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(54) **SYNERGISTIC GOLF CLUB AND GOLF BALL COMBINATION**

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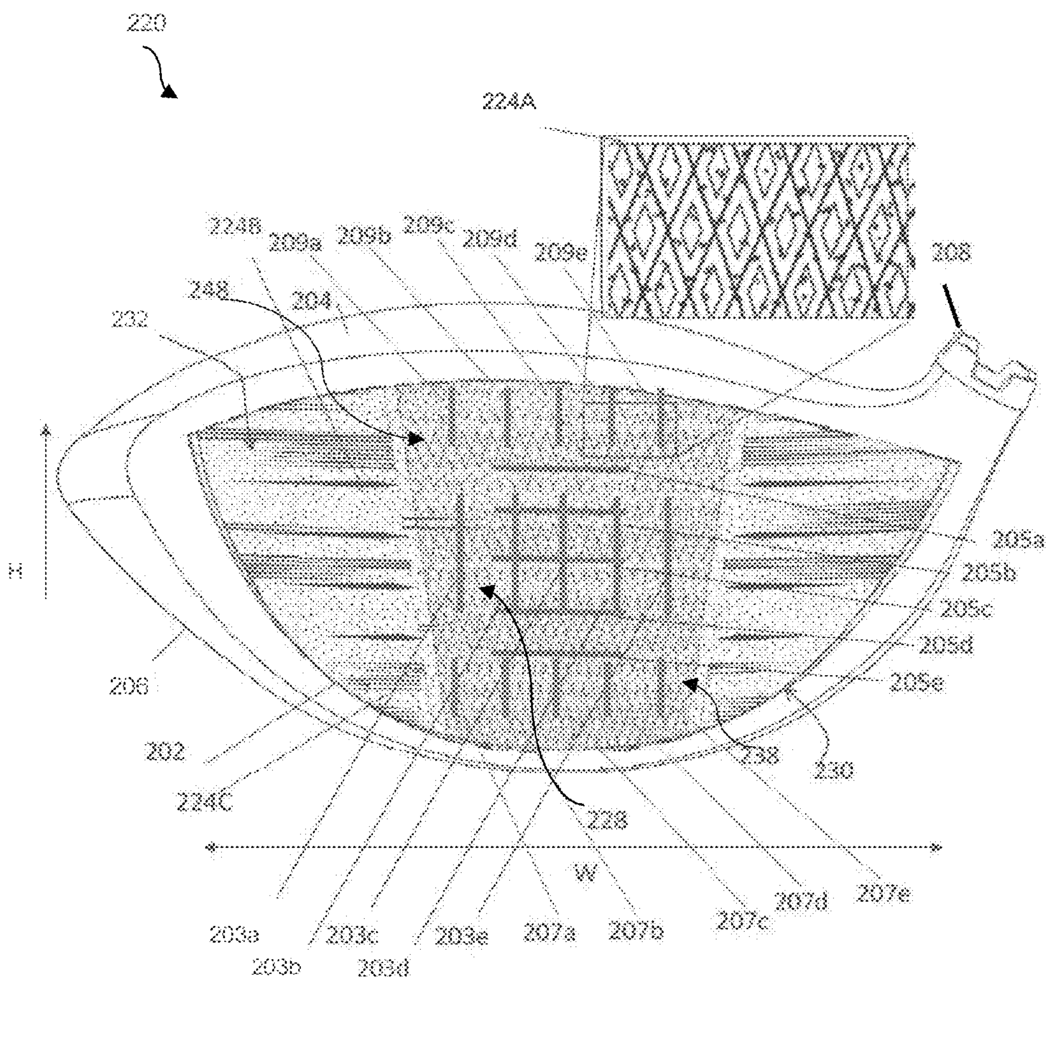
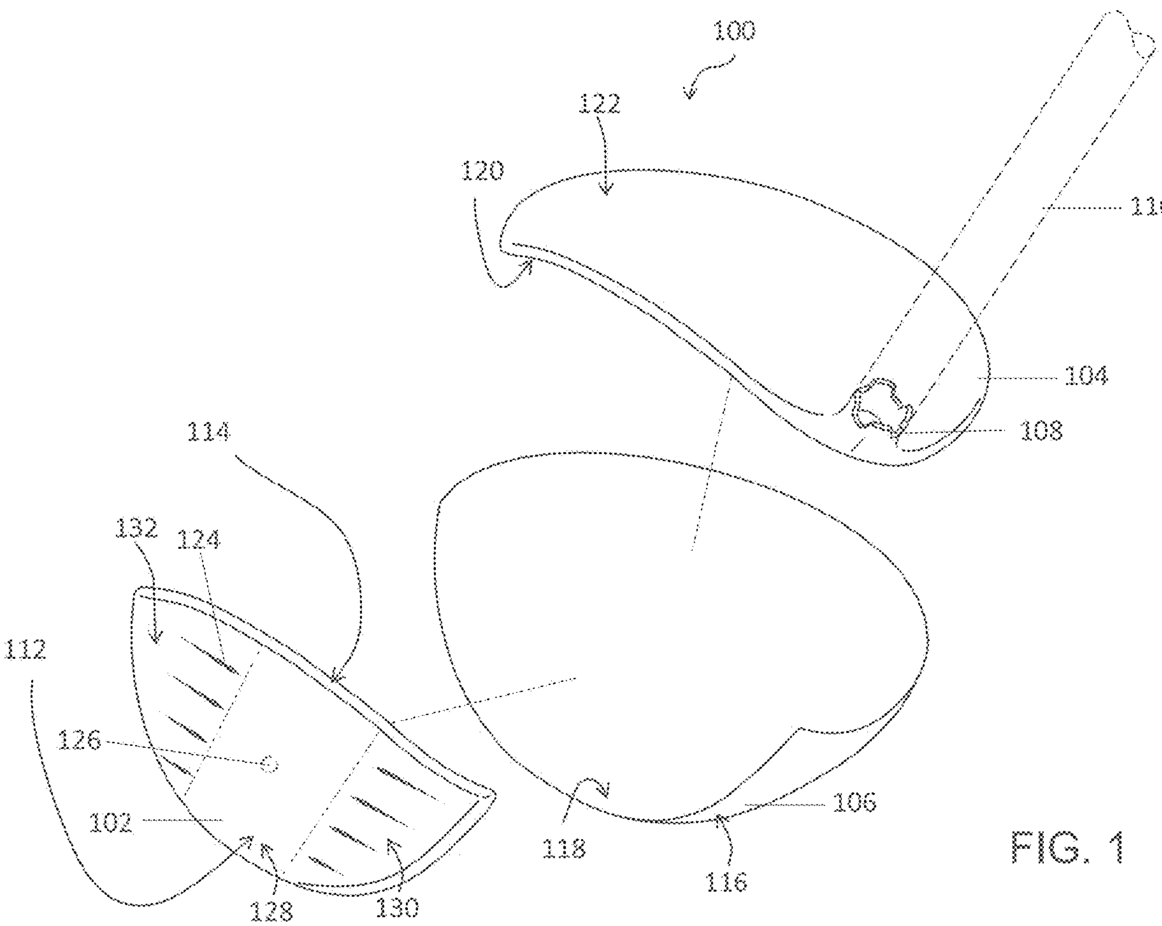
(57) **ABSTRACT**

Synergistic pairings of golf club and golf ball is important to achieve the maximum performance. The golf club and golf ball, although often designed in vacuum, can benefit from a synergistic design concept that base the design of one component based on the design of the other design. In one example, a golf ball may have a higher launch angle, a higher rate of spin generation, higher drag, and/or moderate to relatively higher net lift, which can be paired with a club head that generates a lower launch by having laser-generated features. The laser-generated features can increase the surface roughness value of the external surface of the club face by imparting micro-grooves.




100
122
120
110
104
108
114
132
124
112
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102
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130
118
106
116

FIG. 1

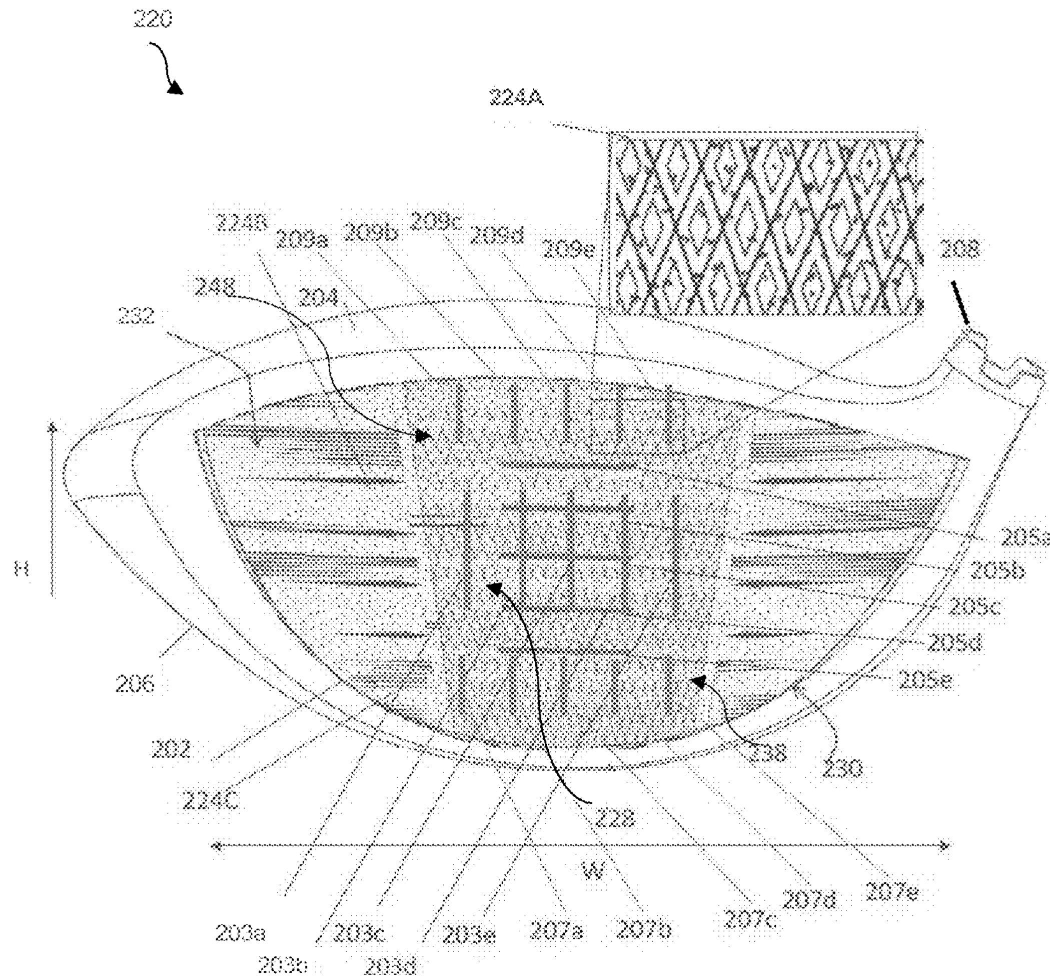

220
224A
224B
209a
209b
209c
209d
209e
208
248
204
232
H
205a
205b
205c
205d
205e
206
202
224C
238
230
228
W
203a
203b
203c
203d
203e
207a
207b
207c
207d
207e

FIG. 2

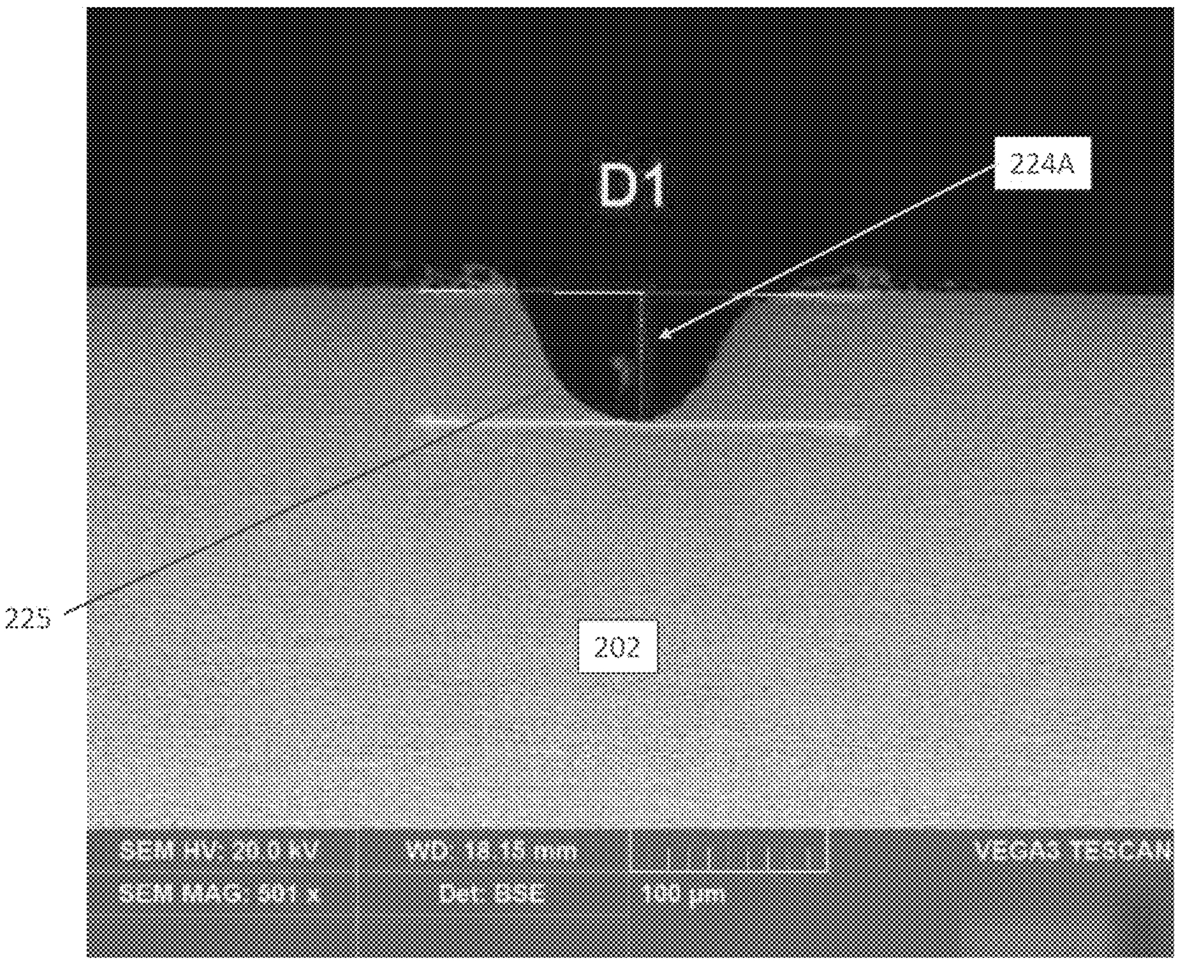

D1
224A
225
202
SEM HV: 20.0 kV
WD: 18.15 mm
VEGA3 TESCAN
SEM MAG: 501 x
Det: BSE
100 μm

