the flight of the ball. Inefficient dimple patterns with low surface coverages have been used for many years. For example, the Atti pattern, which is an octahedron pattern split into eight concentric straight-line rows and covering 66 percent of the ball, was the predominant pattern utilized on golf balls for most of the 20th century. These dimple patterns were composed of substantially uniform dimples (for example, dimples having only one or two dimple diameters) and lacked aerodynamic efficiency. As dimple designers moved toward patterns with increased surface coverages, many more dimple sizes (for example, dimple diameters) were needed to achieve increased coverages and improved aerodynamics, such as increased distance. While these high-performance golf balls have improved aerodynamic consistency, the golf balls will not adhere to a shorter USGA maximum distance.

[0007] In efforts to develop more efficient dimple patterns having low surface coverages, golf ball manufacturers have attempted to vary the properties of the dimple pattern itself, including the number of dimple free great circles on the ball, the dimple dimensions, the number of different sized dimples used in the pattern, and the total dimple count. For instance, some manufacturers have developed high dimple count patterns that include many smaller sized dimples positioned around larger dimples. While the small dimples are present on the golf ball, they may not have a meaningful impact on the aerodynamic performance of the golf ball and typically do not contribute

significantly to the overall surface coverage of the pattern. The use of small dimples in low surface coverage patterns can also lead to dimple free great circles on the ball, which may not be visually appealing to the golfer and may adversely impact the aerodynamic performance of the golf ball.
[0008] Accordingly, there remains a need to fine-tune the dimple patterns and dimple dimensions on high-performance golf balls to reduce the flight distance, while also maintaining the appearance of a high-performance trajectory.

SUMMARY OF THE INVENTION

[0009] The problems expounded above, as well as others, are addressed by the following inventions, although it is to be understood that not every embodiment of the inventions described herein will address each of the problems described above.
[0010] In one embodiment, a golf ball having a substantially spherical surface is provided, the golf ball including a plurality of dimples disposed thereon, wherein the dimples are arranged in a pattern including four substantially identical dimple sections, wherein the dimples in each of the four substantially identical dimple sections include a plurality of dimples having at least two different dimple diameters including a minimum dimple diameter and a maximum dimple diameter and the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.050 inches, and wherein the dimples cover about 75 percent or less of the substantially spherical surface, and the pattern results in no dimple-free great circles on the golf ball.
[0011] In some embodiments, the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.075 inches. In another embodiment, the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.100 inches. In still another embodiment, the pattern is rotationally symmetric about the center of each substantially identical dimple section. In yet another embodiment, the plurality of dimples having the minimum dimple diameter and the plurality of dimples having the maximum dimple diameter each has a coverage contribution, the coverage contributions satisfying the following equation:
[00001] $0.5 \leq \frac{CC_{min}}{CC_{max}}$
where CC.sub.min represents the coverage contribution of the plurality of dimples having the minimum dimple diameter in a decimal form of percentage, CC.sub.max represents the coverage contribution of the plurality of dimples having the maximum dimple diameter in a decimal form of percentage, and CC.sub.min is at least 0.2. In still another embodiment, each substantially identical dimple section includes at least one shared dimple, the shared dimple having a centroid that intersects an edge of the dimple section. In another embodiment, all shared dimples have the maximum dimple diameter.
[0012] In another embodiment, a golf ball having a substantially spherical surface is provided, the golf ball including a plurality of dimples disposed thereon, wherein the dimples are arranged in a pattern including four substantially identical dimple sections, wherein the dimples in each of the four substantially identical dimple sections include a plurality of dimples having at least two different dimple diameters including a minimum dimple diameter and a maximum dimple diameter and the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.055 inches, wherein the plurality of dimples having the minimum dimple diameter has a coverage contribution of at least 20 percent, and wherein the dimples cover about 70 percent or less of the substantially spherical surface, and the pattern results in no dimple-free great circles on the golf ball.
[0013] In some embodiments, the plurality of dimples having the minimum dimple diameter has a coverage contribution of at least 30 percent. In another embodiment, the plurality of dimples having the minimum dimple diameter has a coverage contribution of at least 40 percent. In still another embodiment, the number of the plurality of dimples having the minimum dimple diameter is greater than the number of the plurality of dimples having the maximum dimple diameter. In yet another embodiment, the number of the plurality of dimples having the minimum dimple diameter is at least twice the number of the plurality of dimples having the maximum dimple diameter. In

another embodiment, the total number of dimples disposed on the substantially spherical surface is no more than 450 dimples. In still another embodiment, the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.075 inches.

[0014] In yet another embodiment, a golf ball having a substantially spherical surface is provided, the golf ball including a plurality of dimples disposed thereon, wherein the dimples are arranged in a pattern including four substantially identical dimple sections, wherein the dimples in each of the four substantially identical dimple sections include a plurality of dimples having from two to four different dimple diameters including at least a minimum dimple diameter and a maximum dimple diameter and the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.060 inches, wherein the plurality of dimples having the minimum dimple diameter and the plurality of dimples having the maximum dimple diameter each has a coverage contribution, the coverage contributions satisfying the following equation:

[00002]$0.5 \leq \frac{CC_{min}}{CC_{max}}$

where CC.sub.min represents the coverage contribution of the plurality of dimples having the minimum dimple diameter in a decimal form of percentage, CC.sub.max represents the coverage contribution of the plurality of dimples having the maximum dimple diameter in a decimal form of percentage, and CC.sub.min is at least 0.2, and wherein the dimples cover about 65 percent to about 75 percent of the substantially spherical surface.

[0015] In further embodiments, the pattern results in no dimple-free great circles on the golf ball. In another embodiment, the total number of dimples disposed on the substantially spherical surface is about 300 dimples to about 450 dimples. In still another embodiment, each substantially identical dimple section includes at least one shared dimple, the shared dimple having a centroid that intersects an edge of the dimple section, and all shared dimples have the maximum dimple diameter. In yet another embodiment, the number of the plurality of dimples having the minimum dimple diameter is greater than the number of the plurality of dimples having the maximum dimple diameter. In another embodiment, the CC.sub.min is at least 0.3.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Further features and advantages of the invention can be ascertained from the following detailed description that is provided in connection with the drawings described below:

[0017] FIG. **1** is a schematic diagram illustrating a method for measuring the diameter of a dimple;

[0018] FIG. **2** is a graphical representation of the relationship between edge angle and surface coverage according to one embodiment of the present disclosure;

[0019] FIG. **3** is a graphical representation of the relationship between average dimple volume and surface coverage according to another embodiment of the present disclosure;

[0020] FIG. **4** illustrates a dimple section according to one embodiment of the present disclosure;

[0021] FIG. **5** illustrates a golf ball having a dimple pattern according to the embodiment shown in FIG. **4**;

[0022] FIG. **6** illustrates a dimple section according to a comparative example;

[0023] FIG. **7** illustrates a golf ball having a dimple pattern shown in FIG. **6**;

[0024] FIG. **8** illustrates a dimple section according to another comparative example;

[0025] FIG. **9** illustrates a golf ball having a dimple pattern shown in FIG. **8**;

[0026] FIG. **10** illustrates a dimple section according to still another comparative example;

[0027] FIG. **11** illustrates a golf ball having a dimple pattern shown in FIG. **10**;

[0028] FIG. **12** illustrates a dimple section according to yet another comparative example.