FIG. 2a

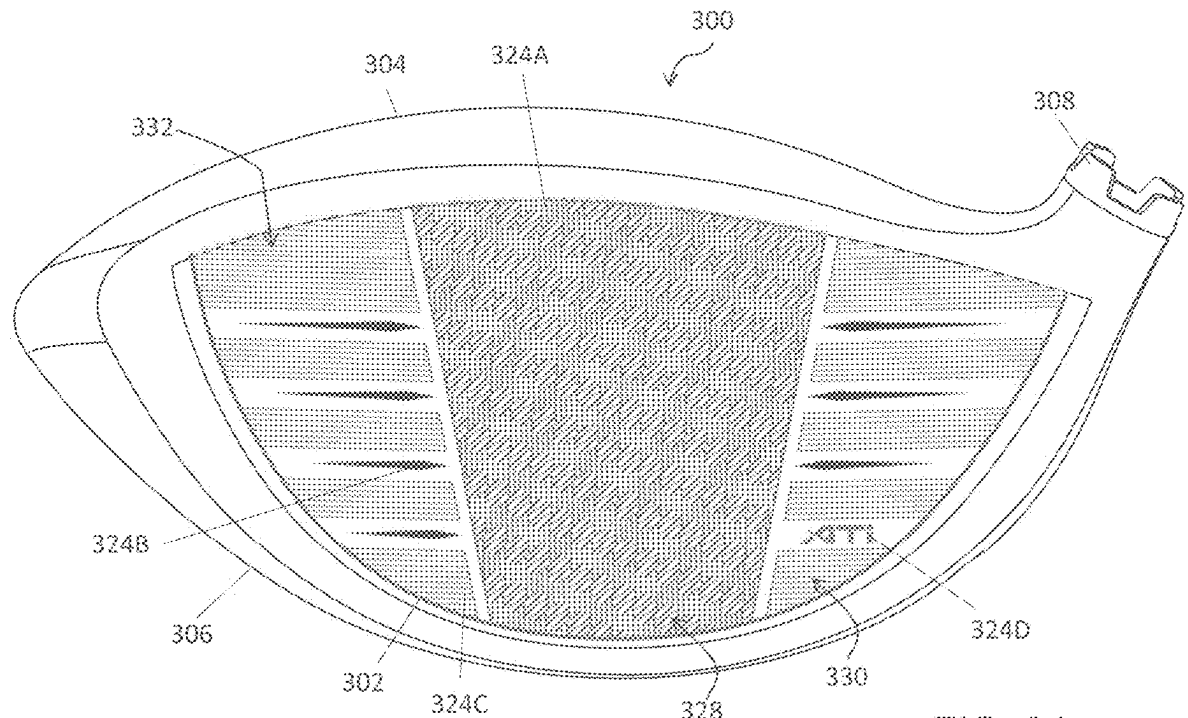


FIG. 3A

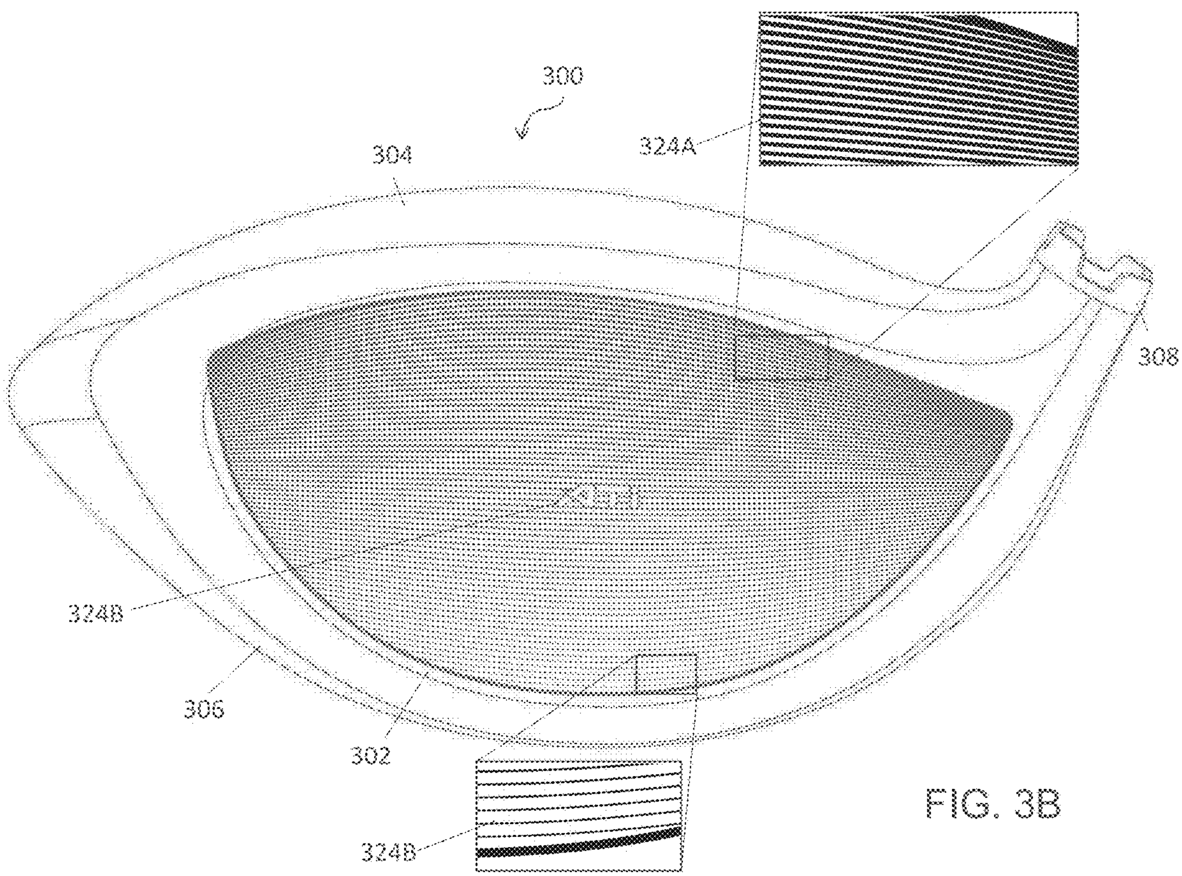


FIG. 3B

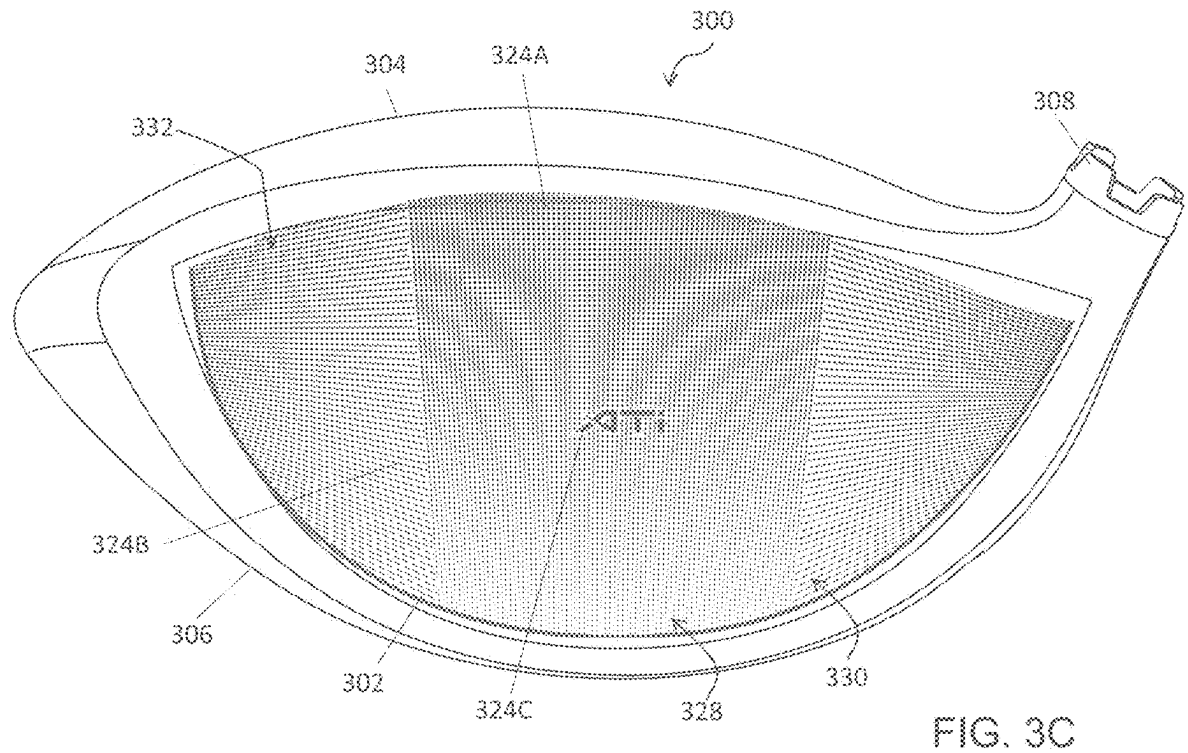


FIG. 3C

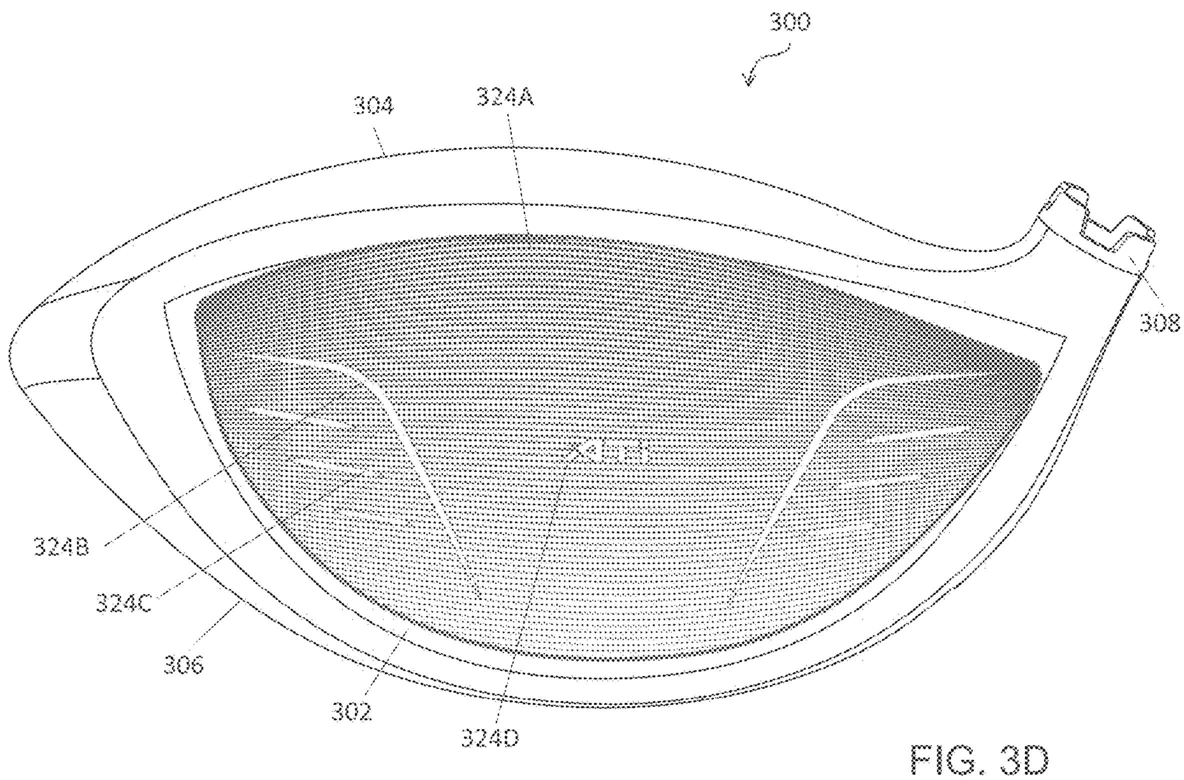


FIG. 3D

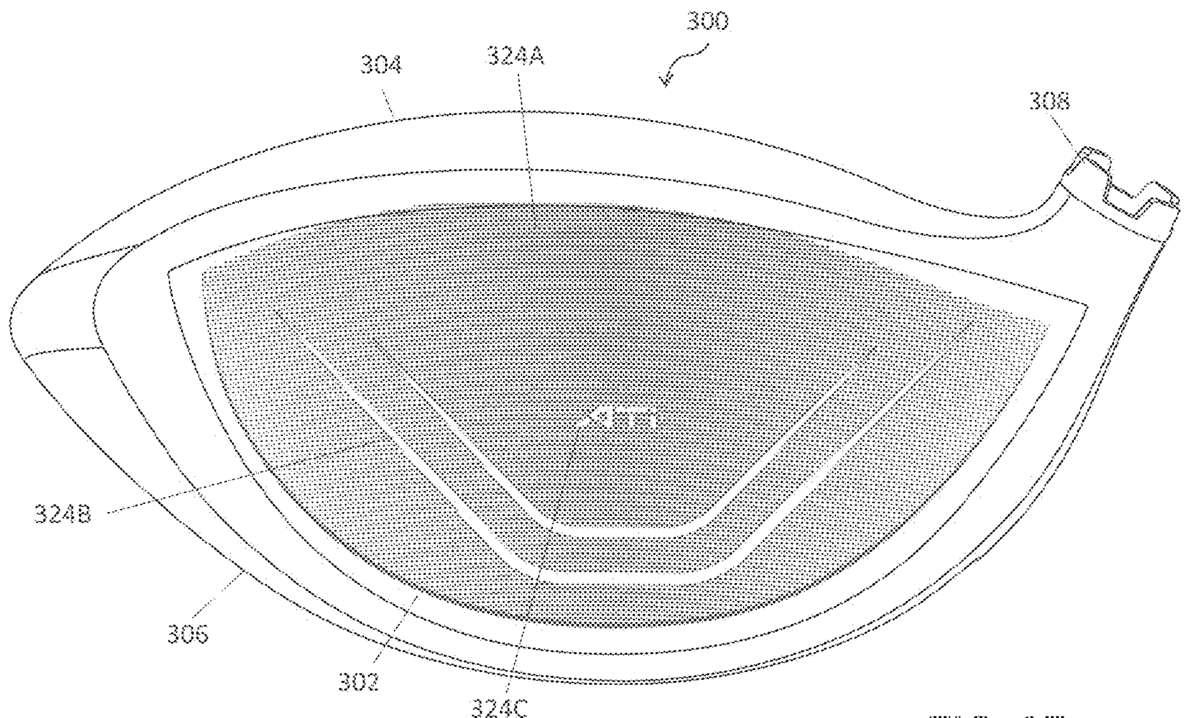


FIG. 3E

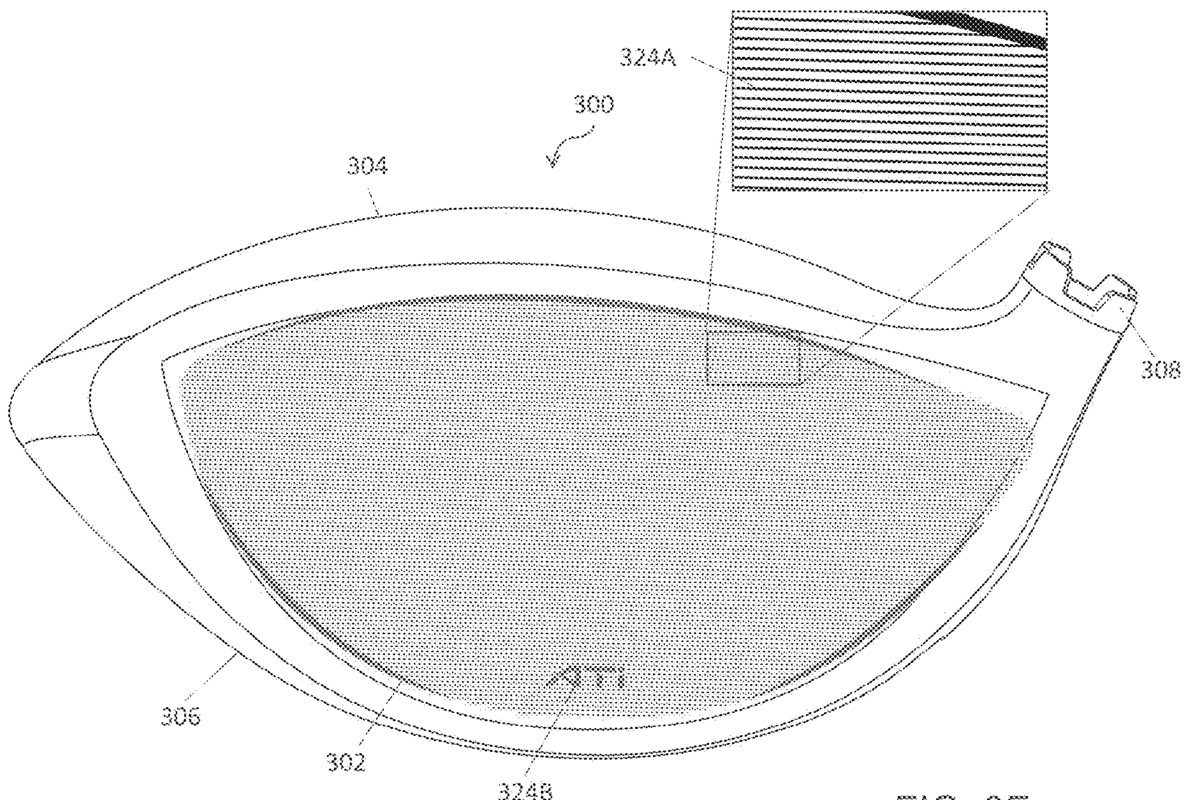


FIG. 3F

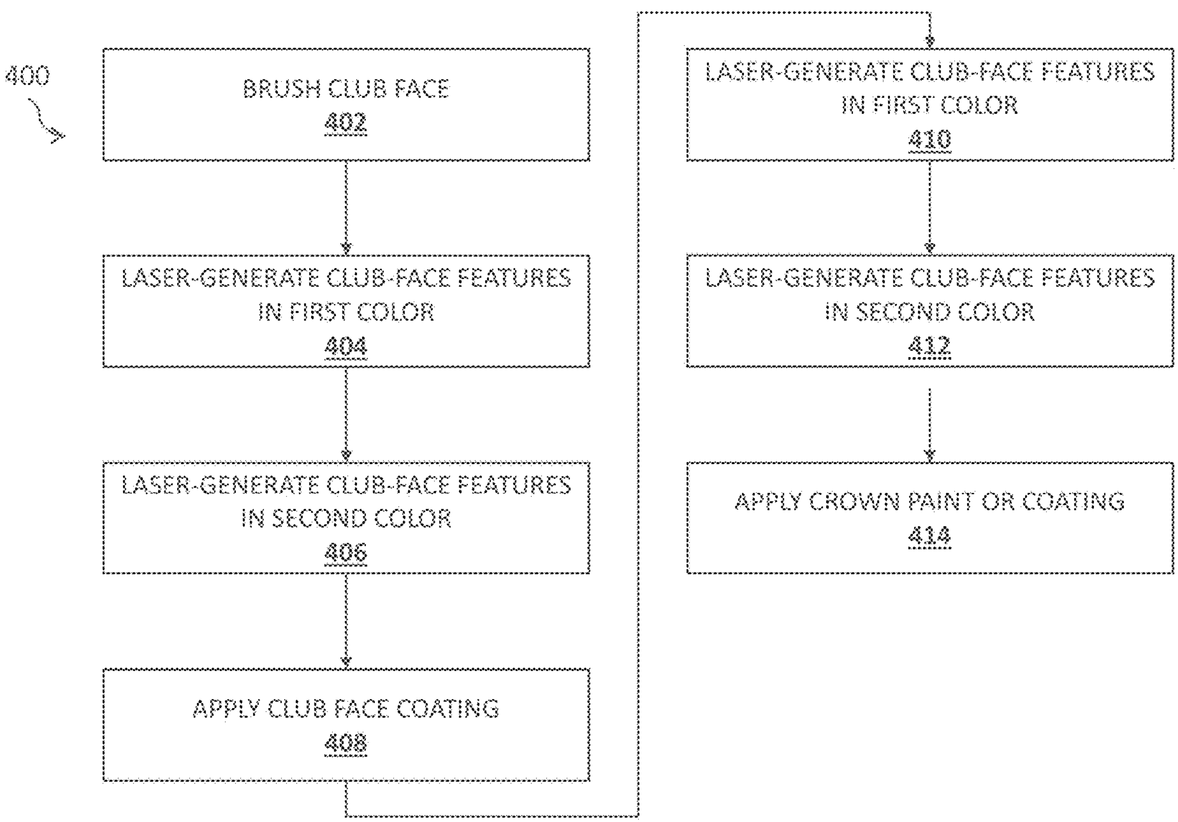

400
BRUSH CLUB FACE
402
LASER-GENERATE CLUB-FACE FEATURES IN FIRST COLOR
404
LASER-GENERATE CLUB-FACE FEATURES IN SECOND COLOR
406
APPLY CLUB FACE COATING
408
LASER-GENERATE CLUB-FACE FEATURES IN FIRST COLOR
410
LASER-GENERATE CLUB-FACE FEATURES IN SECOND COLOR
412
APPLY CROWN PAINT OR COATING
414

FIG. 4

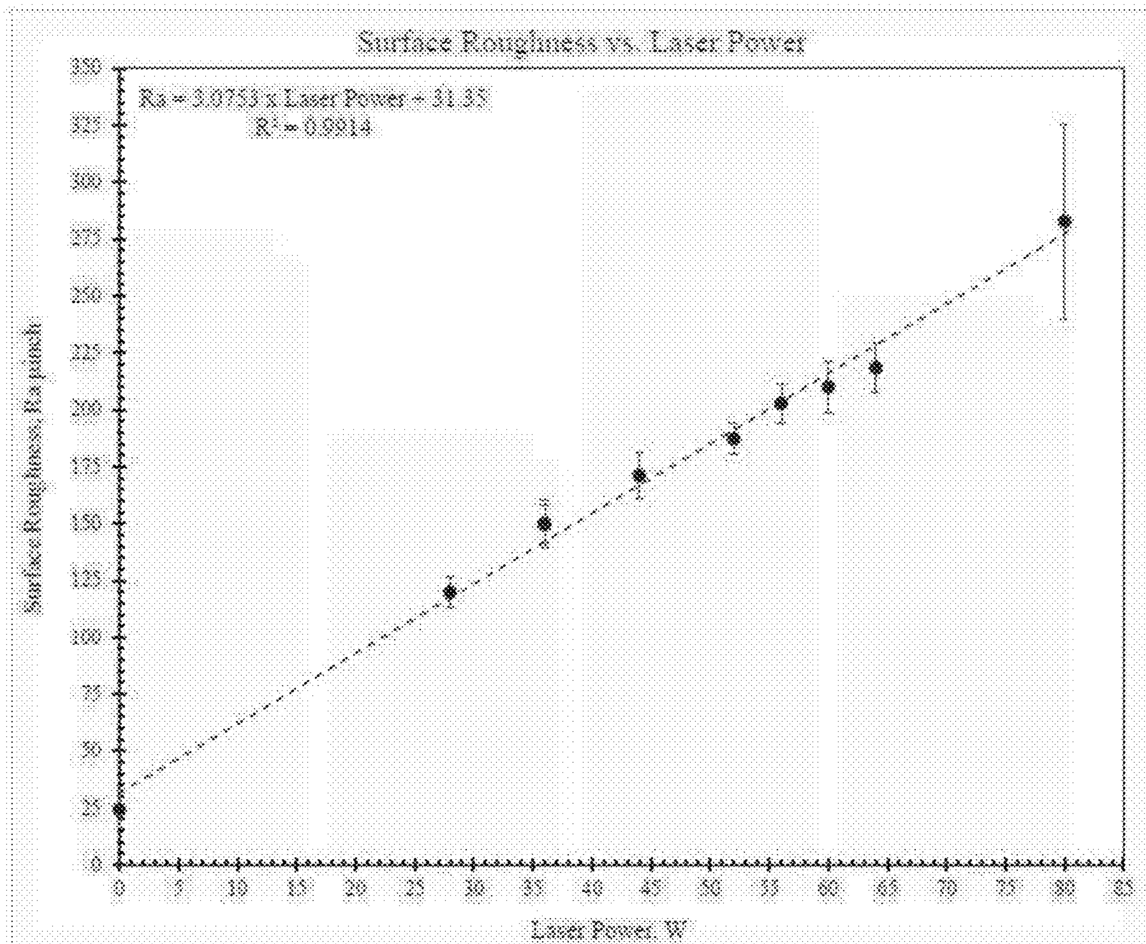

Surface Roughness vs. Laser Power
Ra = 3.0753 x Laser Power + 31.35
R^2 = 0.9914
Surface Roughness, Ra µinch
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
Laser Power, W

FIG. 5

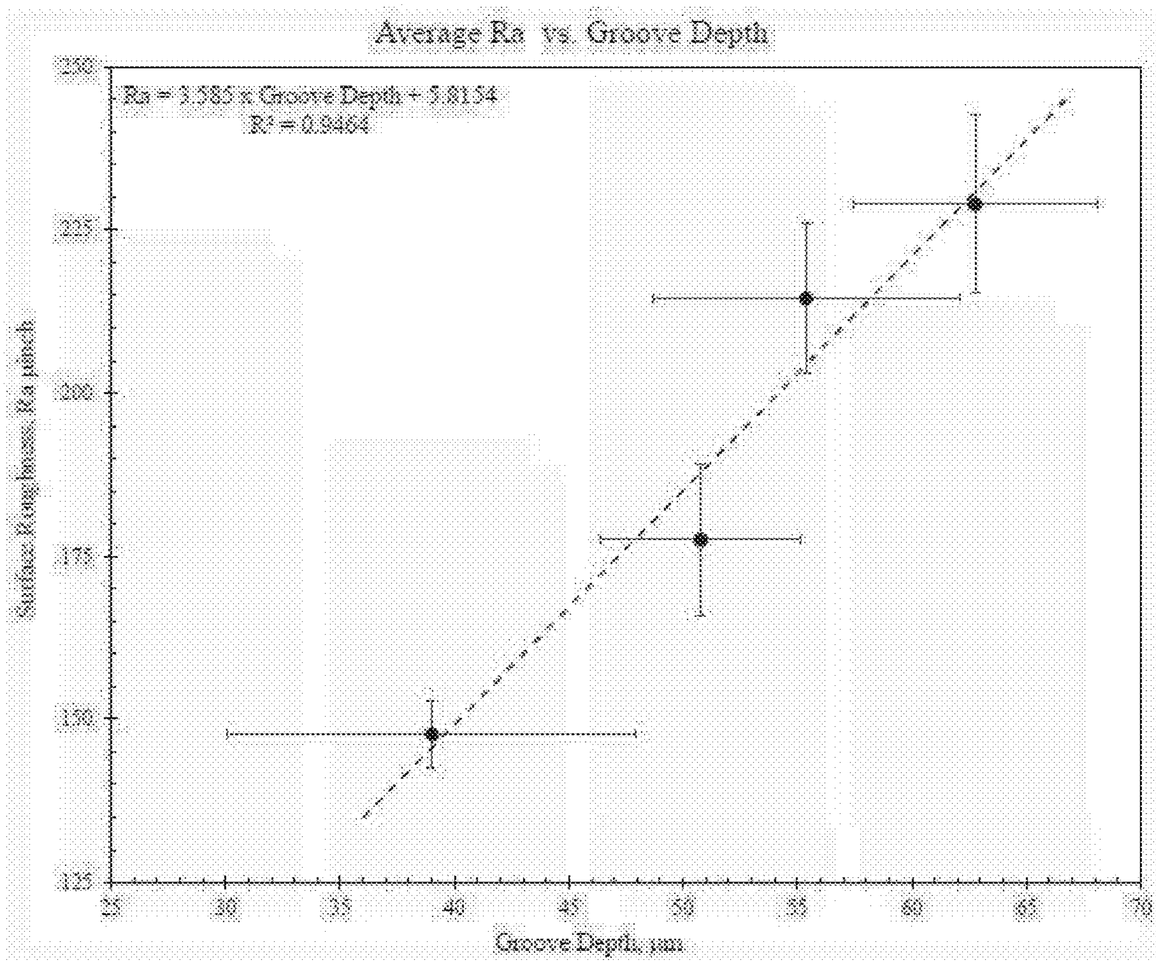

Average Ra vs. Groove Depth
Ra = 3.585 x Groove Depth + 5.8154
R² = 0.9464
250
225
200
175
150
125
Surface Roughness, Ra µinch
25
30
35
40
45
50
55
60
65
70
Groove Depth, µm

FIG. 6

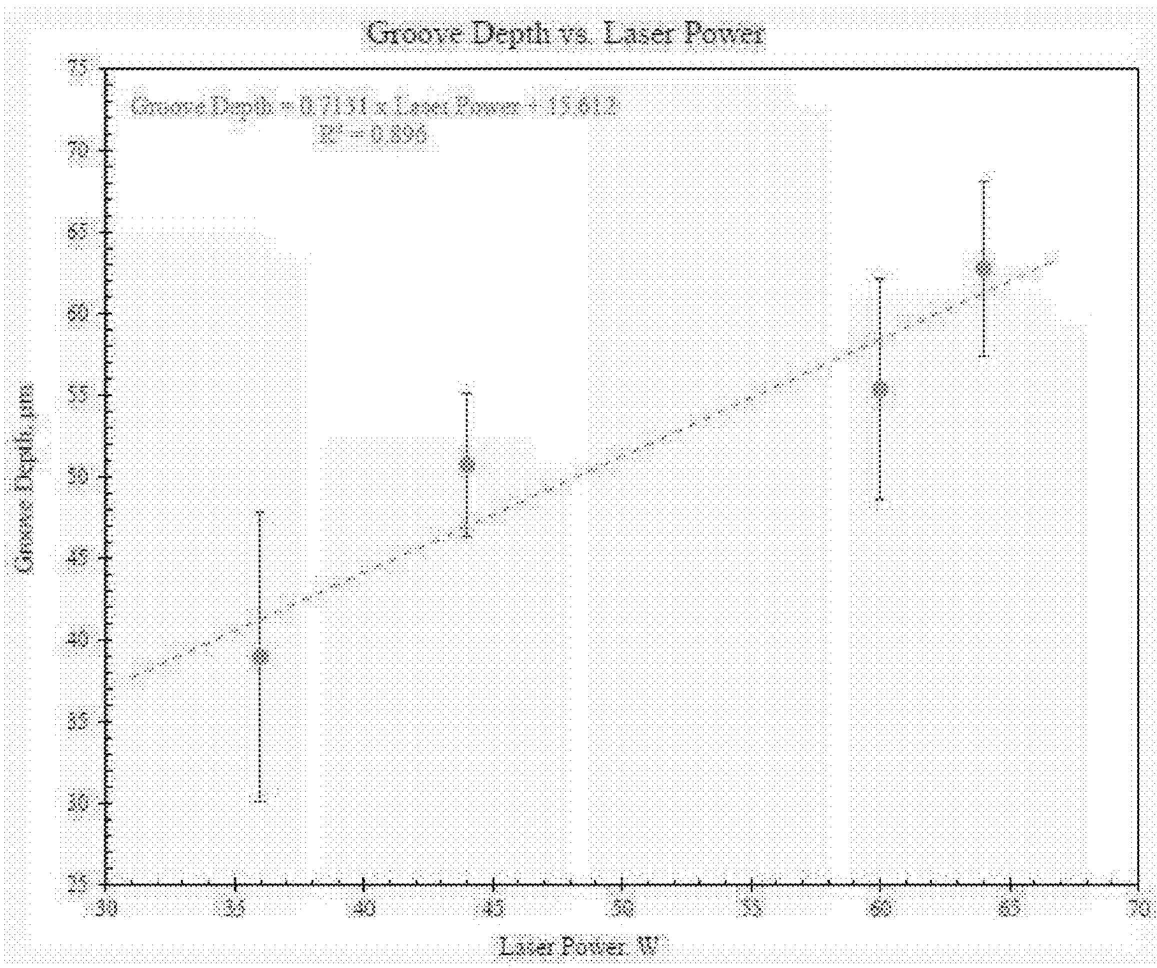

Groove Depth vs. Laser Power
Groove Depth = 0.7131 x Laser Power + 15.612
R² = 0.896
Groove Depth, μm
Laser Power, W
75
70
65
60
55
50
45
40
35
30
25
30
35
40
45
50
55
60
65
70