DETAILED DESCRIPTION OF THE INVENTION

[0029] Unless otherwise defined, all terms (including technical and scientific terms) used herein

have the same meaning as commonly understood by one of ordinary skill in the art of this disclosure. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well known functions or constructions may not be described in detail for brevity or clarity.

[0030] The terms “about” and “approximately” shall generally mean an acceptable degree of error or variation for the quantity measured given the nature or precision of the measurements. Numerical quantities given in this description are approximate unless stated otherwise, meaning that the term “about” or “approximately” can be inferred when not expressly stated.

[0031] The term “substantially” allows for deviations from the descriptor that do not negatively impact the intended purpose. Descriptive terms are understood to be modified by the term “substantially” even if the word “substantially” is not explicitly recited.

[0032] The terms “first,” “second,” “third,” and the like are used herein to describe various features or elements, but these features or elements should not be limited by these terms. These terms are only used to distinguish one feature or element from another feature or element. Thus, a first feature or element discussed below could be termed a second feature or element, and similarly, a second feature or element discussed below could be termed a first feature or element without departing from the teachings of the present disclosure.

[0033] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well (i.e., at least one of whatever the article modifies), unless the context clearly indicates otherwise.

[0034] The present disclosure provides reduced-flight golf balls. That is, golf balls designed to travel a distance that is shorter than the distance traveled by current performance balls. The golf balls of the present disclosure have dimple patterns with low dimple surface coverage and high dimple diameter disparity where the smallest sized dimples contribute significantly to the overall surface coverage. Advantageously, the high diameter disparity generates a turbulent boundary layer that increases the drag force on the golf ball while the low surface coverage contributes to a higher lift force. This combination of higher drag and higher lift symbiotically reduces the flight of the ball while providing improved aerodynamic consistency and maintaining a high-performance trajectory with a peak height in the golfer's desired flight window.

Dimple Arrangement

[0035] In one embodiment, golf ball dimple patterns of the present disclosure are arranged in a tetrahedral layout. The golf ball dimple patterns are arranged in a tetrahedral layout such that there are four identical sections on the golf ball. In one embodiment, each section is in the shape of a spherical triangle. As used herein, “spherical triangle” refers to a figure formed on the surface of a sphere by three circular arcs intersecting pairwise at three vertices. The three circular arcs each represent an edge of the spherical triangle.

[0036] The dimples may be located entirely within a dimple section. For example, in one embodiment, the dimples may be arranged within the edges of the spherical triangle such that no dimples intersect an edge of the spherical triangle. In another embodiment, dimples may be shared between two or more dimples sections. In one aspect of this embodiment, for each dimple that is not located entirely within a dimple section, the centroid of the dimple is located along a side edge or at one or more vertices of the spherical triangle. In another aspect of this embodiment, dimples shared between two sections may include dimples that are positioned such that the centroid of the dimple does not lie along a side edge. For purposes of the present disclosure, the “centroid” of the dimple refers to the center of the dimple.

[0037] In one embodiment of the present invention, the dimple pattern within each of the four identical dimple sections may be arranged such that one or more dimples intersect an edge of the

spherical triangle. In a particular aspect of this embodiment, the edge intersected by the one or more dimples runs through the centroid of the dimple such that half of the dimple is located within one spherical triangle and the other half is located within another spherical triangle. In another aspect of this embodiment, the edge intersected by one or more dimples does not run through the centroid of the dimple. That is, less than half of the dimple is located within one spherical triangle and more than half of the dimple is located within an adjacent spherical triangle.

[0038] In one embodiment, the dimple pattern within each of the four identical dimple sections includes at least three dimples that intersect an edge of the spherical triangle. In another embodiment, the dimple pattern within each of the four identical dimple sections includes at least six dimples that intersect an edge of the spherical triangle. In another embodiment, the dimple pattern within each of the four identical dimple sections includes at least twelve dimples that intersect an edge of the spherical triangle. In another embodiment, the dimple pattern within each of the four identical dimple sections includes at least fifteen dimples that intersect an edge of the spherical triangle. In still another embodiment, the dimple pattern within each of the four identical dimples sections includes at least eighteen dimples that intersect an edge of the spherical triangle.

[0039] In another embodiment, the dimple patterns of the present disclosure may be arranged such that a dimple lies at one or more vertices of the spherical triangle. In this embodiment, the centroid of the dimple is located at the vertex of the spherical triangle and a portion of the dimple is located within three of the spherical triangles. That is, the dimple located at the vertex of the spherical triangle may be centered on the vertices of the spherical triangles. The dimple patterns of the present disclosure may include a dimple located at a single vertex of the spherical triangle. In another embodiment, the dimple patterns may include a dimple located at each of two vertices of the spherical triangle. In still another embodiment, the dimple patterns may include a dimple located at each of the three vertices of the spherical triangle.

[0040] The dimple patterns arranged in each of the dimple sections, for example, in each of the spherical triangles, are substantially identical to each other. For purposes of the present disclosure, dimple patterns are “substantially identical” if they have substantially the same dimple arrangement (i.e., the relative positions of each of the dimples' centroids are about the same) and substantially the same dimple characteristics (e.g., plan shape, cross-sectional shape, diameter, edge angle). Thus, for each dimple located entirely within a particular dimple section, for example, a particular spherical triangle, there is a corresponding dimple in each of the other three dimple sections. For dimples having a centroid located along an edge of the dimple section, there is a corresponding dimple located along the same edge in the other three dimple sections. For dimples located at the one or more vertices of the dimple sections, these dimples are shared between the other dimple sections.

[0041] The dimple patterns within each dimple section, for example, within each spherical triangle, include dimples having varying dimple diameters. In one embodiment, each dimple pattern has at least two different dimple diameters, including a minimum diameter dimple (i.e., the smallest diameter on the golf ball) and a maximum diameter dimple (i.e., the largest diameter on the golf ball). For purposes of the present disclosure, dimples having substantially different diameters include dimples on a finished ball having respective diameters that differ by 0.005 inches or more. In another embodiment, each dimple pattern has from two to four different dimple diameters. For instance, each dimple pattern may have three different dimple diameters, including a minimum diameter dimple, a maximum diameter dimple, and an additional diameter dimple. In another embodiment, each dimple pattern may have four different dimple diameters, including a minimum diameter dimple, a maximum diameter dimple, and two additional diameter dimples.

[0042] As discussed above, in some embodiments, the dimple pattern includes at least one dimple intersecting an edge of the dimple section. In this embodiment, at least one dimple having the maximum dimple diameter intersects the edge of the dimple section. In some embodiments, all dimples intersecting the edge of the dimple section have the maximum dimple diameter. In another

embodiment, at least one dimple having the minimum dimple diameter intersects the edge of the dimple section. In still another embodiment, at least one dimple having neither the minimum nor maximum dimple diameter intersects the edge of the dimple section. Additionally, in some embodiments, the dimple pattern includes at least one dimple lying at a vertex of the dimple section. In this aspect, at least one dimple having the maximum dimple diameter is located at a vertex of the dimple section.

[0043] In one embodiment, the dimple patterns disclosed herein are symmetric. For example, the dimple patterns within each dimple section may be rotationally symmetric about the central point of each dimple section. That is, the dimple patterns may have three-way rotational symmetry about an axis connecting the center of the golf ball and the central point of the dimple section. In another embodiment, the dimple patterns may have mirror symmetry about a central plane of each dimple section, where the central plane is a plane containing the center of the golf ball, the central point of the corresponding dimple section, and one vertex of the corresponding dimple section.

[0044] In further embodiments, the dimples are arranged within each dimple section such that the outer surface of the golf ball has no dimple free great circles. That is, the dimples are arranged within each dimple section such that all great circles on the outer surface of the golf ball intersect dimples. The golf balls of the present disclosure ensure that the symmetry of the underlying tetrahedron is preserved while eliminating the use of dimple-free great circles as a means to reduce the flight of the golf ball.

[0045] The dimples may be positioned within each dimple section according to any packing method known in the art so long as the dimple sections are substantially identical and meet the symmetry, diameter disparity, contribution coverage, and surface coverage requirements discussed herein. For example, the dimples may be arranged within each dimple section according to the methods described in U.S. Pat. No. 10,814,175, the entire disclosure of which is incorporated herein by reference.

Dimple Diameter

[0046] As discussed above, the dimple patterns within each dimple section, for example, within each spherical triangle, include dimples having at least two different dimple diameters, including a minimum dimple diameter and a maximum dimple diameter. Diameter measurements are determined on finished golf balls according to FIG. **1**. Generally, it may be difficult to measure a dimple's diameter due to the indistinct nature of the boundary dividing the dimple from the ball's undisturbed land surface. Due to the effect of paint and/or the dimple design itself, the junction between the land surface and dimple may not be a sharp corner and is therefore indistinct. This can make the measurement of a dimple's diameter somewhat ambiguous.

[0047] To resolve this problem, the dimple diameter on a finished golf ball is measured according to the method shown in FIG. **1**. FIG. **1** shows a dimple half-profile **34**, extending from a dimple centerline **31** to the land surface outside of the dimple **33**. A ball phantom surface **32** is constructed above the dimple as a continuation of the land surface **33**. A first tangent line T1 is then constructed at a point on the dimple sidewall that is spaced 0.003 inches radially inward from the phantom surface **32**. The first tangent line T1 intersects the phantom surface **32** at a point P1, which defines a nominal dimple edge position. A second tangent line T2 is then constructed, tangent to the phantom surface **32** at P1. The edge angle is the angle between the first tangent line T1 and the second tangent line T2. The dimple diameter is the distance between P1 and its equivalent point diametrically opposite along the dimple perimeter. Alternatively, it is twice the distance between P1 and the dimple centerline **31**, measured in a direction perpendicular to the dimple centerline **31**. The dimple depth is the distance measured along a ball radius from the phantom surface **32** of the ball to the deepest point on the dimple. The chord plane runs through the point P1 and is normal to the dimple centerline **31**. The chord depth is the distance from the chord plane to the deepest part of the dimple. The cap height is the distance from the chord plane to the phantom surface **32** along the dimple centerline **31**. The dimple volume is the space enclosed between the phantom surface **32**

and the dimple surface **34** (extended along the first tangent line T1 until it intersects the phantom surface **32**).

[0048] In one embodiment, each dimple may have a dimple diameter of about 0.030 inches to about 0.300 inches. In another embodiment, each dimple has a dimple diameter of about 0.050 inches to about 0.250 inches. In still another embodiment, each dimple has a dimple diameter of about 0.070 inches to about 0.225 inches. In yet another embodiment, each dimple has a dimple diameter of about 0.090 inches to about 0.210 inches. In another embodiment, each dimple has a dimple diameter of about 0.100 inches to about 0.200 inches. In yet another embodiment, each dimple has a dimple dimeter of about 0.120 inches to about 0.180 inches. In still another embodiment, each dimple has a dimple diameter of about 0.140 inches to about 0.160 inches.

[0049] In some embodiments, the dimple patterns of the present disclosure have a high dimple diameter disparity. That is, the difference in diameter between the minimum dimple diameter and the maximum dimple diameter is significantly different. For purposes of the present disclosure, the dimple pattern is “highly disparate” when the difference between the maximum dimple diameter and the minimum dimple diameter is at least 0.050 inches. In another embodiment, the dimple pattern is “highly disparate” when the difference between the maximum dimple diameter and the minimum dimple diameter is at least 0.055 inches. In still another embodiment, the dimple pattern is “highly disparate” when the difference between the maximum dimple diameter and the minimum dimple diameter is at least 0.060 inches. In another embodiment, the dimple pattern is “highly disparate” when the difference between the maximum dimple diameter and the minimum dimple diameter is at least 0.075 inches. In still another embodiment, the dimple pattern is “highly disparate” when the difference between the maximum dimple diameter and the minimum dimple diameter is at least 0.100 inches. In yet another embodiment, the dimple pattern is “highly disparate” when the difference between the maximum dimple diameter and the minimum dimple diameter is at least 0.125 inches. In another embodiment, the dimple pattern is “highly disparate” when the difference between the maximum dimple diameter and the minimum dimple diameter is at least 0.150 inches.

[0050] In embodiments where the highly disparate pattern includes additional dimple diameters other than the minimum dimple diameter and the maximum dimple diameter, the minimum difference between any one of the additional dimple diameters and the minimum or maximum dimple diameter is about 0.010 inches or more. In another embodiment, the minimum difference is about 0.015 inches or more. In yet another embodiment, the minimum difference is about 0.020 inches or more. In still another embodiment, the minimum difference is about 0.030 or more. In other embodiments, the maximum difference between any one of the additional dimple diameters and the minimum or maximum dimple diameter is about is about 0.100 inches or less. In another embodiment, the maximum difference is about 0.075 inches or less. In still another embodiment, the maximum difference is about 0.050 inches or less. For instance, the difference between any one of the additional dimple diameters and the minimum or maximum dimple diameter is about 0.010 inches to about 0.100 inches.

[0051] In one embodiment, the dimples contemplated for use in the dimple patterns of the present disclosure have a circular plan shape. However, the dimples may also have a variety of other plan shapes. The diameter of a dimple having a non-circular plan shape is defined by its equivalent diameter, d.sub.e, which may be calculated according to equation (I):

[00003] $d_e = 2\sqrt{\frac{A}{\pi}}, \quad (I)$

where d.sub.e is the equivalent dimple diameter and A is the plan shape area of the dimple. By the term, “plan shape area,” it is meant the area based on a planar view of the dimple plan shape, such that the viewing plane is normal to an axis connecting the center of the golf ball to the point of the calculated surface depth. In one embodiment, the equivalent diameters of dimples having non-circular plan shapes are the same as the ranges of dimple diameters discussed above for the circular

plan shaped dimples.

Surface Coverage

[0052] Dimple patterns generated by the present disclosure can achieve a low percentage of surface coverage. As used herein, “surface coverage” refers to the percentage of the ball surface that has been removed by the formation of dimples. In other words, the surface coverage is the surface area of a sphere having the diameter of the golf (D.sub.ball) minus the surface area of the fret area of the golf ball. By reducing the surface coverage, the flight and distance of the golf ball can be reduced.

[0053] Surface coverage may be calculated using equation (II):

[00004] $$\text{SurfaceCoverage} = \frac{\text{.Math.}_{i=1}^{n} (r_i^2 + h_i^2)}{4 \left(\frac{D_{\text{ball}}}{2}\right)^2}, \quad \text{(II)}$$

where n is the number of dimples on the ball, r is the dimple plan shape radius (equal to the dimple diameter/2), and h is the cap height as shown in FIG. **1**.