FIG. 7

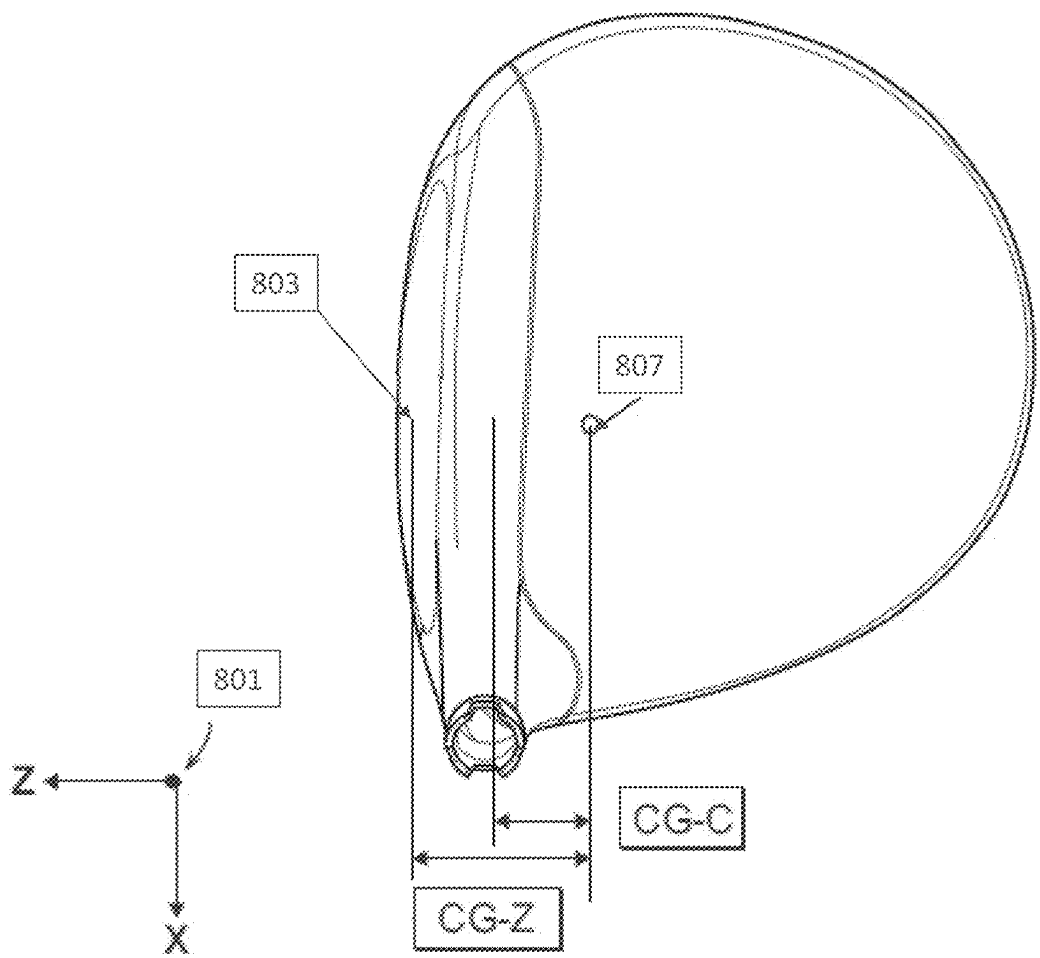


FIG. 8

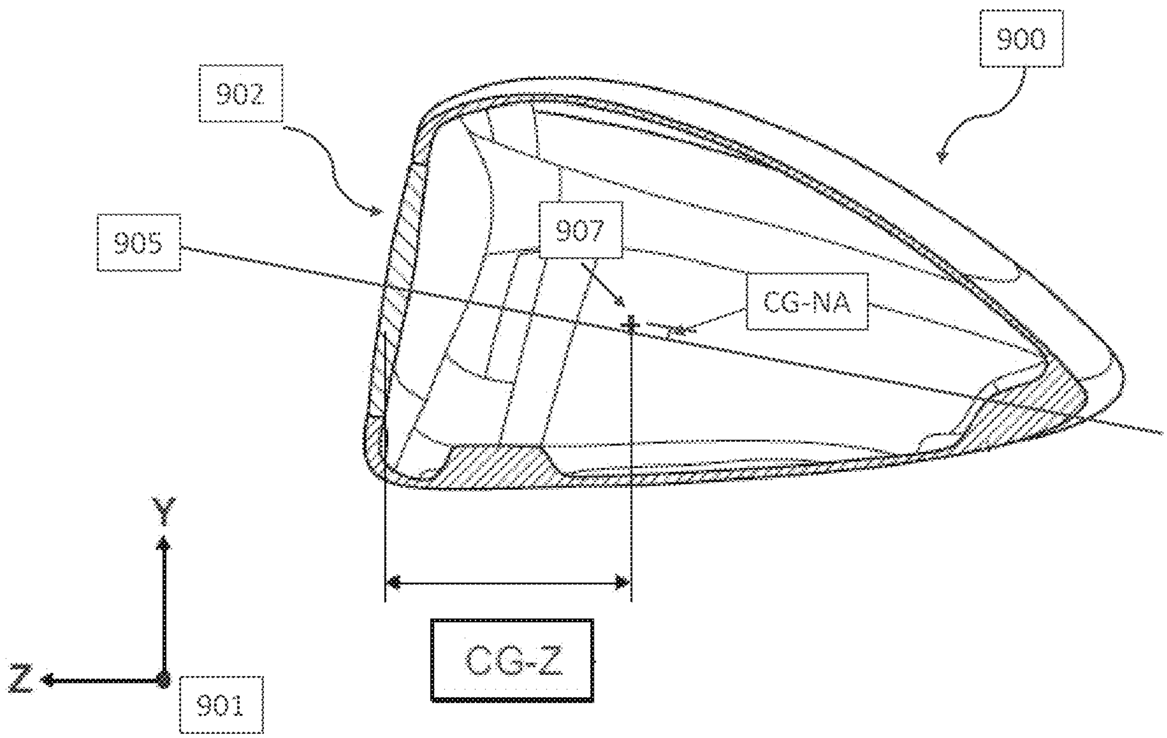


FIG. 9

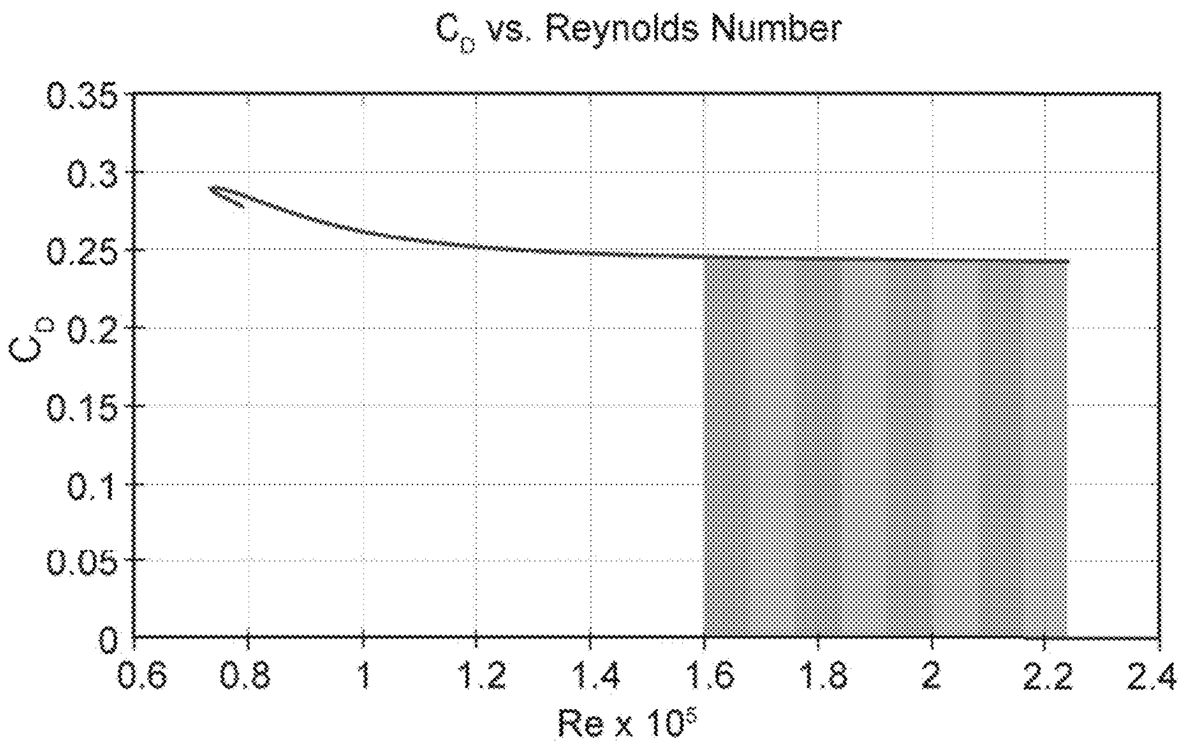
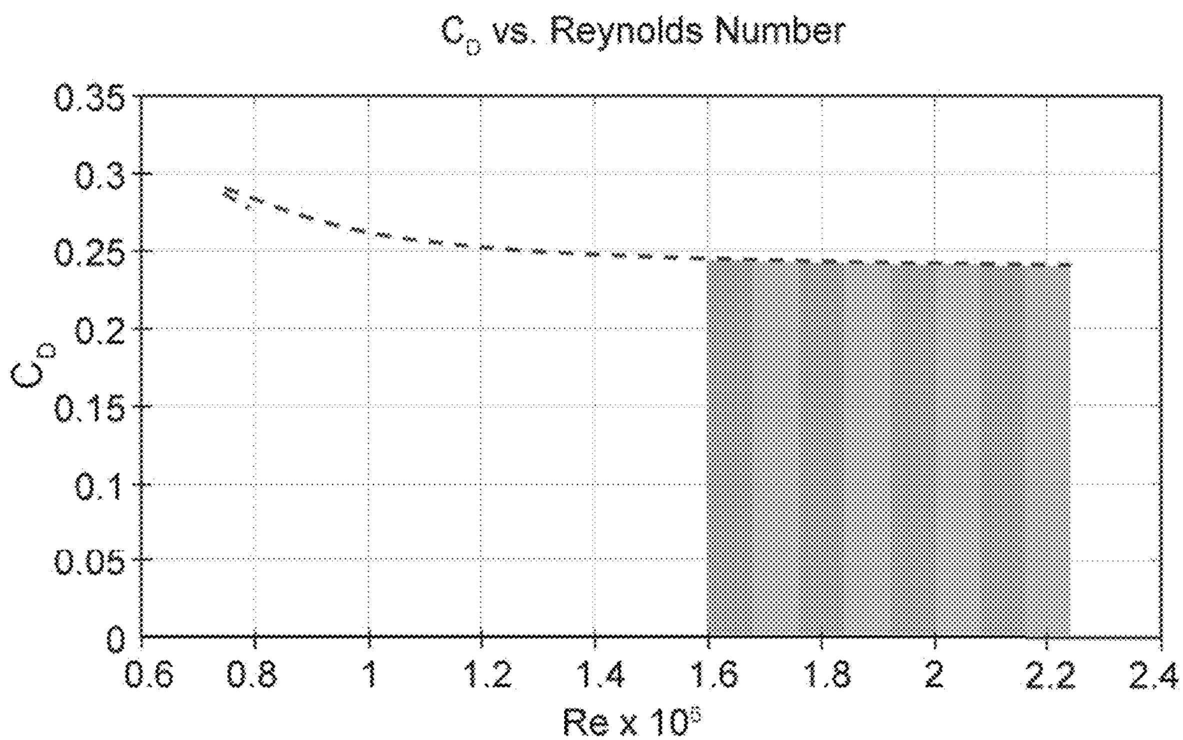

C_D vs. Reynolds Number
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
C_D
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
Re x 10^5

FIG. 10A



C_D vs. Reynolds Number
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
C_D
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
Re x 10^6

FIG. 10B

SYNERGISTIC GOLF CLUB AND GOLF BALL COMBINATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 18/971,900, filed Dec. 6, 2024, which is a continuation-in-part of U.S. patent application Ser. No. 18/830,243, filed Sep. 10, 2024, which is a continuation of U.S. patent application Ser. No. 18/540,738, filed Dec. 14, 2023, now U.S. Pat. No. 12,109,460, the disclosure of which are all incorporated herein by reference in their entirety. To the extent appropriate a claim of priority is made to each of the above-mentioned disclosures.

BACKGROUND

[0002] A golf club head includes a "sweet spot" that is the optimal point for which a golf ball should be struck by the golf club head to produce the best results. The size and location of the sweet spot may change depending on the particular golf club head. A golf club head also includes other characteristics, such as loft, bulge, and roll. The loft of a golf club head is the angle formed by the intersection of the plane of the clubface and the line of the shaft. The bulge of the club face is the curvature of the club face from the heel to the toe, and the roll of the club face is the curvature of the club face from the crown to the sole.

[0003] The golf club is often installed on a shaft, which could also alter the performance of the golf club, all of which is designed to hit a golf ball to achieve a synergistic relationship between the two that achieves the maximum performance.

[0004] The golf club, including the shaft, and golf ball work with one another to help a golfer play better golf. If a golf ball launches inefficiently high for a given golfer, a lower launching golf club can be used to achieve better results, and vice versa. In another example, if a golf ball has a spin rate that is undesirably high for a given golfer, a golf club designed to generate less spin at impact can be used to achieve better results. Inversely, if a golf ball spins at an undesirably low spin rate for a given golfer, a golf club designed to generate more spin at impact can be used to achieve better results. Likewise, a golf club that generates a relatively low rate of backspin and/or launch may provide optimal conditions for a golf ball with relatively high net lift performance, and conversely, a golf club that generates a relatively high rate of backspin and/or launch may provide optimal launch conditions for a golf ball with a relatively low net lift performance. Numerous other examples in addition to launch and spin can be tweaked between the golf club and the golf ball to achieve the synergistic relationship without departing from the scope and content of the present invention.

SUMMARY

[0005] In an aspect, the technology relates to a golf club head that includes a crown, a sole, and a club face, attached to the crown and the sole. The club face includes a central region, a toe region, and a heel region. The central region includes a first plurality of laser-generated features that provide at least one of a height-intersection coverage of the central region of at least 80%, a width-intersection coverage of the central region of at least 80%, or a surface-area coverage of the central region of at least 25%. The toe region includes a second plurality of laser-generated features that provide at least one of a height-intersection coverage of the toe region of at least 50%, a width-intersection coverage of the toe region of at least 50%, or a surface-area coverage of the toe region of at least 25%. The heel region includes a third plurality of laser-generated features that provide at least one of a height-intersection coverage of the heel region of at least 50%, a width-intersection coverage of at least 50%, or a surface-area coverage of the heel region of at least 25%.

[0006] In an example, the height-intersection coverage of the central region is at least 90% and the width-intersection coverage of the central region is at least 90%. In another example, the surface-area coverage of the central region is at least 25%. In still another example, the surface-area coverage of the central region is at least 50%. In yet another example, the club face has a maximum width in a heel-to-toe direction, and the central region has a maximum width between 30-50% of the maximum width of the club face. In a further example, the first plurality of laser-generated features is covered with a physical vapor deposition (PVD) coating.

[0007] In another example, the second plurality of laser-generated features is not covered with a PVD coating. In a further example, the PVD coating is a dark coating, and the first plurality of laser-generated features appear darker than the second plurality of laser-generated features due to the PVD coating covering the first plurality of laser-generated features, thereby creating contrast between the central region and the toe region. In still another example, a portion of the first plurality of laser-engraved features is covered by crown paint.

[0008] In another example, the technology relates to a golf club head including a crown, a sole, and a club face, attached to the crown and the sole, including a central region, a toe region, and a heel region. The central region includes a first plurality of laser-generated features that provide at least two of a height-intersection coverage of the central region of at least 90%, a width-intersection coverage of the central region of at least 90%, or a surface-area coverage of the central region of at least 25%. The toe region includes a second plurality of laser-generated features that provide at least two of a height-intersection coverage of the toe region of at least 60%, a width-intersection coverage of the toe region of at least 60%, or a surface-area coverage of the toe region of at least 10%. The heel region includes a third plurality of laser-generated features that provide at least two of a height-intersection coverage of the heel region of at least 60%, a width-intersection coverage of at least 60%, or a surface-area coverage of the heel region of at least 10%.

[0009] In an example, the height-intersection coverage of the central region is at least 90% and the width-intersection coverage of the central region is at least 90%. In another example, the surface-area coverage of the central region is at least 50%. In still another example, the first plurality of laser-generated features is covered with a physical vapor deposition (PVD) coating; the second plurality of laser-generated features is not covered with a PVD coating; and the first plurality of laser-generated features appear darker than the second plurality of laser-generated features due to the PVD coating covering the first plurality of laser-generated features, thereby creating contrast between the central region and the toe region. In yet another example, the first plurality of laser-generated features is a first color and the second plurality of laser-generated features is a second color.

[0010] In another aspect, the technology relates to a method for manufacturing a golf club head. The method includes generating, by one or more lasers, a first plurality of laser-generated features on a central region of a club face, wherein the first plurality of laser-generated features provide at least one of a height-intersection coverage of the central region of at least 80%, a width-intersection coverage of the central region of at least 80%, or a surface-area coverage of the central region of at least 50%. The method also includes applying a coating to the club face such that the coating covers the first plurality of laser-generated features. The method further includes generating, by the one or more lasers, a second plurality of laser-generated features on a toe region of the club face, wherein generating the second plurality of laser-generated features removes portions of the coating on the toe region; and generating, by the one more lasers, a third plurality of laser-generated features on a heel region of the club face, wherein generating the second plurality of laser-generated features removes portions of the coating on the heel region.

[0011] In an example, the coating is a PVD coating and the first plurality of laser-generated features appear darker than the second plurality of laser-generated features, thereby creating contrast between the central region and the toe region. In another example, the first plurality of laser-generated features and the second plurality of laser-generated features is generated from the same laser. In a further example, the height-intersection coverage of the central region is at least 90% and the width-intersection coverage of the central region is at least 90%. In still another example, the surface-area coverage of the central region is at least 15%. In yet another example, the method further includes painting a crown of the golf club head such that a portion of the first plurality of laser-generated features is covered by the paint.

[0012] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves, and wherein the external surface further includes; a central region occupying a central third of the club face, measured horizontally, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region an internal surface, having an internal surface roughness, and a body portion located rearward of the club face, wherein the central region of the external surface has a Central Region Average Surface Roughness Value of greater than about 100 μin, and wherein the Central Region Average Surface Roughness of the external surface is greater than a surface roughness value of the internal surface.

[0013] In some aspects, the techniques described herein relate to a golf club head, wherein the Central Region Average Surface Roughness of the external surface is greater than about 2 times the surface roughness value of the internal surface.

[0014] In some aspects, the techniques described herein relate to a golf club head, wherein the Central Region Average Surface Roughness of the external surface is greater than about 3 times the surface roughness of the internal surface.

[0015] In some aspects, the techniques described herein relate to a golf club head, wherein the Central Region Average Surface Roughness of the external surface is greater than about 4 times the surface roughness of the internal surface.

[0016] In some aspects, the techniques described herein relate to a golf club head, wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 60 μm.

[0017] In some aspects, the techniques described herein relate to a golf club head, wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 57 μm.

[0018] In some aspects, the techniques described herein relate to a golf club head, wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 55 μm.

[0019] In some aspects, the techniques described herein relate to a golf club head, wherein the Central Region Surface Roughness Value is greater than about 120 μin.

[0020] In some aspects, the techniques described herein relate to a golf club head, wherein the Central Region Surface Roughness Value is greater than about 140 μin.

[0021] In some aspects, the techniques described herein relate to a golf club head, wherein both the toe region and the heel region have an average surface roughness value that is different than the Central Region Average Surface Roughness Value.

[0022] In some aspects, the techniques described herein relate to a golf club head, wherein the Central Region Average Surface Roughness Value is greater than the average surface roughness value of both the toe region and the heel region.

[0023] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves, and wherein the external surface further includes; a central region occupying a central third of the club face, measured horizontally, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region an internal surface, having an internal surface roughness, and a body portion located rearward of the club face, wherein the central region of the external surface has a Central Region Average Vertical Surface Roughness Value of greater than about 100 μin, and wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 60 μm.

[0024] In some aspects, the techniques described herein relate to a golf club head, wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 57 μm.

[0025] In some aspects, the techniques described herein relate to a golf club head, wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 55 μm.

[0026] In some aspects, the techniques described herein relate to a golf club head, wherein both the toe region and the heel region have an average surface roughness value that is different than the Central Region Average Vertical Surface Roughness Value.

[0027] In some aspects, the techniques described herein relate to a golf club head, wherein the Central Region

Average Vertical Surface Roughness Value is greater than the average surface roughness value of both the toe region and the heel region.

[0028] In some aspects, the techniques described herein relate to a golf club head, where both the toe region and the toe region has an average surface roughness value of less than about 100 μin.

[0029] In some aspects, the techniques described herein relate to a golf club head, wherein said club face further includes a coating at an external surface of the club face, wherein the coating exhibits a different coefficient of friction when exposed to water moisture.

[0030] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves, and wherein the external surface further includes; a central region occupying a central third of the club face, measured horizontally, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region an internal surface, having an internal surface roughness, and a body portion located rearward of the club face, wherein the central region of the external surface has a Central Region Average Vertical Surface Roughness that is greater than a surface roughness value of the internal surface, and wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 60 μm.

[0031] In some aspects, the techniques described herein relate to a golf club head, wherein the Central Region Average Vertical Surface Roughness of the external surface has a value that is greater than about 100 μin.

[0032] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the golf club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves of substantially circular shape, and wherein the external surface further includes; a central region occupying a central third of the club face, measured horizontally, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region, and wherein when a plurality of imaginary vertical and horizontal sampling lines are defined within an area measuring about 20 mm×20 mm located in the central region and centered with respect to a geometric center of the club face, the central region of the external surface has a Central Region Average Surface Roughness Value of between 10 μin and 80 μin, and wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and wherein said golf club head has a loft of less than about 10 degrees.

[0033] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the golf club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves of substantially circular shape, and wherein the external surface further includes; a central region occupying a central third of the club face, measured horizontally, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region, and wherein when a plurality of imaginary vertical and horizontal sampling lines are defined within an area measuring about 20 mm×20 mm located in the central region and centered with respect to a geometric center of the club face, the central region of the external surface has a Central Region Average Coefficient of Friction Value is between about 0.10 and about 0.40, and wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and wherein said golf club head has a loft of greater than about 10 degrees.

[0034] In some aspects, the techniques described herein relate to a golf club head, wherein the Average Surface Roughness of the central region bottom portion is greater than about 1.5 times the Average Surface Roughness of the central region top portion.

[0035] In some aspects, the techniques described herein relate to a golf club head, wherein the Average Surface Roughness of the central region bottom portion is greater than about 2 times the Average Surface Roughness of the central region top portion.

[0036] In some aspects, the techniques described herein relate to a golf club head, wherein the plurality of micro-grooves in the central region has an average groove depth of between about 45 μm and about 60 μm in the central region bottom portion and an average groove depth of between about 5 μm and about 40 μm in the central region top portion.

[0037] In some aspects, the techniques described herein relate to a golf club head, wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 57 μm in the central region bottom portion and an average groove depth of between about 10 μm and about 35 μm in the central region top portion.

[0038] In some aspects, the techniques described herein relate to a golf club head, wherein the plurality of micro-grooves has an average groove depth of between about 45 μm and about 55 μm in the central region bottom portion and an average groove depth of between about 10 μm and about 30 μm in the central region top portion.

[0039] In some aspects, the techniques described herein relate to a golf club head, wherein the Surface Roughness Value is greater than about 120 μin in the central region bottom portion and is less than about 100 μin in the central region top portion.

[0040] In some aspects, the techniques described herein relate to a golf club head, wherein the Surface Roughness Value is greater than about 120 μin in the central region bottom portion and is less than about 80 μin in the central region top portion.

[0041] In some aspects, the techniques described herein relate to a golf club head, wherein the Average Surface Roughness Value in the central region bottom portion is greater than the Average Surface Roughness Value of both the toe region and the heel region.

[0042] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves, and wherein the external surface further includes; a central region occupying a central third of the club face, measured horizontally, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region an internal surface, having an internal surface roughness, and a body portion located rearward of the club face, wherein the external surface of the central region bottom portion has an Average Vertical Surface Roughness Value of greater than about 120 μin and micro-grooves with an average groove depth of between about 45 μm and about 60 μm.

[0043] In some aspects, the techniques described herein relate to a golf club head, where both the toe region and the heel region have an average surface roughness value of less than about 100 μin.

[0044] In some aspects, the techniques described herein relate to a golf club head, wherein said club face further includes a coating at an external surface of the club face, wherein the coating exhibits a different coefficient of friction when exposed to water moisture.