[0054] In one embodiment, the dimple patterns generated by the present disclosure have a surface coverage of about 75 percent or less. In another embodiment, the dimple patterns generated by the present disclosure have a surface coverage of about 60 percent to about 75 percent. In still another embodiment, the dimple patterns generated by the present disclosure have a surface coverage of about 65 percent to about 75 percent. In still another embodiment, the dimple patterns generated by the present disclosure have a surface coverage of about 65 percent to about 70 percent. In yet another embodiment, the dimple patterns generated by the present disclosure have a surface coverage of about 70 percent to about 75 percent.

Coverage Contribution

[0055] Each group of dimples having substantially the same dimple diameter contributes to the overall surface coverage of the dimple pattern. As used herein, the term, “coverage contribution,” refers to the percentage of the total surface coverage of the golf ball occupied by a dimple group made up of dimples having substantially the same diameter. In other words, each dimple group on the golf ball, for example, the group of dimples having the minimum diameter, the group of dimples having the maximum diameter, and the groups of dimples having the additional diameters, has a defined coverage contribution. The coverage contribution (CCj) can be calculated for each group of dimples having substantially the same diameter (jth) using the following equation (III):

[00005] $$CC_j = \frac{n_j (r_j^2 + h_j^2)}{\text{.Math.}_{i=1}^{n} (r_i^2 + h_i^2)} \quad \text{(III)}$$

where n.sub.j is the total number of jth group dimples on the ball, n is the total number of dimples on the ball, r is the dimple plan shape radius (equal to half the dimple diameter), and h is the cap height as shown in FIG. **1**.

[0056] In one embodiment, the present disclosure contemplates dimple patterns where the dimple group having the minimum diameter substantially contributes to the overall surface coverage of the dimple pattern. For purposes of the present disclosure, to “substantially contribute” to the overall surface coverage of the dimple pattern, the dimple group has a coverage contribution of at least about 20 percent and preferably at least about 25 percent. In this embodiment, the coverage contribution of the dimple group having the minimum dimple diameter (CC.sub.min) is at least about 20 percent. In another embodiment, the coverage contribution of the dimple group having the minimum dimple diameter (CC.sub.min) is at least about 25 percent. In still another embodiment, the coverage contribution of the dimple group having the minimum dimple diameter (CC.sub.min) is at least about 30 percent. In yet another embodiment, the coverage contribution of the dimple group having the minimum dimple diameter (CC.sub.min) is at least about 35 percent. In another embodiment, the coverage contribution of the dimple group having the minimum dimple diameter (CC.sub.min) is at least about 40 percent. In still another embodiment, the coverage contribution of the dimple group having the minimum dimple diameter (CC.sub.min) is at least about 45 percent. In yet another embodiment, the coverage contribution of the dimple group having the minimum dimple diameter (CC.sub.min) is at least about 50 percent. In another embodiment, the coverage

contribution of the dimple group having the minimum dimple diameter (CC.sub.min) is at least about 60 percent. In still another embodiment, the coverage contribution of the dimple group having the minimum dimple diameter (CC.sub.min) may be up to about 75 percent.

[0057] In this aspect, since the dimple group having the minimum dimple diameter substantially contributes to the overall surface coverage of the dimple pattern, the relationship between the coverage contribution of the dimple group having the minimum dimple diameter and the dimple group having the maximum dimple diameter can be defined according to the following equation (IV):

[00006] $0.5 \leq \frac{CC_{min}}{CC_{max}}$ (IV)

where CC.sub.min represents the coverage contribution of the dimple group having the minimum dimple diameter in the decimal form of percentage (for example, 20 percent coverage contribution is 0.20) and CC.sub.max represents the coverage contribution of the dimple group having the maximum dimple diameter in the decimal form of percentage. In another embodiment, the relationship between the coverage contribution of the dimple group having the minimum dimple diameter and the dimple group having the maximum dimple diameter is defined according to the following equation (V):

[00007] $0.6 \leq \frac{CC_{min}}{CC_{max}}$ (*V*)

where CC.sub.min represents the coverage contribution of the dimple group having the minimum dimple diameter in the decimal form of percentage and CC.sub.max represents the coverage contribution of the dimple group having the maximum dimple diameter in the decimal form of percentage. In still another embodiment, the relationship between the coverage contribution of the dimple group having the minimum dimple diameter and the dimple group having the maximum dimple diameter is defined according to the following equation (VI):

[00008] $0.7 \leq \frac{CC_{min}}{CC_{max}}$ (VI)

where CC.sub.min represents the coverage contribution of the dimple group having the minimum dimple diameter in the decimal form of percentage and CC.sub.max represents the coverage contribution of the dimple group having the maximum dimple diameter in the decimal form of percentage. In yet another embodiment, the relationship between the coverage contribution of the dimple group having the minimum dimple diameter and the dimple group having the maximum dimple diameter is defined according to the following equation (VII):

[00009] $0.8 \leq \frac{CC_{min}}{CC_{max}}$ (VII)

where CC.sub.min represents the coverage contribution of the dimple group having the minimum dimple diameter in the decimal form of percentage and CC.sub.max represents the coverage contribution of the dimple group having the maximum dimple diameter in the decimal form of percentage.

[0058] In some embodiments, in order to substantially contribute to the overall surface coverage, the number of dimples having the minimum dimple diameter is greater than the number of dimples having the maximum dimple diameter. In one embodiment, the number of dimples having the minimum dimple diameter is at least twice the number of dimples having the maximum dimple diameter. In other words, the number of dimples having the maximum dimple diameter may be about one half of the number of dimples having the minimum dimple diameter. In another embodiment, the number of dimples having the minimum dimple diameter is at least 2.5 times the number of dimples having the maximum dimple diameter. In another embodiment, the number of dimples having the minimum dimple diameter is at least three times the number of dimples having the maximum dimple diameter.

Other Dimple Dimensions

[0059] The dimple patterns of the present disclosure may have varying edge angles depending on

the desired surface coverage. Optimization of the edge angles using the equations provided herein can help reduce the flight of the ball while maintaining ideal trajectories. For spherical dimples, the edge angle is defined as the angle between the first tangent line T1 and the second tangent line T2, as shown in FIG. **1**. In one embodiment, the average edge angle (θ.sub.μ) of all the dimple edge angles on the golf ball is related to the surface coverage based on the range displayed in equation (VIII) below:

[00010] $88.8(SC)^2 - 116.9(SC) + 47.7 \leq \quad \leq 170.(SC)^2 - 242.5(SC) + 106.6,$ (VIII)

where SC is the surface coverage and the format for SC is the decimal form of percentage (for example, 50 percent coverage is 0.50). FIG. **2** is a graphical representation of the relationship between edge angle and surface coverage of spherical dimples according to an embodiment of the present disclosure. In one embodiment, the dimples of the present disclosure may have any edge angle falling within the range of values shown in FIG. **2**. For instance, with a desired surface coverage of about 70 percent, the average edge angle of all the dimple edge angles on the golf ball may range from about 9.38 degrees to about 20.15 degrees. In another embodiment, with a desired surface coverage of about 50 percent, the average edge angle of all the dimple edge angles on the golf ball may range from about 11.45 degrees to about 27.85 degrees. In still another embodiment, with a desired surface coverage of about 30 percent, the average edge angle of all the dimple edge angles on the golf ball may range from about 20.62 degrees to about 49.15 degrees. In yet another embodiment, with a desired surface coverage of about 15 percent, the average edge angle of all the dimple edge angles on the golf ball may range from about 32.16 degrees to about 74.05 degrees. Accordingly, in some embodiments, as the surface coverage of the dimple patterns generated by the present disclosure decreases, the average edge angles may increase.