[0045] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the golf club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves of substantially circular shape, and wherein the external surface further includes; a central region occupying a central third of the club face, measured horizontally, and including a central region top portion in the central portion adjacent the golf club head crown, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region, and wherein when a plurality of imaginary vertical and horizontal sampling lines are defined within an area measuring about 20 mm×20 mm located in the central region top portion, the central region top portion of the external surface has an Average Surface Roughness Value of between 10 μin and 80 μin, and wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and wherein said golf club head has a loft of less than about 10 degrees.

[0046] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the golf club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves of substantially circular shape, and wherein the external surface further includes; a central region occupying a central third of the club face measured horizontally, with a central region bottom portion adjacent to the golf club head sole, a central region top portion adjacent to the golf club head crown, and a central region center portion therebetween, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region, and wherein when a plurality of imaginary vertical and horizontal sampling lines are defined within an area measuring about 20 mm×20 mm located in the central region bottom portion, the central region center portion and the central region top portion and centered with respect to a geometric center of the club face in the x-direction (the heel-to-toe direction), the central region bottom portion has an Average Coefficient of Friction Value of greater than about 0.30 and the central region top portion has an Average Coefficient of Friction Value of less than about 0.20, and wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and wherein said golf club head has a loft of greater than about 10 degrees.

[0047] In some aspects, the techniques described herein relate to a golf club head including: a club face located at a frontal portion of the golf club head, the golf club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves of substantially circular shape, and wherein the external surface further includes; a central region occupying a central third of the club face measured horizontally, with a central region bottom portion adjacent to the golf club head sole, a central region top portion adjacent to the golf club head crown, and a central region center portion therebetween, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region, and wherein when a plurality of imaginary vertical and horizontal sampling lines are defined within an area measuring about 20 mm×20 mm located in the central region bottom portion, the central region center portion and the central region top portion and centered with respect to a geometric center of the club face in the x-direction (the heel-to-toe direction), the central region bottom portion has an Average Coefficient of Friction Value of between about 0.30 and about 0.40 and the central region top portion has an Average Coefficient of Friction Value of between about 0.10 and about 0.20, and wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and wherein said golf club head has a loft of greater than about 10 degrees.

[0048] In some aspects, the techniques described herein relate to a synergistic golf club and golf ball including: a golf club head further including; a club face located at a frontal portion of the golf club head, the club head further including; an external surface, having an external surface roughness formed by a plurality of micro-grooves of substantially circular shape, and wherein the external surface further includes; a central region occupying a central third of the club face, measured horizontally, a toe region occupying a region toeward of the central region, and a heel region occupying a region heelward of the central region, wherein when a plurality of imaginary vertical and horizontal sampling lines are defined within an area measuring about 20 mm×20 mm located in the central region and centered with respect to a geometric center of the club face, the central region of the external surface has a Central Region Average Coefficient of Friction Value is between about 0.10 and about 0.40, wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and wherein said golf club head has a loft of less than about 10 degrees; a golf ball including at least a core and a cover, the golf ball having a weight of 1.600 ounces-1.620 ounces, the golf ball having a diameter of 1.680 inches-1.700 inches, the cover including a plurality of dimples arranged in a dimple pattern having the following aerodynamic characteristics: $0.230 \leq C_D \leq 0.250$ at a Reynolds number of 220,000 and a spin ratio of 0.070, and $0.230 \leq C_D \leq 0.250$ at a Reynolds number of 160,000 and a spin ratio of 0.095, and $0.230 \leq C_D \leq 0.250$ at a Reynolds number of 120,000 and a spin ratio of 0.100.

[0049] 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 claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] Non-limiting and non-exhaustive examples are described with reference to the following Figures.

[0051] FIG. **1** depicts an exploded perspective view of a golf club head.

[0052] FIG. **2** depicts an example golf club head having a club face with laser-generated features.

[0053] FIG. **2***a* depicts an enlarged view of the laser-generated feature under a high powered microscope, showing the micro-grooves.

[0054] FIGS. **3**A-**3**F depict example golf club heads having club faces with laser-generated features.

[0055] FIG. **4** depicts an example manufacturing method for manufacturing a golf club head with laser-generated features.

[0056] FIG. **5** depicts a chart that establishes the relationship between surface roughness of a club face and the power level used to generate the laser-generated features.

[0057] FIG. **6** depicts a chart that establishes the relationship between a surface roughness of a club face and the resultant depth of the micro-grooves.

[0058] FIG. **7** depicts a chart that establishes the relationship between a power level used to generate the laser-generated feature and the resultant depth of the micro-grooves.

[0059] FIG. **8** depicts a top view of a golf club head in accordance with an exemplary embodiment of the present invention.

[0060] FIG. **9** depicts a cross-sectional side view of a golf club head in accordance with an exemplary embodiment of the present invention.

[0061] FIG. **10**A illustrates an exemplary integrated drag area profile for a golf ball in accordance with an exemplary embodiment of the present invention.

[0062] FIG. **10**B illustrates an exemplary integrated drag area profile for a golf ball in accordance with an exemplary embodiment of the present invention.

DETAILED DESCRIPTION

[0063] Understanding and seeing how a tool or sporting equipment, such as a golf club, is to be used increases the effectiveness of the tool. For instance, being able to see where a tool is in relation to an object to be struck is beneficial. Being able to see other aspects or characteristics of the impact surface is also useful in operating the tool. Seeing such features becomes particularly challenging, however, when the impact surface of the tool is difficult to see during use or can be seen only from a slight angle during use.

[0064] In creating the synergistic golf club **100** and golf ball, the design of one is heavily correlated to the design of the other. Beginning with the inventive golf ball, the performance of a golf ball can be boiled down to two major variables, its construction, which affects the properties of the finished ball such as the Coefficient of Restitution and compression and influences how the ball interacts with the club face during impact, and its aerodynamic properties, which affect the flight of the golf ball after it separates from the club face.

[0065] The "Coefficient of Restitution" or "COR" of a golf ball refers to the ratio of a ball's rebound velocity to its initial incoming velocity when the ball is fired out of an air cannon into a rigid vertical plate. The COR is determined according to a known procedure, wherein a golf ball or golf ball subassembly (for example, a golf ball core) is fired from an air cannon at two given velocities and a velocity of 125 ft/s is used for the calculations. Ballistic light screens are located between the air cannon and steel plate at a fixed distance to measure ball velocity. As the ball travels toward the steel plate, it activates each light screen and the ball's time period at each light screen is measured. This provides an incoming transit time period which is inversely proportional to the ball's incoming velocity. The ball makes impact with the steel plate and rebounds so it passes again through the light screens. As the rebounding ball activates each light screen, the ball's time period at each screen is measured. This provides an outgoing transit time period which is inversely proportional to the ball's outgoing velocity. The COR is then calculated as the ratio of the ball's outgoing transit time period to the ball's incoming transit time period (COR=Vout/Vin=Tin/Tout).

[0066] In one aspect, a golf ball having any one or more of the aerodynamic characteristics disclosed herein can have a COR of at least 0.770, or more preferably at least 0.790, or most preferably at least 0.800. In another aspect, a golf ball having any one or more of the aerodynamic characteristics disclosed herein can have a COR of 0.800-0.815, or 0.805-0.825, or 0.810-0.820. In one aspect, a golf ball having any one or more of the aerodynamic characteristics disclosed herein can have a COR of at least 0.805. In one aspect, a golf ball having any one or more of the aerodynamic characteristics disclosed herein can have a COR of at least 0.810. In one aspect, a golf ball having any one or more of the aerodynamic characteristics disclosed herein can have a COR of at least 0.815.

[0067] Because the initial velocity of a golf ball is often an interplay between the COR and the compression of a golf ball, the compression of a golf ball is also very relevant. In one aspect, the golf ball can have a compression of at least 80. In one aspect, the golf ball can have a compression of at least 90. In another example, the golf ball can have a compression of at least 95. In another aspect, the golf ball can have a compression of less than 90. In another example, the golf ball can have a compression of not greater than 85. One of ordinary skill in the art would understand that the compression can vary.

[0068] The "aerodynamic properties" of the golf ball may be much more complicated, as it involved numerous variables such as the Coefficient of Drag (C_D), Coefficient of Lift (C_L), and the resultant relationship between the C_D and the C_L. The golf ball Coefficient of Drag C_D and Coefficient of Lift C_L are defined by the following equations:

$$C_D = \frac{\text{Drag Force}}{(0.5 * \rho * A * V^2)}$$

$$C_L = \frac{\text{Lift Force}}{(0.5 * \rho * A * V^2)}$$

wherein the drag force is the aerodynamic force component acting parallel to the golf ball's flight direction; the lift force is the aerodynamic force component acting in a direction dictated by the cross product off the spin vector and the velocity vector; where p=density of air (slugs/ft^3); A=projected area of the ball (ft^2) ((π/4)D^2); D=golf ball diameter (ft); and V=ball velocity (ft/s).

[0069] More specifically, a golf ball having the improved synergistic aerodynamic properties may have a C_D at the three different Reynolds numbers (Re) and spin ratios (SR) set forth below:

[0070] $0.230 \le C_D \le 0.250$ at a Reynolds number of 220,000 and a spin ratio of 0.070

[0071] $0.230 \le C_D \le 0.250$ at a Reynolds number of 160,000 and a spin ratio of 0.095

[0072] $0.230 \le C_D \le 0.250$ at a Reynolds number of 120,000 and a spin ratio of 0.100;

Additionally, the golf ball may have the following C_L at the two Reynolds numbers and spin ratios set forth below:

[0073] $CL \ge 0.115$ at Reynolds number of 240,000 and a spin ratio of 0.060;

[0074] $CL \ge 0.200$ at Reynolds number of 185,000 and a spin ratio of 0.105.

wherein Reynolds number and spin ratio are calculated by the following equations:

$$Re = \frac{\rho V(D/2)}{\mu}$$

$$SR = \frac{\omega(D/2)}{V}$$

where ω=ball rotation rate (radians/s) (2π(RPS)); RPS=golf ball rotation rate (revolution/s); V=ball velocity (ft/s); D=golf ball diameter (ft); ρ=air density (slugs/ft^3); and μ=absolute viscosity of air (lb/ft^2-s).

More information relating the C_D and C_L values of the inventive golf ball may be found in U.S. patent application Ser. No. 18/915,741, filed Oct. 15, 2024, the disclosure of which is incorporated by reference in its entirety. Moreover, there are a number of suitable methods for determining the lift and drag coefficients for a given range of spin rates and Reynolds numbers, including the use of indoor test ranges have been disclosed in U.S. Pat. Nos. 6,186,002. 6,285,445, and 6,729,976, the disclosures of which are all also incorporated by references herein.

[0075] In addition to the pure C_D and C_L numbers at different Reynolds numbers and spin rates, the synergistic inventive golf ball, in order to function well with a golf club, may have a "flight window" unique to the present invention. More specifically, in one aspect, the drag coefficient and the lift coefficient can have the following relationship at a Reynolds number of 225,000 and a spin ratio of 0.070:$1.400 \le C_D/C_L \le 2.000$. In another aspect, the drag coefficient and the lift coefficient can have the following relationship at a Reynolds number of 225,000 and a spin ratio of 0.070:$2.000 \le C_D/C_L$. In yet another aspect, the drag coefficient and the lift coefficient can have the following relationship at a Reynolds number of 225,000 and a spin ratio of 0.070:$C_D/C_L \le 1.800$. In yet another aspect, the drag coefficient and the lift coefficient can have the following relationship at a Reynolds number of 225,000 and a spin ratio of 0.070:$C_D/C_L \le 1.600$. In a further aspect, the drag coefficient and the lift coefficient can have the following relationship at a Reynolds number of 225,000 and a spin ratio of 0.070:$1.400 \le C_D/C_L$. In a further aspect, the drag coefficient and the lift coefficient can have the following relationship at a Reynolds number of 225,000 and a spin ratio of 0.070:$1.400 \le C_D/C_L \le 1.600$. In a further aspect, the drag coefficient and the lift coefficient can have the following relationship at a Reynolds number of 225,000 and a spin ratio of 0.070:$1.600 \le C_D/C_L \le 1.800$. In a further aspect, the drag coefficient and the lift coefficient can have the following relationship at a Reynolds number of 225,000 and a spin ratio of 0.070:$1.600 \le C_D/C_L \le 2.000$. In one example, the values below can correspond to a golf ball having a COR of at least 0.800 and/or an initial velocity of at least 250 feet/second.

Flight Window	Drag Coefficient to Lift Coefficient Ratio (C_D/C_L) at Re = 225,000 and SR = 0.070
Comparatively High	$1.400 \le \frac{C_D}{C_L} < 1.600$
Middle	$1.600 \le \frac{C_D}{C_L} < 1.800$
Comparatively Low	$1.800 \le \frac{C_D}{C_L} \le 2.000$

[0076] Various other details regarding the relationship between the drag and lift coefficients are provided herein. Once again, more info relating to the flight window as a function of the CD and CL relationship can be found in U.S. patent application Ser. No. 18/915,741, filed Oct. 15, 2024, the disclosure of which is incorporated by reference in its entirety.

[0077] Finally, the inventive synergistic golf ball in accordance with the present invention may have a cover comprising a plurality of dimples arranged in a dimple pattern having an integrated drag area (DA) defined by:

$$DA = \int_{160,000}^{225,000} C_D(Re)dRe$$

[0078] where C_D(Re) is established at a setup condition including a golf ball speed of 182.0 mph, a launch angle of 10.0 degrees, and a spin rate of 2,700 rpm, and wherein $14,500 \le DA \le 15,500$. The golf ball further has a lift coefficient such that $C_L \ge 0.115$ at a Reynolds number of 240,000 and a spin ratio of 0.060. In one aspect, this particular golf ball can have a COR of at least 0.780, and/or an initial velocity of at least 240 feet/second. In one aspect, this particular golf ball can have a COR of at least 0.790, and/or an initial velocity of at least 248 feet/second. In one aspect, this particular golf ball can have a COR of at least 0.800, and/or an initial velocity of at least 250 feet/second. In another aspect, this particular golf ball can have a COR of at least 0.805, and/or an initial velocity of at least 252 feet/second. One of ordinary skill in the art would understand that the COR, initial velocity, compression, and other golf ball construction related parameters or values can vary.

Integrated Drag Area

[0079] The drag area characterizes the effectiveness of the aerodynamic performance of a dimple pattern throughout approximately the first second of flight, during which aerodynamic forces are most pronounced.

[0080] A lower drag area can be indicative of a more efficient aerodynamic pattern, representing a longer predicted distance at the specified launch conditions and using the disclosed methodology. Likewise, a pattern with a higher drag area may have a shorter predicted flight distance under the discussed methodology.

[0081] Once the median golf ball lift and drag coefficients are established for the golf ball dimple pattern under analysis, the predicted trajectory for the golf ball is then calculated by the USGA's computation procedure with initial launch inputs (i.e., initial or launch condition) of a golf ball speed of 182.0 mph, a launch angle 10.0 degrees, and a spin rate of 2,700 rpm for each orientation, pole-over-pole and poles-horizontal, and the Reynolds numbers and drag coefficients from the simulation for the median ball are retained and have a functional relationship CD(Re). Whenever referenced herein, the integrated drag area is established using the golf ball speed, launch angle, and spin rate disclosed above.

[0082] The drag area for the pole-over-pole (DAPP) and the poles-horizontal (DAPH) orientations is given by:

$$DA_{PP} = \int_{160,000}^{225,000} C_D(Re)dRe \quad \text{(Equation 8)}$$

$$DA_{PH} = \int_{160,000}^{225,000} C_D(Re)dRe \quad \text{(Equation 9)}$$

[0083] and the average drag area is given by:

$$DA = \frac{DA_{PP} + DA_{PH}}{2} \quad \text{(Equation 10)}$$

When presented herein as a single value, it is understood to refer to the average drag area DA.

[0084] The integrals are calculated by a Reimann sum with at least eight trapezoidal partitions. One of ordinary skill in the art will understand that alternative partition shapes may be used in conjunction with a Reimann or other summation.

[0085] As shown in FIGS. **10**A and **10**B, the integrated drag area is illustrated for an exemplary golf ball having a relatively higher drag coefficient profile according to the present disclosure. The integrated drag area shown in FIGS. **10**A and **10**B can be measured using a setup condition of 182.0 mph golf ball speed, 10.0 degree launch angle, and 2,700 rpm spin rate or rotational speed. More specifically, FIG. **10**A illustrates the integrated drag area for a golf ball tested using a pole-over-pole orientation, and FIG. **10**B illustrates the integrated drag area for a golf ball tested using the poles-horizontal orientation. Although not specifically illustrated, one of ordinary skill in the art would understand that all of the Preferred Examples disclosed herein would have associated integrated drag profiles similar to FIGS. **10**A and **10**B, and that the associated integrated drag profiles may be higher or lower than those illustrated in FIGS. **10**A and **10**B. One of ordinary skill in the art would also understand that an illustration of the integrated drag area similar to that in FIG. **10**A may be associated with the poles-horizontal orientation and one similar to that of FIG. **10**B may be associated with the pole-over-pole orientation. Once again, more details relating to the concept of integrated drag area (DA) can be found in U.S. patent application Ser. No. 18/915,741, filed Oct. 15, 2024, the disclosure of which is incorporated by reference in its entirety.

[0086] In one example embodiment of the present invention, the synergistic golf ball may have a "Middle" or "Relatively High" flight window, as indicated above by the C_D/C_L ratio of between 1.400 and 1.800, which for some golfers may generally need to be paired with a synergistic golf club head and shaft that produces lower launching characteristics and/or decreased backspin to mitigate or even negate the potential inefficient effect of a golf ball with relatively high drag and moderate to relatively high net lift.

[0087] With a golf club, the impact surface is the club face of the golf club head. When a player addresses a golf ball with a golf club, the player is looking down at the golf club head and can clearly see the crown of the golf club head. For a driver or other low-loft golf club, however, the striking face is viewed at a narrow angle that causes difficulty in viewing the club face. Thus, properly perceiving the characteristics or features of the club face, such as the location of the sweet spot, the loft of the club face, the bulge of the club face, and/or the roll of the club face is challenging. Accordingly, players may struggle to properly align the golf club and ultimately properly strike the golf ball, resulting in lesser performance of the golf club head.