[0060] In one embodiment, the edge angle of all the dimples within a dimple section is substantially the same. For purposes of the present disclosure, edge angles on a finished golf ball are substantially identical if they differ by less than about 0.25 degrees. In another embodiment, the dimples within a dimple section may have two different edge angles. That is, the dimples within a dimple section may have two different edge angles that differ by more than about 0.25 degrees. In still another embodiment, the dimples within a dimple section may have three different edge angles, where each edge angle differs from the others by more than about 0.25 degrees.

[0061] In the embodiments where the dimples may have varying edge angles, the maximum difference in edge angle between any two dimples within a dimple section may be about 1 degree to about 4 degrees. In one embodiment, the maximum difference in edge angle between any two dimples within a dimple section may be about 1 degree to about 3 degrees. For example, in a preferred embodiment, the maximum difference in edge angle between any two dimples within a dimple section is about 1 degree.

[0062] The spherical dimples contemplated by the present disclosure may also have a dimple depth, chord depth, and cap height, as defined and shown in FIG. **1**. In one embodiment, when golf balls of the present disclosure have a desired surface coverage of about 70 percent, the dimple depths may range from about 0.0049 inches to about 0.0146 inches. In another embodiment, when golf balls of the present disclosure have a desired surface coverage of about 50 percent, the dimple depths may range from about 0.0049 inches to about 0.0175 inches. In still another embodiment, when golf balls of the present disclosure have a desired surface coverage of about 30 percent, the dimple depths may range from about 0.0063 inches to about 0.0259 inches. In yet another embodiment, when golf balls of the present disclosure have a desired surface coverage of about 15 percent, the dimple depths may range from about 0.0072 inches to about 0.0369 inches.

Dimple Plan Shapes and Profiles

[0063] The present disclosure contemplates dimples having a circular plan shape. A “plan shape,” as used herein, refers to the perimeter of the dimple as seen from a top view of the dimple, or the demarcation between the dimple and the outer surface of the golf ball or fret surface. However,

non-circular plan shapes may also be suitable for use with the present disclosure. For example, the plan shape may be any one of a circle, square, triangle, rectangle, oval, or other geometric or non-geometric shape. In another embodiment, the dimples may have a plan shape defined by low frequency periodic functions or high frequency periodic functions.

[0064] In one embodiment, the dimples contemplated for use in the dimple patterns are spherical dimples (i.e., dimples having a circular plan shape and a dimple profile based on a spherical function). A "dimple profile," as used herein, refers to the cross section of the dimple as seen from a side view of the dimple. However, other dimple profile shapes may also be suitable for use with the present disclosure. For example, the dimples may be defined by the revolution of a catenary curve about an axis, such as that disclosed in U.S. Pat. Nos. 6,796,912 and 6,729,976, the entire disclosures of which are incorporated by reference herein. In another embodiment, the dimple profiles may correspond to ellipses, saucer-shapes, truncated cones, and flattened trapezoids.

[0065] In still another embodiment, the dimples may have profiles defined by a continuous function, such as a polynomial function, an exponential function, a trigonometric function, and a hyperbolic function. Specific non-limiting examples of suitable dimple profiles contemplated by the present disclosure include those that can be defined by the following functions: conical, catenary, polynomial, Witch of Agnesi, frequency, Neiles parabola, sine, cosine, hyperbolic sine, and hyperbolic cosine profiles.

[0066] The dimple profile may also be defined by combining a spherical curve and a different curve, such as a cosine curve, a frequency curve or a catenary curve, as disclosed in U.S. Patent Publication No. 2012/0165130, which is incorporated in its entirety by reference herein. Similarly, the dimple profile may be defined by a combination of two or more curves. For example, in one embodiment, the dimple profile is defined by combining a spherical curve and a different curve. In another embodiment, the dimple profile is defined by combining a cosine curve and a different curve. In still another embodiment, the dimple profile is defined by combining a frequency curve and a different curve. In yet another embodiment, the dimple profile is defined by combining a catenary curve and a different curve. In still another embodiment, the dimple profile may be defined by combining three or more different curves. In yet another embodiment, one or more of the curves may be a functionally weighted curve, as disclosed in U.S. Patent Publication No. 2013/0172123, which is incorporated in its entirety by reference herein.

Dimple Count

[0067] The present disclosure contemplates golf balls having low dimple counts. As used herein, the "dimple count" of a golf ball refers to how many dimples are present on the golf ball. The total number of dimples may be based on, for instance, the number of differently sized dimples, the maximum and minimum diameters of the dimples, the dimple arrangement, and the desired surface coverage.

[0068] In one embodiment, the total number of dimples on the golf ball may be about 450 dimples or less. For example, the total number of dimples on the golf ball may range from about 300 dimples to about 450 dimples. In another embodiment, the total number of dimples on the golf ball may range from about 328 dimples to about 425 dimples. In still another embodiment, the total number of dimples on the golf ball may range from about 344 dimples to about 400 dimples. In yet another embodiment, the total number of dimples on the golf ball may range from about 352 dimples to about 388 dimples. In another embodiment, the total number of dimples on the golf ball may range from about 328 dimples to about 388 dimples.

Golf Ball Construction

[0069] Dimple patterns according to the present disclosure may be used with practically any type of ball construction. For instance, the golf ball may have a two-piece design, a double cover, or veneer cover construction depending on the type of performance desired of the ball. Other suitable golf ball constructions include solid, wound, liquid-filled, and/or dual cores, and multiple intermediate layers.

[0070] Different materials may be used in the construction of golf balls according to the present disclosure. For example, the cover of the ball may be made of a thermoset or thermoplastic, a castable or non-castable polyurethane and polyurea, an ionomer resin, balata, or any other suitable cover material known to those skilled in the art. Conventional and non-conventional materials may be used for forming core and intermediate layers of the ball including polybutadiene and other rubber-based core formulations, ionomer resins, highly neutralized polymers, and the like.

[0071] The golf balls of the present disclosure may be formed using a variety of application techniques. For example, the golf ball layers may be formed using compression molding, flip molding, injection molding, retractable pin injection molding, reaction injection molding (RIM), liquid injection molding (LIM), casting, vacuum forming, powder coating, flow coating, spin coating, dipping, spraying, and the like. Conventionally, compression molding and injection molding are applied to thermoplastic materials, whereas RIM, liquid injection molding, and casting are employed on thermoset materials.

EXAMPLES

[0072] The following non-limiting examples demonstrate dimple patterns that may be made in accordance with the present disclosure. The examples are merely illustrative of the preferred embodiments of the present disclosure and are not to be construed as limiting the disclosure, the scope of which is defined by the appended claims.

Example 1

[0073] A dimple pattern according to an embodiment of the present disclosure is illustrated in FIGS. **4** and **5**. FIG. **4** shows a section **50** of a tetrahedral pattern packed with dimples. FIG. **5** shows the section **50** of FIG. **4** patterned around a golf ball **100**. The golf ball **100** has four identical sections **50** packed with the same dimple pattern shown in FIG. **4**. The golf ball **100** has a diameter of 1.68 inches and the resulting overall dimple pattern has a total of 388 dimples with a total surface coverage of about 72 percent. There are no dimple free great circles on the golf ball **100**.