[0088] Examples of the present technology provide for laser-generated features that provide enhanced visual indicators of the characteristics of the club face, such as the sweet spot or optimal striking area. Thus, the player's ability to properly align the golf club head with the golf ball is enhanced, and the utility of the golf club head is improved. The laser-engraving and/or laser-marking process may also provide contrast between regions of the club face and/or contrast between the club face and the crown. The contrast may have an effect of improving the player's ability to see loft, bulge, and/or roll of the club face, which may improve the player's biomechanical response when using the golf club head—leading to further improved results. Additionally, the laser-engraving and/or laser marking process may also help increase the surface roughness of the club face by imparting micro-grooves on the external surface of the golf club head.

[0089] The surface roughness of the club face can be a function of several variable, including but not limited to the pattern of the laser generated features used on the club face, the speed of the laser, the feed of the laser, the type of pattern being generated, the underlying substrate, any additional coating applied to the club face, the sequence of the manufacturing technique, and most importantly, the depth of the laser generated features. The depth of the laser generated features, often manifesting itself as the micro-grooves discussed above, is often a result of the laser power setting, which the present invention utilizes.

[0090] The laser-generated features and contrast of the club face may be achieved through a combination of manufacturing processes. For example, the manufacturing process may include providing a coating or finish, such as a physical vapor deposition (PVD) coating, to the club face. The coating may darken the club face. Laser-generated features may be generated before and after the application of the coating. When the laser-generated features are applied subsequent to the coating, a laser engraving process removes the coating, which results in lightened features of the club face compared to the remainder of the club features. In other examples, the club face may not have a coating, and the laser-engraving or laser-marking process may be used to create darkened features on the club face. In either example, improvements to manufacturing processes may be achieved. For example, other manufacturing processes utilize masks prior to applying a PVD coating. The masking process is susceptible to human error in alignment of the mask. The masking process also introduces contamination into the PVD chamber, which leads to lower yields and potentially lower quality parts or components. With the laser-engraving and laser-marking process discussed herein, the masking process is no longer necessary. In addition, the laser engraving process allows for a more efficient and more precise process than the masking process.

[0091] FIG. **1** depicts an exploded perspective view of an example of a golf club head **100**. The golf club head **100** includes a club face **102** located at a frontal portion of the golf club **100**, a crown **104**, and a sole **106**. The club face **102** may comprise any type of club face, such as a face insert, a face cup, an L-cup, a C-cup, or other construction, without departing from the scope and content of the present disclosure. The club face **102** may be made from a titanium alloy or other metal. The club face **102** has an external surface **112** and an internal surface **114**. The crown **104** forms the top portion of the club head **100** and is generally made of a rigid material, such as a metal or a rigid composite. The crown **104** has an outer crown surface **122** and an inner crown surface **120**. The sole **106** forms the bottom, or underside, portion of the golf club head **100** and is generally also made of a rigid material, such as a metal or a rigid composite. The sole **106** has an outer sole surface **116** and an inner sole surface **118**. The crown **104**, sole **106**, and club face **102**, when fitted together, define an interior void within the golf club head **100**. The crown **104** and the sole **106** combine together to form a body portion of the golf club head **100**, which is located rearward of the club face **102**. The outer crown surface **122** and the outer sole surface **116** may also be coated with additional substances, such as paints, coatings or films. In addition, further structures or materials may also be attached to the outer crown surface **122** and the outer sole surface **116**. Similarly, the inner crown surface **120** and the inner sole surface **118** may also be coated with additional substances, such as paints or coatings. The inner crown surface **120** and the inner sole surface **118** may also have structural materials, such as ribs or other components, attached to the surfaces. The golf club head **100** may also include a hosel **108** having components for attaching a shaft **110**, as is well-understood by those having skill in the art. As used herein, the “heel” portion of the golf club is the portion of the golf club located closest to the hosel **108** and the “toe” portion of the golf club is the portion of the golf club furthest away from the hosel **108**. While the figures generally depict a driver, the technology discussed herein is equally applicable to fairway metals, hybrid clubs, and other similar clubs containing both a crown, a club face, and a sole.

[0092] The club face **102** of the present technology includes one or more laser-generated features **124** on the external surface **112** of the club face **102**. These laser generated features **124**, may often take on the shape of a micro-grooves **225** (shown in FIG. **2**), the details of which will be illustrated later in subsequent figures. The laser-generated features **124** may be generated through laser engraving, laser etching, and/or laser marking, as discussed further below. The laser-generated features **124** of the striking face provide an indication of the optimal locations on the club face **102** where a golf ball should be struck. For instance, the club face **102** has a “sweet spot” **126**. The sweet spot **126** of the club face is the engineered best or optimal position for a golf ball strike to occur. The location, size, and shape of the sweet spot **126** may depend on the particular design of the golf club head **100**. In some examples, the sweet spot **126** may be located in the geometric center of the striking face. In other examples, the sweet spot **126** may be located at a center point of the club face **102** between the toe portion and the heel portion, but the sweet spot **126** may be offset from a center point between the crown **104** and the sole **106**. In different examples, the sweet spot **126** may be located at a center point between the crown **104** and the sole **106**, but the sweet spot **126** may be offset from a center point between the toe portion and the heel portion. Other positions of locations of the sweet spot **126** are also possible.

[0093] In any of the preceding examples, the sweet spot **126** is located in a central region **128** of the club face **102**. The central region **128** may be approximately and occupying the central third of the club face **102**. A toe region **132** is located towards the toe portion of the club head **100** and occupying the region toeward and adjacent to the central region **128**. A heel region **130** is located towards the heel portion of the club head **100** and occupying the region heelward and adjacent the central region **128**. The laser-generated features **124** may be included in the heel region **130**, the central region **128**, and/or the toe region **132**. The laser-generated features **124** are provided on the club face **102** to visually indicate the central region **128** of the club face **102**. In some examples, the location of the sweet spot **126** may also be identified by the laser-generated features **124**. The laser-generated features **124** may positively identify the central region **128** and/or sweet spot **126** by included laser-generated features **124** in those areas or to define the boundaries of those areas. The laser-generated features **124** may also be used to negatively identify the central region **128** and/or sweet spot **126** by including laser-generated features **124** in portions or regions of the club face **102** other than the central region **128** and/or sweet spot **126**. For instance, in the example depicted in FIG. **1**, laser-generated features **124** may be provided in the toe region **132** and the heel region **130** but not in the central region **128**. In other examples, a first type of engraved feature or features may be included in the central region **128** and a second type of laser-generated features **124** may be provided in the toe region **132** and the heel region **130**. In contrast to grooves or scorelines of the club head (not depicted), in some examples, the laser-generated features **124** may have little to no effect on the flight of a golf ball that is struck by the club head **100**. That is, the depth of the laser-generated features **124** may be extremely small in comparison to a groove or scoreline.

[0094] The micro-grooves **225** (shown in FIG. **2***a*) of the laser generated features **124**, as illustrated in this embodiment of the present invention, may generally help the surface roughness of the external surface **112** of the club face **102**. In one embodiment, if the desire is to reduce surface roughness, the micro-grooves **225** may decrease the Central Region Average Surface Roughness Value. The Central Region Average Surface Roughness Value, in accordance with the present invention, may generally be between about 10 μin and about 80 μin, more preferably between about 10 μin and about 60 μin, and most preferably between about 10 μin and about 40 μin. It should be noted here that the range articulated here is critical because values outside the range will produce undesirable affects to the golf ball performance.

[0095] The surface roughness of a club face **102**, although can be effective in changing the launch and spin conditions of a golf ball, has diminishing returns at the extremities of the value range. More specifically, if the surface roughness is too high in the range of above 180 μin, the diminishing return becomes almost negligible. Even worse, if the surface roughness of the club face **102** is too low, the launch and spin conditions with a golf ball becomes unpredictable, especially if there is any moisture present during the contact. As such, the surface roughness ranges articulated above is critical to the present invention.

[0096] Central Region Average Surface Roughness Value, as defined in the present invention, relates to an average of 10 individual surface roughness values (Ra) taken within the central region **128** of the club face. The individual surface roughness values (Ra), which is also known as the Arithmetic Average (AA) and Center Line Average (CLA), is a measure of the distance from the peaks and valleys to the center line or mean. It is calculated as the integral of the absolute value of the roughness profile height over the evaluation length:

$$Ra = \frac{1}{L}\int_0^L |Z(x)|dx$$

More details regarding our methodology of measuring surface roughness can be found in standard ASME B46.1-2009, the disclosure of which is incorporated by reference in its entirety.

[0097] In order to illustrate the location and direction of the ten individual surface roughness values (Ra) to create the Central Region Average Surface Roughness, FIG. **2** of the accompanying drawings shows five "imaginary" vertical sampling lines **203***a*, **203***b*, **203***c*, **203***d*, and **203***e* and five horizontal sampling lines **205***a*, **205***b*, **205***c*, **205***d*, and **205***e*. The vertical sampling lines **203** are generally vertical to the golf club head **100** in a crown to sole direction, while the horizontal sampling lines **205** are generally horizontal to the golf club head **100** in a heel to toe direction. Each individual sampling line measures the surface roughness value (Ra) based on the ASME B46.1-2009 previously described, and these ten values are averaged with one another to create the Central Region Average Surface Roughness Value previously mentioned.

[0098] It should be noted that the location of the vertical sampling lines **203** are roughly distributed to cover the central region center portion **228** of the central region **128** of the external surface **112** of the club face **102**, with the middle most vertical sampling line **203***c* being located at the geometric center of the club face **102**. The outermost vertical sampling lines **203***a* and **203***e* are located roughly about 20 mm away from the middle most vertical sampling line **203***c* on each side, with the intermediary vertical sampling lines **203***b* and **203***d* taken roughly in between the middle most vertical sampling line **203***c* and the outermost vertical sampling lines **203***a* and **203***e*. Similarly, the horizontal sampling lines are also roughly distributed to cover the central portion of the central region of the external surface **112** of the club face **102**, with the middle most horizontal sample line **205***c* being located at the geometric center of the club face **102**. The outermost horizontal sampling lines **205***a* and **205***e* are located roughly about 20 mm away from the middle most horizontal sampling line **203***c* on each side, with the intermediary horizontal sampling lines **205***b* and **205***d* taken roughly in between the middle most horizontal sampling line **205***c* and the outermost horizontal sampling lines **205***a* and **205***e*.

[0099] It should be noted that the location of the vertical sampling lines **207** are distributed to cover the central region bottom portion **238** of the external surface **112** of the club face **102**, with the middle most vertical sampling line **207***c* being located at the geometric center of the club face **102** in the heel-to-toe direction, the x-axis direction. The outermost vertical sampling lines **207***a* and **207***e* are located roughly about 20 mm away from the middle most vertical sampling line **207***c* on each side, with the intermediary vertical sampling lines **207***b* and **207***d* taken roughly in between the middle most vertical sampling line **207***c* and the outermost vertical sampling lines **207***a* and **207***e*. Each of the sampling lines **207** in the central region bottom portion **238** should extend to within 5 mm of the sole **206**. As discussed above, the micro-grooves **225** (shown in FIG. **2***a*) of the laser generated features **124**, as illustrated in this embodiment of the present invention, may generally help the surface roughness of the external surface **112** of the club face **102**. In one embodiment, if the desire is to increase the surface roughness of the central region bottom portion, the micro-grooves **225** may be used to increase the Average Surface Roughness Value. The Average Surface Roughness Value of the central region bottom portion, in accordance with the present invention, may generally be greater than about 120 μin, and more preferably between about 120 μin and about 180 μin. It should be noted here that the range articulated here is critical because values outside the range will produce undesirable affects to the golf ball performance. Each individual sampling line **207** measures the surface roughness value (Ra) based on the ASME B46.1-2009 previously described, and these five values are averaged with one another to create the Average Surface Roughness Value of the central region bottom portion previously mentioned.

[0100] It should be noted that the location of the vertical sampling lines **209** are distributed to cover the central region top portion **248** of the external surface **112** of the club face **102**, with the middle most vertical sampling line **209***c* being located at the geometric center of the club face **102** in the heel-to-toe direction, the x-axis direction. The outermost vertical sampling lines **209***a* and **209***e* are located roughly about 20 mm away from the middle most vertical sampling line **209***c* on each side, with the intermediary vertical sampling lines **209***b* and **209***d* taken roughly in between the middle most vertical sampling line **209***c* and the outermost vertical sampling lines **209***a* and **209***e*. Each of the sampling lines **209** in the central region top portion **248** should extend to within 5 mm of the crown **204**. As discussed above, the micro-grooves **225** (shown in FIG. **2***a*) of the laser generated features **124**, as illustrated in this embodiment of the present invention, may generally help the surface roughness of the external surface **112** of the club face **102**. In one embodiment, if the desire is to decrease the surface roughness of the central region top portion, the micro-grooves **225** may be used to decrease the Average Surface Roughness Value. The Average Surface Roughness Value of the central region top portion, in accordance with the present invention, may generally be less than about 100 μin, and more preferably between about 20 μin and about 80 μin. Each individual sampling line **209** measures the surface roughness value (Ra) based on the ASME B46.1-2009 previously described, and these five values are averaged with one another to create the Average Surface Roughness Value of the central region top portion previously mentioned.

[0101] Although loosely correlated, the Coefficient of Friction (COF) and the surface roughness are positively correlated. In another words, when the surface roughness of the striking club face **102** of the golf club head **100** decreases as previously mentioned via the incorporation of micro-grooves **225** or via other means, the COF generally decreases with it.

[0102] Similarly, in this embodiment of the present invention, when the above discussion focuses on the Central Region Average Surface Roughness Value, a similar COF value can be created using the sampling lines **203***a* through **203***e* as well as **205***a* through **205***e* discussed previously. In this embodiment of the present invention, the Central Region Average Coefficient of Friction Value of this club face, having the Central Region Average Surface Roughness Values articulated above, may generally be between about 0.10 and about 0.40, more preferably between about 0.10 and about 0.38, and most preferably between about 0.10 and about 0.36, all without departing from the scope and content of the present invention. It is worth noting here that the Central Region Average Coefficient of Friction Value, similar to the Central Region Average Surface Roughness value previously mentioned, are terms of art within the context of this application, and refer to the average of 10 values taken vertically and horizontally at the central region **228** of the club face **202** instead of the standard coefficient of friction value that refers to the overall club face **202**.

[0103] Although the above discussion focuses on the values of the Central Region Average Surface Roughness Value, it should be noted that the vertical sampling lines **203** are more critical to the performance of the golf club head **100** in affecting the performance of a golf ball. Hence, some emphasis should be placed on the Central Region Average Vertical Surface Roughness Value. The Central Region Average Vertical Surface Roughness Value in accordance with the present invention may generally be greater than about 100 μin, more preferably greater than about 120 μin, and most preferably greater than about 140 μin as well. The Central Region Average Vertical Surface Roughness Value, similar to the Central Region Average Surface Value is an average of the values taken, but this time, only takes in consideration of the five vertical measurements taken at the vertical sampling lines **203***a*, **203***b*, **203***c*, **203***d*, and **203***f*.

[0104] Similarly, in an embodiment of the present invention, when the above discussion focuses on the Average Surface Roughness Value, a similar COF value for the central region bottom portion can be created using the sampling lines **207***a* through **207***e*. In this embodiment of the present invention, the Average Coefficient of Friction Value for the central region bottom portion of this club face, having the Average Surface Roughness Values articulated above, may generally be between about 0.20 and about 0.40. The Average Coefficient of Friction Value for the central region bottom portion, similar to the Average Surface Roughness value previously mentioned, are terms of art within the context of this application and refer to the average of the five values taken vertically in the central region bottom portion **238** of the club face **202** instead of the standard coefficient of friction value that refers to the overall club face **202**.

[0105] Similarly, in an embodiment of the present invention, when the above discussion focuses on the Average Surface Roughness Value, a similar COF value for the central region top portion can be created using the sampling lines **209***a* through **209***e*. In this embodiment of the present invention, the Average Coefficient of Friction Value for the central region top portion of this club face, having the Average Surface Roughness Values articulated above, may generally be less than about 0.20. The Average Coefficient of Friction Value for the central region top portion, similar to the Average Surface Roughness value previously mentioned, are terms of art within the context of this application and refer to the average of the five values taken vertically in the central region top portion **248** of the club face **202** instead of the standard coefficient of friction value that refers to the overall club face **202**.

[0106] In a substantially isotropic type of face pattern as the one shown in FIG. **2**, the Central Region Average Vertical Surface Roughness Value may be the same as the Central Region Average Horizontal Surface Roughness Value, resulting in the Central Region Average Surface Roughness Value to remain unchanged. However, in an anisotropic type of pattern for the laser generated feature **124**, these two values may be different from one another, and it may be worthwhile to focus more on the values of the Central Region Average Vertical Surface Roughness instead.

[0107] Before the discussion moves on to specific design patterns in FIGS. **2** through 3F, it is worth noting here that because the laser generated features **124** have only been applied to the external surface **112** of the club face **102** and not the internal surface **114**, the surface roughness values of the external surface **112** and the internal surface **114** could be different from one another. In one exemplary embodiment of the present invention, the surface roughness value (Ra) of the external surface **112** could be greater than about 2 times the surface roughness value (Ra) of the internal surface **114**, more preferably greater than about 3 times, and most preferably greater than about 4 times, all without departing from the scope and content of the present invention. Based on the surface roughness value (Ra) of the external surface **112** provided above, the surface roughness value (Ra) of the internal surface **114** may generally be less than about 60 μin, more preferably less than about 50 μin, and most preferably less than about 45 μin.

[0108] FIG. **2** depicts an example golf club head **200** having a club face **202** with laser-generated features **224**A-C. The golf club head has crown **204**, a sole **206**, a hosel **208**, and a club face **202**. The club face **202** has a maximum width W that is measured in a toe-to-heel direction parallel to the ground plane when the club is at address. The club face **202** also has a maximum height H, which is a maximum distance between two points on the face along a line orthogonal to the ground plane when club is at address. The width W and height H depicted in FIG. **2** indicate the measurement directions but may not be actual measurements of the club face **202**. The club face **202** includes a central region **228**, a heel region **230**, and a toe region **232**. The central region **228** may comprise approximately a central third of the club face **202**. For example, the maximum width of the central region may be approximately one-third of the maximum width W of the club face **202**. In other examples, the central region **228** may have a maximum width of at least 35%, 40%, 45%, or 50% of the width W of the club face **202**. The maximum width of the central region **228** may be between 30-50% of the width W of the club face **202**. The heel region **230** and the toe region **232** may have the same maximum width, which may be equal to half of the remaining width W of the club face **202** not comprised by the central region **228**. The central region **228** extends the entire height H of the club face **202**. Due to the shape of the club face **202**, the heel region **230** and the toe region **232** may have heights that are less than the maximum height H of the club face **202**.

[0109] The central region bottom portion **238** has a height within the central region **228** that is approximately ⅓ the maximum height H of the club face **202**. Similarly, the central region top portion **248** has a height within the central region **228** that is approximately ⅓ the maximum height H of the club face **202**.

[0110] The club face **202** includes a coating or finish, such as a physical vapor deposition (PVD) coating, which is indicated by the speckled dots on the club face **202**. The coating may be applied before and/or after generating the laser-generated features **224**A-C. When the laser-generated features **224**A-C are generated subsequent to the coating being applied to the face, generating the laser-generated features **224**A-C may include removing or vaporizing a portion of the coating.

[0111] The club face **202** includes a plurality of laser-generated features **224**A-C that create contrast across the club face **202**. The first plurality of laser-generated features **224**A are included in the central region **228** of the club face **202**. The first plurality of laser-generated features **224**A are in the shape of diamonds; however, other shapes and designs are also possible. In examples, the particular shape of the features may be based on aesthetic choices. The first plurality of laser-generated features **224**A may be generated before or after the application of the coating, such as a PVD coating. The laser process to generate the first plurality of laser-generated features **224**A may also cause the laser-generated features **224**A to be a particular color, such as blue. The first plurality of laser-generated features **224**A may extend under the paint or coating of the crown **204**. For instance, the first plurality of laser-generated features **224**A may be provided on a region of the golf club head **200** that is later painted, coated, or covered with the same paint, coating, or covering that is used for the crown **204**.

[0112] The first plurality of laser-generated features **224**A are included across almost the entirety of the central region **228**. Thus, the first plurality of laser-generated features **224**A provide an aggregate contrast for the central region **228** as compared to the toe region **232** and the heel region **230**. As an example, the first plurality of laser-generated features **224**A may cover at least 50%, 60%, 70%, 80%, or 90% of the central region **228**. By increasing the coverage of the central region **228** by the first plurality of laser-generated features **224**A, the contrast effect is further enhanced, and the utility of the golf club is increased thus causing an improvement of the performance of the golf club head.

[0113] The coverage of the central region by the first plurality of laser-generated features **224**A may be measured in multiple different manners. For example, an intersection-measurement method may be used where a determination is made at each height and/or width increment whether there is a laser-generated feature **224**A. In a height-intersection measurement method, a determination is made for each height increment in the total height of the region whether there is a laser-generated feature **224**A at the particular height increment. The height increment may be 1 mm or less, such as 0.1 mm. If there is a laser-generated feature **224**A at the particular height increment, then the central region **228** is considered covered at that particular height increment. The coverage according to the height-intersection measurement method is the number of height increments that include a laser-generated feature **224**A as compared to the total number of height increments, and such coverage is referred to herein as a height-intersection coverage. The height-intersection coverage may be expressed in the form of a percentage, fraction, or decimal expression. In the example depicted in FIG. **2**, the only heights at which the central region **228** is not covered by the first plurality of laser-generated features **224**A are heights of the club face **202** very near the sole. Accordingly, the height-intersection coverage of the central region **228** is at least 98%. In other examples, the height-intersection coverage of the central region **228** may be greater than 80%, 90%, or 95%, among other values.

[0114] A width-intersection measurement method may also be used. In a width-intersection measurement method, a determination is made for each width increment in the total width of the region whether there is a laser-generated feature **224**A. The width increment may be 1 mm or less, such as 0.01 mm. If there is a laser-generated feature **224**A at the particular width increment, then the central region **228** is considered covered at that particular width increment. The coverage according to the width-intersection measurement method is the number of width increments that include a laser-generated feature **224**A as compared to the total number of width increments, and such coverage is referred to herein as a width-intersection coverage. The width-intersection coverage may be expressed in the form of a percentage, fraction, or decimal expression. In the example depicted in FIG. **2**, each width increment of the central region **228** includes a laser-generated feature **224**A. Accordingly, the width-intersection coverage of the central region **228** is 100%. In other examples, the width-intersection coverage of the central region **228** may be greater than 80%, 90%, or 95%, among other values.

[0115] A surface-area measurement method may also be used. In a surface-area measurement method, the surface area of the central region **228** that comprises a laser-generated feature **224**A is compared to the total surface area of the central region **228**. For instance, the surface area that has been laser marked, etched, and/or engraved is compared to the total surface area for the region. The coverage may be expressed in the form of a percentage, a fraction, or decimal expression, and such coverage is referred to herein as surface-area coverage. In the example depicted in FIG. **2**, the surface-area coverage is less than the width-intersection coverage or the height-intersection coverage due to the width lines of the diamond pattern used. Thus, the surface-area coverage for the central region **228** may be greater than approximately 25%. The surface-area coverage changes based on the pattern of the first plurality of laser-generated features **224**A and the line thickness of the features. For instance, in other examples, the surface-area coverage for the central region **228** may be at least 40%, 50%, 60%, 70% or greater.

[0116] The toe region **232** and the heel region **230** also include a second plurality of laser-generated features **224**B and a third plurality of laser-generated features **224**C. The second plurality of laser-generated features **224**B may comprise spear-shaped features that point in a heel-to-toe direction. The third plurality of laser-generated features **224**C may comprise line segments that run in a heel-to-toe direction. The third plurality of laser-generated features **224**C may extend under the paint or coating of the crown **204**. For instance, the third plurality of laser-generated features **224**C may be provided on a region of the golf club head **200** that is later painted, coated, or covered with the same paint, coating, or covering that is used for the crown **204**. The third plurality of laser-generated features **224**C may also include a band that is contoured to match the shape of the lower boundary of the club face **202**. That band may be offset from the perimeter of the club face **202** by an offset distance. The offset distance may be less than 5 mm, such as 2 mm. The offset may be from the perimeter of the club face **202** or from the edge of the club face area that is finished or coated, such as by a brushing process.

[0117] In examples, the particular shape of the laser-generated features **224**B-C, such as a spear-shape, may be chosen based on aesthetic design choices. The overall contrast effect of the combination and coverage of the laser-generated features **224**A-C, however, provides a functional benefit to the golf club head, as discussed above. The second plurality of laser-generated features **224**B and the third plurality of laser-generated features **224**C may be generated before and/or after the coating is applied to the club face **202**. The coverage of toe region **232** and the heel region **230** by the laser-generated features **224**B-C may be determined using the height-intersection measurement method, the width-intersection measurement method, and/or the surface-area measurement method. A height-intersection coverage, width-intersection coverage, and a surface-area coverage may be determined for the entire club face as well.

[0118] In one example for manufacturing the club face depicted in FIG. **2**, the first plurality of laser-generated features **224**A may be generated (e.g., laser engraved, etched, and/or marked) prior to the application of a black PVD coating. The second plurality of laser-generated features **224**B and the third plurality of laser-generated features **224**C may generated after the application of the black PVD coating. In other examples, all the laser-generated features **224**A-C may be generated before or after the PVD coating. In yet other examples, a PVD coating may be applied only to the central region **228** or the toe region **232** and the heel region **230**. In still other examples, the PVD coating may not be applied. Generating laser-generated features prior to the PVD coating may result in darker laser-generated features after they are coated with the dark PVD coating. Conversely, generating the laser-generated features subsequent to the application of the PVD coating may result in lighter laser-generated features. Thus, by having the laser-generated features in the center portion be generated prior to the PVD coating and having the laser-generated features in the toe portion and the heel portion generated after the PVD coating, additional contrast between the center region and the toe and heel regions may be achieved, which results in improved functionality of the golf club head.

[0119] Some example combinations of height-intersection coverage, width-intersection coverage, and surface area coverage are provided in the tables below.

Example Club 1

Face Region	Height-Intersection Coverage	Width-Intersection Coverage	Surface-Area Coverage
Entire Face	>95%	>97%	>10%
Central Region	>95%	100%	>15%
Toe Region	>60%	>95%	>5%
Heel Region	>60%	>95%	>5%

Example Club 2

Face Region	Height-Intersection Coverage	Width-Intersection Coverage	Surface-Area Coverage
Entire Face	>95%	>97%	>10%
Central Region	>95%	>95%	>15%
Toe Region	>95%	>60%	>5%
Heel Region	>95%	>60%	>5%

Example Club 3

Face Region	Height-Intersection Coverage	Width-Intersection Coverage	Surface-Area Coverage
Entire Face	>95%	>97%	>25%
Central Region	>95%	100%	>40%
Toe Region	>60%	>95%	>10%
Heel Region	>60%	>95%	>10%

Example Club 4

Face Region	Height-Intersection Coverage	Width-Intersection Coverage	Surface-Area Coverage
Entire Face	>90%	>90%	>25%
Central Region	>90%	>90%	>40%
Toe Region	>90%	>60%	>10%
Heel Region	>90%	>60%	>10%

Example Club 5

Face Region	Height-Intersection Coverage	Width-Intersection Coverage	Surface-Area Coverage
Entire Face	>90%	>90%	>30%
Central Region	>90%	>90%	>60%
Toe Region	>60%	>90%	>20%
Heel Region	>60%	>90%	>20%

Example Club 6

Face Region	Height-Intersection Coverage	Width-Intersection Coverage	Surface-Area Coverage
Entire Face	>95%	>97%	>30%
Central Region	>95%	>95%	>60%
Toe Region	>95%	>60%	>20%
Heel Region	>95%	>60%	>20%

Example Club 7			
Face Region	Height-Intersection Coverage	Width-Intersection Coverage	Surface-Area Coverage
Entire Face	>60%	>60%	>25%
Central Region	>80%	>80%	>40%
Toe Region	>40%	>40%	>10%
Heel Region	>40%	>40%	>10%

Example Club 8			
Face Region	Height-Intersection Coverage	Width-Intersection Coverage	Surface-Area Coverage
Entire Face	>50%	>50%	>10%
Central Region	>50%	>30%	>15%
Toe Region	>30%	>30%	>5%
Heel Region	>30%	>30%	>5%

[0120] In addition to the above, the club face **202** shown in FIG. **2** illustrates another feature of the golf club head **200** that is worth mentioning. FIG. **2** of the accompanying drawing illustrates that in an embodiment of the present invention, the surface roughness value may be different at different regions of the club face **202**. More specifically, it can be seen that the central region **228** may have a first plurality of laser generated features **224**A, while the heel region **230** and toe region **232** may both be formed out of a combination of second plurality of laser generated features **224**B and third plurality of laser generated features **224**C, which resultingly yields a different surface roughness value. Hence it can be said that the different regions of the club face **202** may have different values of surface roughness value without departing from the scope and content of the present invention. In this current exemplary embodiment, the central region **228** may have a higher surface roughness value (Ra) then the heel region **230** and the toe region **232**, but in alternative embodiments the heel region **230** or the toe region **232** may have the higher surface roughness value (Ra) without departing from the scope and content of the present invention. In fact, in further alternative embodiments of the present invention, the regions need not be broken down into the central region **228**, the heel region **230**, and the toe region **232**, but could be other boundaries such as high toe, high heel, low toe, low heel to name a few, also without departing from the scope and content of the present invention.

[0121] Referring back to the current preferred embodiment, the Central Region Average Surface Roughness value has already been described above as being greater than 100 μin, more preferably greater than about 120 μin, and most preferably greater than about 140 μin. Meanwhile the average surface roughness value of the heel region **230** and the toe region **232** may generally be less than about 100 μin, more preferably less than about 80 μin, and most preferably less than about 60 μin.

[0122] Furthermore, in a preferred embodiment, the Average Surface Roughness value of the central region bottom portion has already been described above as being greater than 120 μin, and more preferably greater than about 140 μin, and the Average Surface Roughness value of the central region top portion has already been described above as being less than 100 μin, and more preferably less than 80 μin. Meanwhile the average surface roughness value of the heel region **230** and the toe region **232** may generally be less than about 100 μin, more preferably less than about 80 μin, and most preferably less than about 60 μin.

[0123] FIG. **2***a* of the accompanying drawings depict an enlarged microscopic view of the micro-grooves **225** capable of achieving the surface roughness values discussed above, using the face pattern shown in FIG. **2**. It should be noted that as previously mentioned, the surface roughness value is often a function of several variables, the most important of which is the pattern of the face and the depth of the micro-grooves **225**. In this enlarged microscopic view, we can see that the microgroove **225** formed as part of the first plurality of laser-generated features **224**A may generally have a depth D**1**. Depth D**1**, as shown in accordance with this exemplary embodiment of the present invention may generally be between about 45 μm and about 60 μm, preferably between about 45 μm and about 57 μm, and most preferably between about 45 μm and about 55 μm. It should be noted that in alternative embodiments where the pattern of the laser generated features **224** take on a different shape, the depth D**1** of the micro-grooves may need to different to achieve the surface roughness value discussed above without departing from the scope and content of the present invention.

[0124] Depth D**1**, in a preferred embodiment of the present invention, varies in depth vertically across the face. In this exemplary embodiment of the present invention D**1** may generally be between about 45 μm and about 60 μm in the central region bottom portion **238** and between about 5 μm and about 40 μm in the central region top portion **248**. More preferably, D**1** may generally be between about 45 μm and about 57 μm in the central region bottom portion **238** and between about 10 μm and about 35 μm in the central region top portion **248**. Most preferably, D**1** may generally be between about 45 μm and about 55 μm in the central region bottom portion **238** and between about 10 μm and about 30 μm in the central region top portion. It should be noted that in alternative embodiments where the pattern of the laser generated features **224** take on a different shape, the depth D**1** of the micro-grooves may be different to achieve the surface roughness values discussed above without departing from the scope and content of the present invention.

[0125] In the exemplary embodiment shown in FIG. **2***a*, we can see that the micro-grooves **225** may generally exhibit a geometry that is substantially circular. However, in alternative embodiments of the present invention, the shape of the micro-grooves may be triangular, rectangular, or other types of geometry so long as it is capable of altering the surface roughness of the club face **202** without departing from the scope and content of the present invention.

[0126] FIGS. **3**A-**3**F depict example golf club heads **300** having club faces with laser-generated features **324**. Each of the golf club heads **300** include a club face **302**, a crown **304**, a sole **306**, and a hosel **308**. The laser-generated features **324** in each of the club faces **302**, however, differ and provide a different contrast effect for the overall club face **302**. The coverage of the club face **302** by the laser-generated features **324** may be within the ranges discussed above and in the above tables.

[0127] The example club face **302** of FIG. **3**A includes laser-generated features **324** that are similar to the laser-generated features of the example golf club head **200** depicted in FIG. **2**. For instance, the club face **302** in FIG.

3A includes a first plurality of laser-generated features **324**A in a central region **328** of the club face **302**. Rather than a diamond shape, the first plurality of laser-generated features **324**A have an angled or chevron pattern. The club face **302** also includes a second plurality of laser-generated features **324**B and a third plurality of laser-generated features **324**C that are substantially similar to the second plurality of laser-generated features **224**B and a third plurality of laser-generated features **224**C discussed above with respect to FIG. **2**. The club face **302** further includes a fourth laser-engraved feature **324**D, which may be a logo or other indicia. The fourth laser-engraved feature **324**D may be generated before or after the coating is applied.

[0128] FIG. **3**B depicts another example club face **302** with a first plurality of laser-generated features **324**A and second laser-generated feature **324**B. The first plurality of the laser-generated features **324**A include lines that extend across the club face **302** in a heel-to-toe direction. The thickness of the first plurality of the laser-generated features **324** (e.g, the line thickness) may vary based on the position of the lines relative to the crown **304** and the sole **306**. For instance, the first plurality of the laser-generated features **324**A near the crown **304** are thicker than the first plurality of the laser-generated features **324** near the sole **306**. The thickness of the laser-generated feature **324**A nearest the crown **304** may be 0.4 mm and the thickness of the laser-generated feature nearest the sole **306** may be 0.1 mm. The ratio between the thickest laser-generated feature **324**A and the thinnest laser-generated feature **324**B may be between 2:1 to 6:1. In other examples, the change in thickness may be reversed such that the thinnest laser-generated feature **324**A is near the crown **304** and the thickest laser-generated feature **324**A is near the sole **306**. The inclusion of the first plurality of laser-generated features may improve the functionality of the golf club head by allowing the player to better perceive the characteristics of the golf club head **300**, such as the loft, bulge, and roll of the golf club head. The second laser-generated feature **324**B may be a logo or other indicia. The first plurality of laser-generated features **324**A do not overlap with the second laser-generated feature **324**B.

[0129] FIG. **3**C depicts another example club face **302** with a first plurality of laser-generated features **324**A and a second plurality of laser-generated features **324**B. The first plurality of laser-generated features **324**A are located in a central region **328** of the club face **302**. The first plurality of laser-generated features **324**A are formed as lines running in a crown-to-sole direction. The thickness of the first plurality of laser-generated features **324**A may decrease from the crown **304** towards the sole **306**. Thus, the thinnest portion of each of the laser-generated features **324**A may be at a point nearest the sole **306** and thickest portion of each of the laser-generated features **324**A may be at a point nearest the crown **304**. The toe region **332** and the heel region **330** include a second plurality of laser-generated features **324**B. The second plurality of laser-generated features **324**B are substantially similar to the first plurality of laser-generated features depicted in FIG. **3**B and described above. The central region **328** also includes a third laser-generated feature **324**C that may be a logo or other indicia. The third laser-generated feature **324**C may located at or near the sweet spot of the golf club to indicate the location of the sweet spot.

[0130] FIG. **3**D depicts another example club face **302** with a first plurality of laser-generated features **324**A that are substantially similar to the first plurality of laser-generated features **324**A depicted in FIG. **3**B and discussed above. The club face **302** also includes a second plurality of laser-generated features **324**B and a third plurality of laser-generated features **324**C. The second plurality of laser-generated features **324**B may extend in multiple directions and be located to help identify the central region. The third plurality of laser-generated features **324**C may be formed to appear more akin grooves or score lines of the golf club head **300**. A fourth laser-generated feature **324**D may be located at the sweet spot to indicate the location of the sweet spot.