[0074] In FIGS. **4** and **5**, the alphabetic labels within the dimples designate dimples having substantially the same dimple diameter. In the illustrated embodiment, there are two different dimple diameters: the dimples labeled A have a diameter of about 0.100 inches (which is the minimum diameter) and the dimples labeled B have a diameter of about 0.210 inches (which is the maximum diameter). The difference between the maximum dimple diameter and the minimum dimple diameter is about 0.110 inches.

[0075] The dimples are arranged within each section **50** such that some of the maximum diameter dimples, for example, a number of dimples labeled “B,” intersect the edges of the section **50**. The edges run through the centroids of the intersecting “B” dimples. The resulting dimple pattern has three-way rotational symmetry about an axis connecting the center of the golf ball **100** and the center of the spherical triangle **50**.

[0076] Table 1 below summarizes the properties of the dimple pattern arranged on the golf ball **100** shown in FIG. **5**, including the dimple quantity, the dimple surface coverage percentage, and the coverage contribution for each dimple group on the golf ball. As shown in FIGS. **4**-**5** (and demonstrated by the data in Table 1), the dimples are arranged in a tetrahedral pattern comprised of two dimple diameters and the two diameters are highly disparate from one another. The dimples having the minimum diameter (i.e., Dimple Group A) also have a coverage contribution of 48.1 percent, which means the minimum diameter dimple group contributes significantly to the overall surface coverage of the dimple pattern.

TABLE-US-00001 TABLE 1 Properties of Dimple Pattern Shown in FIG. 5 Dimple Dimple Dimple Surface Coverage Dimple Diameter Quantity Coverage Contribution Group (inches) (n.sub.j) Percentage (CC.sub.j) A 0.100 264 23.4% 48.1% B 0.210 124 48.6% 67.5% Total Surface Coverage (%) 72.0% [00011]$\frac{CC_{min}}{CC_{max}}$ 0.71 Total Dimple Count 388

Comparative Example 1

[0077] A comparative tetrahedral dimple pattern is illustrated in FIGS. **6** and **7**. FIG. **6** shows a

spherical triangle **10** packed with dimples and having three edges **16**. FIG. **7** shows the spherical triangle **10** of FIG. **6** patterned around a golf ball **12**. The golf ball **12** has four spherical triangles **10** packed with the same dimple pattern shown in FIG. **6**. The golf ball **12** has a diameter of 1.68 inches and the resulting overall dimple pattern has a total of 352 dimples with a surface coverage of about 63.4 percent. The dotted lines identify three dimple free great circles **14** on the surface of the golf ball **12**.

[0078] In FIGS. **6** and **7**, the alphabetic labels within the dimples designate dimples having substantially the same dimple measurements, for instance, substantially the same diameter, depth, chord depth, cap height, and edge angle. In the illustrated embodiment, the dimples labeled A-D have the diameters, depths, chord depths, cap heights, and edge angles given in Table 2 below:

TABLE-US-00002 TABLE 2 Dimple Measurements of FIGS. 6 and 7 Dimple Dimple Chord Cap Edge Diameter Depth Depth Height Angle Dimple (inches) (inches) (inches) (inches) (degrees) A 0.109 0.0080 0.0062 0.0018 16.75 B 0.139 0.0102 0.0073 0.0029 16.75 C 0.149 0.0109 0.0076 0.0033 16.75 D 0.154 0.0113 0.0078 0.0035 16.75

[0079] As shown in FIGS. **6** and **7** and Table 2, the dimples have a total of four different dimple diameters, including a minimum dimple diameter of about 0.109 inches (represented by dimples labeled “A”), a maximum dimple diameter of about 0.154 inches (represented by dimples labeled “D”), and two additional dimple diameters of about 0.139 inches (represented by dimples labeled “B”) and about 0.149 inches (represented by dimples labeled “C”). The difference between the maximum dimple diameter and the minimum dimple diameter is about 0.045 inches, which is also the maximum difference between any two dimple diameters. All the dimples have the same edge angle of about 16.75 degrees.

[0080] The dimples are arranged within each spherical triangle **10** such that some dimples, for example, a number of dimples labeled “B,” intersect the edges **16** of the spherical triangle **10**. The edges **16** run through the centroids of the intersecting “B” dimples. Also shown in the illustrated embodiment, three dimples labeled “D” lie at each of the vertices **18** of the spherical triangle **10**. The dimples located at each of the vertices **18** are centered such that a portion of each of the dimples is located within three of the spherical triangles **10**. The resulting dimple pattern has three-way rotational symmetry about an axis connecting the center of the golf ball and the center **11** of the spherical triangle **10**.

[0081] Table 3 below summarizes the properties of the dimple pattern arranged on the golf ball **12** shown in FIG. **7**, including the dimple quantity, the dimple surface coverage percentage, and the coverage contribution for each dimple group on the golf ball. As shown in FIGS. **6-7** (and demonstrated by the data in Table 3), the dimples are arranged in a tetrahedral pattern comprised of four dimple diameters where the minimum and maximum dimple diameters are not highly disparate from one another. Additionally, the dimples having the minimum diameter (i.e., Dimple Group A) do not contribute significantly to the overall surface coverage of the dimple pattern as the dimple group only has a coverage contribution of 8 percent.

TABLE-US-00003 TABLE 3 Properties of Dimple Pattern Shown in FIG. 7 Dimple Dimple Dimple Surface Coverage Dimple Diameter Quantity Coverage Contribution Group (inches) (n.sub.j) Percentage (CC.sub.j) A 0.109 48 5.1% 8.0% B 0.139 120 20.6% 32.5% C 0.149 72 14.2% 22.4% D 0.154 112 23.6% 37.2% Total Surface Coverage (%) 63.4% [00012]$\frac{CC_{min}}{CC_{max}}$ 0.21 Total Dimple Count 352

Comparative Example 2

[0082] A comparative tetrahedral dimple pattern is illustrated in FIGS. **8** and **9**. FIG. **8** shows a spherical triangle **20** packed with dimples and having three edges **16**. FIG. **9** shows the spherical triangle **20** of FIG. **8** patterned around a golf ball **22**. The golf ball **22** has four spherical triangles **20** packed with the same dimple pattern shown in FIG. **8**. The golf ball **22** has a diameter of 1.68 inches and the resulting overall dimple pattern has a total of 352 dimples with a surface coverage of about 43.2 percent. The dotted lines identify three dimple free great circles **14** on the surface of the

golf ball **22**.

[0083] In FIGS. **8** and **9**, the alphabetic labels within the dimples designate dimples having substantially the same dimple measurements, for instance, substantially the same diameter, depth, chord depth, cap height, and edge angle. In the illustrated embodiment of FIGS. **8** and **9**, the dimples labeled A-D have the diameters, depths, chord depths, cap heights, and edge angles given in Table 4 below:

TABLE-US-00004 TABLE 4 Dimple Measurements of FIGS. 8 and 9 Dimple Dimple Chord Cap Edge Diameter Depth Depth Height Angle Dimple (inches) (inches) (inches) (inches) (degrees) A 0.084 0.0091 0.0080 0.0010 24.50 B 0.114 0.0123 0.0104 0.0019 24.50 C 0.124 0.0134 0.0111 0.0023 24.50 D 0.129 0.0139 0.0115 0.0025 24.50

[0084] As shown in FIGS. **8** and **9** and Table 4, the dimples have a total of four different dimple diameters, including a minimum dimple diameter of about 0.084 inches (represented by dimples labeled "A"), a maximum dimple diameter of about 0.129 inches (represented by dimples labeled "D"), and two additional dimple diameters of about 0.114 inches (represented by dimples labeled "B") and about 0.124 inches (represented by dimples labeled "C"). The difference between the maximum dimple diameter and the minimum dimple diameter is about 0.045 inches, which is also the maximum difference between any two dimple diameters. All the dimples have the same edge angle of about 24.50 degrees.

[0085] The dimples are arranged within each spherical triangle **20** such that some dimples, for example, a number of dimples labeled "B," intersect the edges **16** of the spherical triangle **20**. The edges **16** run through the centroids of the intersecting "B" dimples. Also shown in the illustrated embodiment, three dimples labeled "D" lie at each of the vertices **18** of the spherical triangle **20**. The dimples located at each of the vertices **18** are centered such that a portion of each of the dimples is located within three of the spherical triangles **20**. The resulting dimple pattern has three-way rotational symmetry about an axis connecting the center of the golf ball and the center **11** of the spherical triangle **20**.

[0086] Table 5 below summarizes the properties of the dimple pattern arranged on the golf ball **22** shown in FIG. **9**, including the dimple quantity, the dimple surface coverage percentage, and the coverage contribution for each dimple group on the golf ball. As shown in FIGS. **8**-**9** (and demonstrated by the data in Table 5), the dimples are arranged in a tetrahedral pattern comprised of four dimple diameters where the minimum and maximum dimple diameters are not highly disparate from one another. Additionally, the dimples having the minimum diameter (i.e., Dimple Group A) do not contribute significantly to the overall surface coverage of the dimple pattern as the dimple group only has a coverage contribution of 7 percent.

TABLE-US-00005 TABLE 5 Properties of Dimple Pattern Shown in FIG. 9 Dimple Dimple Dimple Surface Coverage Dimple Diameter Quantity Coverage Contribution Group (inches) (n.sub.j) Percentage (CC.sub.j) A 0.084 48 3.0% 7.0% B 0.114 120 13.8% 32.0% C 0.124 72 9.8% 22.7% D 0.129 112 16.5% 38.3% Total Surface Coverage (%) 43.2% [00013] $\frac{CC_{min}}{CC_{max}}$ 0.18 Total Dimple Count 352

Comparative Example 3

[0087] A comparative tetrahedral dimple pattern is illustrated in FIGS. **10** and **11**. FIG. **10** shows a spherical triangle **40** packed with dimples and having three edges **16**. FIG. **11** shows the spherical triangle **40** of FIG. **10** patterned around a golf ball **42**. The golf ball **42** has four spherical triangles **40** packed with the same dimple pattern shown in FIG. **10**. The golf ball **42** has a diameter of 1.68 inches and the resulting overall dimple pattern has a total of 352 dimples with a surface coverage of about 23.6 percent. The dotted lines identify three dimple free great circles **14** on the surface of the golf ball **42**.

[0088] In FIGS. **10** and **11**, the alphabetic labels within the dimples designate dimples having substantially the same dimple measurements, for instance, substantially the same diameter, depth, chord depth, cap height, and edge angle. In the illustrated embodiment of FIGS. **10** and **11**, the

dimples labeled A-D have the diameters, depths, chord depths, cap heights, and edge angles given in Table 6 below:

TABLE-US-00006 TABLE 6 Dimple Measurements of FIGS. 10 and 11 Dimple Dimple Chord Cap Edge Diameter Depth Depth Height Angle Dimple (inches) (inches) (inches) (inches) (degrees) A 0.053 0.0114 0.0110 0.0004 47.00 B 0.083 0.0179 0.0168 0.0010 47.00 C 0.093 0.0200 0.0187 0.0013 47.00 D 0.098 0.0211 0.0196 0.0014 47.00

[0089] As shown in FIGS. **10** and **11** and Table 6, the dimples have a total of four different dimple diameters, including a minimum dimple diameter of about 0.053 inches (represented by dimples labeled "A"), a maximum dimple diameter of about 0.098 inches (represented by dimples labeled "D"), and two additional dimple diameters of about 0.083 inches (represented by dimples labeled "B") and about 0.093 inches (represented by dimples labeled "C"). The difference between the maximum dimple diameter and the minimum dimple diameter is about 0.045 inches, which is also the maximum difference between any two dimple diameters. All the dimples have the same edge angle of about 47.00 degrees.

[0090] The dimples are arranged within each spherical triangle **40** such that some dimples, for example, a number of dimples labeled "B," intersect the edges **16** of the spherical triangle **40**. The edges **16** run through the centroids of the intersecting "B" dimples. Also shown in the illustrated embodiment, three dimples labeled "D" lie at each of the vertices **18** of the spherical triangle **40**. The dimples located at each of the vertices **18** are centered such that a portion of each of the dimples is located within three of the spherical triangles **40**. The resulting dimple pattern has three-way rotational symmetry about an axis connecting the center of the golf ball and the center **11** of the spherical triangle **40**.

[0091] Table 7 below summarizes the properties of the dimple pattern arranged on the golf ball **42** shown in FIG. **11**, including the dimple quantity, the dimple surface coverage percentage, and the coverage contribution for each dimple group on the golf ball. As shown in FIGS. **10**-**11** (and demonstrated by the data in Table 7), the dimples are arranged in a tetrahedral pattern comprised of four dimple diameters where the minimum and maximum dimple diameters are not highly disparate from one another. Additionally, the dimples having the minimum diameter (i.e., Dimple Group A) do not contribute significantly to the overall surface coverage of the dimple pattern as the dimple group only has a coverage contribution of 5.1 percent.

TABLE-US-00007 TABLE 7 Properties of Dimple Pattern Shown in FIG. 11 Dimple Dimple Dimple Surface Coverage Dimple Diameter Quantity Coverage Contribution Group (inches) (n.sub.j) Percentage (CC.sub.j) A 0.053 48 1.2% 5.1% B 0.083 120 7.3% 31.1% C 0.093 72 5.5% 23.4% D 0.098 112 9.5% 40.4% Total Surface Coverage (%) 23.6% [00014]$\frac{CC_{min}}{CC_{max}}$ 0.13 Total Dimple Count 352

Comparative Example 4

[0092] A comparative tetrahedral dimple pattern is illustrated in FIG. **12** where first domain **14***a* and second domain **14***b* are tessellated to cover the surface of a golf ball. The golf ball has a diameter of 1.68 inches and the resulting overall dimple pattern has a total of 696 dimples with a surface coverage of about 72.5 percent.

[0093] In FIG. **12**, the alphabetic labels within the dimples designate dimples having substantially the same dimple measurements, for instance, substantially the same diameter, depth, and edge angle. In the illustrated embodiment of FIG. **12**, the dimples labeled A-G have the diameters, depths, and edge angles given in Table 8 below:

TABLE-US-00008 TABLE 8 Dimple Measurements of FIG. 12 Dimple Dimple Edge Diameter Depth Angle Dimple (inches) (inches) (degrees) A 0.030 0.0020 15.0 B 0.115 0.0060 12.0 C 0.135 0.0071 12.0 D 0.150 0.0079 12.0 E 0.160 0.0084 12.0 F 0.170 0.0089 12.0 G 0.185 0.0097 12.0

[0094] As shown in FIG. **12** and Table 8, the dimples have a total of seven different dimple diameters, including a minimum dimple diameter of about 0.030 inches (represented by dimples labeled "A"), a maximum dimple diameter of about 0.185 inches (represented by dimples labeled

"G"), and five additional dimple diameters of about 0.115 inches (represented by dimples labeled "B"), about 0.135 inches (represented by dimples labeled "C"), about 0.150 inches (represented by dimples labeled "D"), about 0.160 inches (represented by dimples labeled "E"), and about 0.170 inches (represented by dimples labeled "F"). The difference between the maximum dimple diameter and the minimum dimple diameter is about 0.155 inches.

[0095] Table 9 below summarizes the properties of the dimple pattern arranged on the golf ball shown in FIG. **12**, including the dimple quantity, the dimple surface coverage percentage, and the coverage contribution for each dimple group on the golf ball. As shown in FIG. **12** (and demonstrated by the data in Table 9), the dimples are arranged in a tetrahedral pattern comprised of seven dimple diameters and, while the minimum and maximum dimple diameters may be highly disparate from one another, the dimples having the minimum diameter (i.e., Dimple Group A) do not contribute significantly to the overall surface coverage of the dimple pattern as the dimple group only has a coverage contribution of 3.8 percent.

TABLE-US-00009 TABLE 9 Properties of Dimple Pattern Shown in FIG. 12 Dimple Dimple Dimple Surface Coverage Dimple Diameter Quantity Coverage Contribution Group (inches) (n.sub.j) Percentage (CC.sub.j) A 0.030 348 2.8% 3.8% B 0.115 48 5.6% 7.8% C 0.135 72 11.6% 16.1% D 0.150 80 16.0% 22.0% E 0.160 76 17.3% 23.8% F 0.170 48 12.3% 17.0% G 0.185 24 6.9% 9.5% Total Surface Coverage (%) 72.5% [00015]$\frac{CC_{min}}{CC_{max}}$ 0.40 Total Dimple Count 696

[0096] The golf balls and dimple patterns described and claimed herein are not to be limited in scope by the specific embodiments herein disclosed, since these embodiments are intended as illustrations of several aspects of the disclosure. Any equivalent embodiments are intended to be within the scope of this disclosure. Indeed, various modifications of the device in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims. All patents and patent applications cited in the foregoing text are expressly incorporated herein by reference in their entirety. Any section headings herein are provided only for consistency with the suggestions of 37 C.F.R. § 1.77 or otherwise to provide organizational queues. These headings shall not limit or characterize the invention(s) set forth herein.

Claims

1. A golf ball having a substantially spherical surface, comprising: a plurality of dimples disposed thereon, wherein the dimples are arranged in a pattern comprising four substantially identical dimple sections, wherein the dimples in each of the four substantially identical dimple sections comprise a plurality of dimples having at least two different dimple diameters including a minimum dimple diameter and a maximum dimple diameter and the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.050 inches, and wherein the dimples cover about 75 percent or less of the substantially spherical surface, and the pattern results in no dimple-free great circles on the golf ball.

2. The golf ball of claim 1, wherein the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.075 inches.

3. The golf ball of claim 1, wherein the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.100 inches.

4. The golf ball of claim 1, wherein the pattern is rotationally symmetric about the center of each substantially identical dimple section.

5. The golf ball of claim 1, wherein the plurality of dimples having the minimum dimple diameter and the plurality of dimples having the maximum dimple diameter each has a coverage contribution, the coverage contributions satisfying the following equation: $0.5 \leq \frac{CC_{min}}{CC_{max}}$ where CC.sub.min represents the coverage contribution of the plurality of dimples having the minimum

dimple diameter in a decimal form of percentage, CC.sub.max represents the coverage contribution of the plurality of dimples having the maximum dimple diameter in a decimal form of percentage, and CC.sub.min is at least 0.2.

6. The golf ball of claim 1, wherein each substantially identical dimple section comprises at least one shared dimple, the shared dimple having a centroid that intersects an edge of the dimple section.

7. The golf ball of claim 6, wherein all shared dimples have the maximum dimple diameter.

8. A golf ball having a substantially spherical surface, comprising: a plurality of dimples disposed thereon, wherein the dimples are arranged in a pattern comprising four substantially identical dimple sections, wherein the dimples in each of the four substantially identical dimple sections comprise a plurality of dimples having at least two different dimple diameters including a minimum dimple diameter and a maximum dimple diameter and the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.055 inches, wherein the plurality of dimples having the minimum dimple diameter has a coverage contribution of at least 20 percent, and wherein the dimples cover about 70 percent or less of the substantially spherical surface, and the pattern results in no dimple-free great circles on the golf ball.

9. The golf ball of claim 8, wherein the plurality of dimples having the minimum dimple diameter has a coverage contribution of at least 30 percent.

10. The golf ball of claim 8, wherein the plurality of dimples having the minimum dimple diameter has a coverage contribution of at least 40 percent.

11. The golf ball of claim 8, wherein the number of the plurality of dimples having the minimum dimple diameter is greater than the number of the plurality of dimples having the maximum dimple diameter.

12. The golf ball of claim 8, wherein the number of the plurality of dimples having the minimum dimple diameter is at least twice the number of the plurality of dimples having the maximum dimple diameter.

13. The golf ball of claim 8, wherein the total number of dimples disposed on the substantially spherical surface is no more than 450 dimples.

14. The golf ball of claim 8, wherein the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.075 inches.

15. A golf ball having a substantially spherical surface, comprising: a plurality of dimples disposed thereon, wherein the dimples are arranged in a pattern comprising four substantially identical dimple sections, wherein the dimples in each of the four substantially identical dimple sections comprise a plurality of dimples having from two to four different dimple diameters including at least a minimum dimple diameter and a maximum dimple diameter and the difference between the maximum dimple diameter and the minimum dimple diameter is at least about 0.060 inches, wherein the plurality of dimples having the minimum dimple diameter and the plurality of dimples having the maximum dimple diameter each has a coverage contribution, the coverage contributions satisfying the following equation: $0.5 \leq \frac{CC_{min}}{CC_{max}}$ where CC.sub.min represents the coverage contribution of the plurality of dimples having the minimum dimple diameter in a decimal form of percentage, CC.sub.max represents the coverage contribution of the plurality of dimples having the maximum dimple diameter in a decimal form of percentage, and CC.sub.min is at least 0.2, and wherein the dimples cover about 65 percent to about 75 percent of the substantially spherical surface.

16. The golf ball of claim 15, wherein the pattern results in no dimple-free great circles on the golf ball.

17. The golf ball of claim 15, wherein the total number of dimples disposed on the substantially spherical surface is about 300 dimples to about 450 dimples.

18. The golf ball of claim 15, wherein each substantially identical dimple section comprises at least one shared dimple, the shared dimple having a centroid that intersects an edge of the dimple

section, and all shared dimples have the maximum dimple diameter.

19. The golf ball of claim 15, wherein the number of the plurality of dimples having the minimum dimple diameter is greater than the number of the plurality of dimples having the maximum dimple diameter.

20. The golf ball of claim 15, wherein CC.sub.min is at least 0.3.