[0131] FIG. **3**E depicts another example club face **302** having a first plurality of laser-generated features **324**A, a second plurality of laser-generated features **324**B, and a third laser-generated feature **324**C. The first plurality of laser-generated features **324**A may be similar to the first plurality of laser-generated features **324**A depicted in FIG. **3**B and discussed above. The first plurality of laser-generated features **324**A in FIG. **3**E, however, may have a consistent line thickness. The second plurality of laser-generated features **324**B extend in a first direction in the central region and in a different direction in the toe region and the heel region. Accordingly, a player may be able to more easily identify the central portion and/or the center point of the width of the club face **302**. The third laser-generated feature **324**C may be located at the sweet spot to identify the sweet spot for the player.

[0132] FIG. **3**F depicts another example club face having a first plurality of laser-generated features **324**A and a second laser-generated feature **324**B. The laser-generated features **324** are formed as lines running in a heel-to-toe direction. Each of the first plurality of laser-generated features **324**A has a consistent thickness. The second laser-generated feature **324**B is located at a center width of the club face **302** to help the player identify the lateral geometric center of the club face **302** to provide more contrast on the face to help with alignment.

[0133] FIG. **4** depicts an example method **400** for manufacturing a golf club head. At operation **402**, a club face for the golf club head is brushed and/or polished. The brushing and/or polishing process provides one type of initial finish on the club face. The brushing and/or polishing of the face may be a mechanical process and may be performed in a horizontal direction (e.g., in a heel-to-toe direction), a vertical direction (e.g., in a crown to sole direction), or another direction.

[0134] At operation **404**, a first plurality of club-face features is laser-generated on the club face. The first plurality of laser-generated features may be any of the laser-generated features discussed above, among other possible laser-generated features. The first plurality of laser-generated features may be a first color. The first color may be gold, but other colors are also possible. The first set of laser-generated features may cover the majority of the surface of the central region. In other examples, the first set of laser-generated features may cover a majority of the surface of the toe region and/or the heel region. For example, the height-intersection coverage and the width-intersection coverage of the central region may be greater than 90%. By covering a majority of a particular region or regions, additional contrast between the regions may be generated. In addition, contrast between other components of the club head, such as the crown or hosel, may also be generated. The first plurality of laser-generated features is generated prior to the application of a coating, such as a PVD coating. Such an order of operations is contrary to previous methods, which generally performed any type of engraving after the application of a PVD. In addition, any such post-PVD engraving was on a smaller scale than what is provided by the present technology. Again, the scale at which the present laser-generated features is provided also previous methods that assumed that generating such large-scale, high-coverage features with a laser would be too time consuming and the heat generation during such a process may be too high, potentially causing damage to the underlying product.

[0135] Laser-generating a feature on the club face may be performed through a laser-etching process, a laser-engraving process, and/or a laser-marking process. The laser-engraving process and laser-etching process remove material from the face through the use of a laser beam generated from a laser source. The laser-engraving process uses high-power laser beam to heat and effectively vaporize material from the club face. In some examples, the depth of the laser-engraved features may be between 0 inches and 0.02 inches. The laser-etching process may be similar to the laser-engraving process, the laser-etching process may cause the material of the club face to melt. The melted material may expand to cause a raised mark. The depth of the laser-etched features may be between 0.000 and 0.001 inches.

[0136] The laser-marking process may discolor the material but may not remove any of the material (or remove a very small amount of material). The laser-marking process may use a lower power beam to create the change in color or discoloration of the club face. The laser-marking process may be an annealing process, a carbon migration process, and/or a coloration process. The annealing process may cause an oxidation of the metal due to the heat generated on the club face by the laser. The annealing process can create a darkened feature (such as a black feature) and may also be used to generate other color features, such as yellow, red, and green. The carbon migration technique cause carbon properties of the material to appear on the surface, creating a darker feature. The coloration process may change the color of the surface of the club face to a wide variety of colors. In some examples, the coloration process may be achieved via multiple different manners, such as laser oxidation that produces a thin oxide film on the metal surface that create color due to light interference occurring in the film, generating subwavelength nanoparticles, and/or structuring periodic gratings on the surface, among other manners. Generating the different colors on the surface of the club face may be based on changing the laser properties, such as laser frequency, power, speed, and/or focal distance, among other properties.

[0137] At operation **406**, a second plurality of club-face features is laser-generated. The laser-generation process may be similar to the laser-generation process described above in operation **406**. The second plurality of laser-generated features may be any of the laser-generated features described above, among other types of laser-generated features. The second set of laser-generated features may be for a second color. The second color may be blue, but other colors are also possible. To generate the second color, a separate laser may be utilized, or the characteristics of the same laser may be adjusted. For example, the focal length, time of exposure, and/or power of the laser may be adjusted to change the resultant color of the feature generated by the laser.

[0138] At operation **408**, a coating is applied to the club face subsequent to the first plurality of laser-generated features and the second plurality of laser generated features being generated on the club face. The coating may be a PVD coating among other types of coating. A PVD coating may be used to darken the club face. The thickness of the coating may be set such that the first plurality and second plurality of laser-generated features may still be seen, at least partially, through the coating.

[0139] At operation **410**, subsequent to the application of the coating, a third plurality of club face features are laser generated on the club face. The third plurality of laser-generated features may be any of the laser-generated features described above, among other possible features. The third plurality of laser-generated features may be of the same color as the first plurality of laser-generated features that were generated in operation **404**. Laser-generating the features subsequent to the coating may cause the coating to be removed or vaporized by the laser beam. Where the coating is a dark coating, such as a black PVD, the laser-generation process lightens portion of the club face where the laser beam is directed by removing the dark coating. At operation **412**, also subsequent to the application of the coating, a fourth plurality of club-face features is laser-generated. The fourth plurality of laser-generated features may be any of the laser-generated features described above, among other possible features. The fourth plurality of laser-generated may be the same color as the first plurality of laser generated features.

[0140] Subsequent to the laser-generated features being manufactured on the club face, at operation **414**, paint or another coating is added to one or more components of the club head, such as the crown. The paint may cover a portion of the laser-generated features, such as a portion of the laser-generated features located near the crown.

[0141] FIG. **5** of the accompanying drawings depicts a chart that further explains how the laser generated features **124** are formed in the club face **102** of the golf club head **100** as described in operation **404** in FIG. **4**. More specifically, the chart shown in FIG. **5** establishes a correlation between the surface roughness value and the laser power setting used to create these laser generated features **124**. This well correlated relationship, as illustrated by the R^2 value of 0.9914, corroborates the earlier statement wherein the surface roughness of the club face **102** is highly attributable to the laser power that form the depth of the micro-grooves. Thus, in a preferred embodiment where the surface roughness of the central region bottom portion **238** is greater than the surface roughness of the central region top portion **248**, the laser power setting can be adjusted appropriately to modify the surface roughness between the two portions. In a preferred embodiment, the laser power can be adjusted linearly as the surface roughness is being formed in the central region as the laser moves from the sole to the crown. More preferably, the laser power forming the central region bottom portion **238** is in the range of about 40 W to 55 W and is decreased as the laser moves up the face such that the laser power forming the central region top portion **248** is in the range of about 5 W to 20 W. Most preferably, the laser power forming the surface roughness is varied when forming the central region **228** and is constant when forming the toe region **232** and the heel region **230**.

[0142] FIG. **6** of the accompanying drawings depicts a chart that establishes the relationship between the depth D**1**

of the micro-grooves **225** and the resultant surface roughness (Ra). Once again, the high R^2 value shown in this FIG. **6** indicates that there is a highly predictable correlation between the depth of the micro-grooves **225** and the surface roughness (Ra) of the club face **202**. Thus, in a preferred embodiment where the micro-groove depth D**1** of micro-grooves in the central region bottom portion **238** is greater than the micro-groove depth D**1** of the micro-grooves in the central region top portion **248**, the laser power setting can be adjusted appropriately to modify the micro-groove depth D**1** between the two portions. In a preferred embodiment, the laser power can be adjusted linearly as the micro-grooves are being formed in the central region **228** as the laser moves from the sole to the crown.

[0143] Reading the results of FIG. **5** and FIG. **6** concurrently, once can see that the depth of the micro-grooves **225** may be adjusted merely by adjusting the wattage of the laser power used to create the laser-generated features **224**, as the two are both highly correlated to the surface roughness value of the resultant club face **202**. As such, FIG. **7** of the accompanying drawing is provided, establishing such a correlation.

[0144] It should be noted here that in further alternative embodiments, the club face **202** may be further comprised out of a coating to work in combination with the underlying laser generated features **224** to even further improve the performance of the golf club head **200**. Coatings in general have been known to have the ability to alter the coefficient of friction that can be independent of the underlying surface roughness value. Certain coating may even have the ability to perform differently in dry conditions than in wet conditions. Hence, it can be said that the addition of a coating may be used to further improve the performance of a club face **202** of a golf club head **200**.

[0145] In one exemplary embodiment, the club face **102** of the golf club head **100** may contain a coating on the external surface **112** of the club face **102** that reduces the coefficient of friction such as a tungsten disulfide, molybdenum disulfide, nicklon, nicklon plus, Teflon (PTFE), or even Xylan, as such coating are reported to have a coefficient of friction in the 0.035-0.08 range. In addition to the ability to decrease the coefficient of friction, certain coatings that are high in sulfide have the ability to decrease the lubricity under wet conditions that happens due to the breakdown of the bonds in the sulfide at an atomic level due to attack from the water molecules. Coatings such as tungsten disulfide in particular exhibit the ability described above of decreasing the coefficient of friction under wet conditions, or when exposed to water moisture and could be added as coating to the external surface **112** of the club face **102** to further improve the performance of the golf club head **100**.

[0146] Although the club face **102** and the surface roughness values are an important aspect of creating a synergistic golf club head **100** and golf ball combination, it is just one of the variables in the creation of this symbiotic synergistic relationship. Another one of the key variables in the golf club head **100** that pairs with the inventive golf ball mentioned above is the loft of inventive golf club head **100** itself. More specifically, the loft of the inventive golf club head **100** may generally be less than about 10 degrees, more preferably less than about 9 degrees, and most preferably less than about 8 degrees.

[0147] Another variable that is important to creating the synergistic golf club **100** and golf ball combination is the aerodynamic property of the golf club head **100** itself. The aerodynamic golf club head **100** containing all the features described above may generally have a drag force of less than about 4.7 Newtons at a Reynolds number of about 384,000, more preferably less than about 4.5 Newtons at the same Reynolds number of about 384,000, and most preferably less than about 4.3 Newtons at the same Reynolds number of about 384,000. In addition to the drag force, it is worth while to calculate the Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) based on the drag force above based on the equation below:

$$C_{D-Clubhead} = \frac{\text{Drag Force}}{(0.5 * \rho * A * V^2)}$$

[0148] As such, the Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of a golf club head in accordance with an exemplary embodiment of the present invention is less than about 0.40, more preferably less than about 0.38, and most preferably less than about 0.36, assuming an atmospheric temperature of 72 degrees Fahrenheit, an atmospheric pressure of about 14.7 PSI, 50% relative humidity, and 115 mph clubhead speed.

[0149] Another variable that is important to creating the synergistic golf club **100** and golf ball combination is having a shallower center of gravity (CG) **807** along the Z-direction as illustrated by the coordinate system **801**. FIG. **8** of the accompanying drawings shows a top perspective view of a golf club head **100** in accordance with the present invention, allowing the CG-Z of the golf club head **100** to be shown more clearly. The CG-Z measurement shown in FIG. **8** may generally refer to the distance of the location of the center of gravity (CG) **807** rearward of the geometric face center **803**, along the Z-direction. More specifically, in order to create the synergistic relationship between a golf ball and a golf ball, the location of the center of gravity **807** along the z-direction may generally be less than about 30 mm, more preferably less than about 29 mm, and most preferably less than about 28 mm, all without departing from the scope and content of the present invention. Having a shallower center of gravity (CG) **807** helps improve the launch characteristics of a golf club head **100**, hence further improving the synergistic affect between the golf club head **100** and the golf ball.

[0150] Yet another variable that is important to creating the synergistic golf club **100** and golf ball combination is to have a slightly lower CG **907** location relative to the neutral axis, which is better known as CG-NA. FIG. **9** of the accompanying drawing shows a cross-sectional view of a golf club head **900** showing the measurement of CG-NA in more detail. More specifically, the CG-NA is a measurement of the CG **907** location relative to a neutral axis **905** (NA). The neutral axis, as it is commonly known in the industry, relates to an axis that passes through the geometric center of the face at a plane that is perpendicular to the loft angle of the golf club head **900** as viewed from the y-z plane shown by the coordinate system **901** in FIG. **9**. The next step in determining CG-NA is by measuring the distance of the CG **907** location relative to the neutral axis along a distance that is perpendicular to the neutral axis **905**, with a positive number indicating a location being above the neutral axis **905** and a negative number indicating a location being below the neutral axis **905**.

[0151] In this exemplary embodiment of the invention, the synergistic golf club **900** may generally have a CG-NA between about −2.0 mm to about +2.0 mm, more preferably between about −1.5 mm to about +1.5 mm, and most preferably between about −1.0 mm to about +1.0 mm, all without departing from the scope and content of the present invention.

[0152] Another further variable that could impact and affect the performance of the club head **9100** to help create the synergistic pairing with the current inventive golf ball can be achieved by manipulating the roll radius of the club face **902** at the central region bottom portion of the club face **902**. More specifically, in order to lower the launch angle, the lower part of the club face **902** could be tucked in a little bit to reduce the roll radius, in accordance with an exemplary embodiment of the present invention. In one exemplary embodiment of the present invention, the roll radius at the upper portion of the club face **902** above the neutral axis **905** could be a standard roll radius of between about 260 mm to about 300 mm, more preferably between about 270 mm to about 290 mm, and most preferably about 280 mm; however, the roll radius below the neutral axis **905** could be greater than about 300 mm, more preferably greater than about 310 mm, and most preferably greater than about 320 mm without departing from the scope and content of the present invention.

[0153] Finally, another variable that is important in creating the synergistic golf club **100** and golf ball combination is the moment of inertia of the golf club head **100**, about the center of gravity around the Y-axis, which is commonly known as MOI-Y. The MOI-Y of the synergistic golf club head **100** in accordance with this exemplary embodiment of the present invention may generally be greater than about 4,300 g-cm2, more preferably greater than about 4,450 g-cm2, and most preferably greater than about 4,600 g-cm2, all without departing from the scope and content of the present invention.

[0154] Some aspects of the present disclosure are described above with reference to block diagrams. The functions, operations, and/or acts noted in the blocks may occur out of the order that is shown in any respective flowchart. For example, two blocks shown in succession may in fact be executed or performed substantially concurrently or in reverse order, depending on the functionality and implementation involved.

[0155] This disclosure describes some embodiments of the present technology with reference to the accompanying drawings, in which only some of the possible embodiments were shown. Other aspects may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments were provided so that this disclosure was thorough and complete and fully conveyed the scope of the possible embodiments to those skilled in the art. Further, as used herein and in the claims, the phrase "at least one of element A, element B, or element C" is intended to convey any of: element A, element B, element C, elements A and B, elements A and C, elements B and C, and elements A, B, and C. Further, one having skill in the art will understand the degree to which terms such as "about" or "substantially" convey in light of the measurement techniques utilized herein. To the extent such terms may not be clearly defined or understood by one having skill in the art, the term "about" shall mean plus or minus ten percent.

[0156] Although specific embodiments are described herein, the scope of the technology is not limited to those specific embodiments. Moreover, while different examples and embodiments may be described separately, such embodiments and examples may be combined with one another in implementing the technology described herein. One skilled in the art will recognize other embodiments or improvements that are within the scope and spirit of the present technology. Therefore, the specific structure, acts, or media are disclosed only as illustrative embodiments. The scope of the technology is defined by the following claims and any equivalents therein.

What is claimed is:

1. A golf club head comprising:

a club face located at a frontal portion of the golf club head, the golf club head further comprising;

an external surface, having an external surface roughness formed by a plurality of micro-grooves of substantially circular shape, and

wherein the external surface further comprises;

a central region occupying a central third of the club face, measured in a horizontal direction, being comprised of a central region bottom portion adjacent a sole portion of the golf club head and a central region top portion adjacent to a crown portion of the golf club head,

a toe region occupying a region toeward of the central region, and

a heel region occupying a region heelward of the central region, and

wherein when a plurality of imaginary vertical sampling lines are defined within an area measuring about 20 mm×20 mm located in the central region bottom portion and about 20 mm×20 mm located in the central region top portion and centered with respect to a geometric center of the club face in a heel-to-toe direction, the central region bottom portion of the external surface has a first Average Surface Roughness Value and the central region top portion of the external surface has a second Average Surface Roughness Value and the first Average Surface Roughness Value is at least 1.5 times greater than a second Average Surface Roughness Value

wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and

wherein said golf club head has a loft of less than about 10 degrees.

2. The golf club head of claim **1**, wherein the first Average Surface Roughness Value is greater than about 120 μin.

3. The golf club head of claim **1**, wherein the first Average Surface Roughness Value is greater than about 120 μin and the second Average Surface Roughness Value is less than about 80 μin.

4. The golf club head of claim **1**, wherein both the toe region and the heel region have an average surface roughness value that is less than the first Average Surface Roughness Value.

5. The golf club head of claim **4**, wherein the Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) is less than about 0.38 at the Reynolds Number of about 384,000.

6. The golf club head of claim **5**, wherein the Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) is less than about 0.36 the Reynolds Number of about 384,000.

7. A golf club head comprising:

a club face located at a frontal portion of the golf club head, the golf club head further comprising:

an external surface, having an external surface roughness formed by a plurality of micro-grooves, and

wherein the external surface further comprises:

a central region occupying a central portion of the club face, measured in a horizontal direction, and being comprised of a central region bottom portion adjacent a sole portion of the golf club head and a central region top portion adjacent a crown portion of the golf club head,

a toe region occupying a region toeward of the central region, and

a heel region occupying a region heelward of the central region, and

wherein when a plurality of imaginary vertical sampling lines are defined within a first area measuring about 20 mm×20 mm located in the central region bottom portion and a second area measuring about 20 mm×20 mm located in the central region top portion, wherein the central region bottom portion has a first Average Coefficient of Friction Value of greater than about 0.30 and the central region top portion has a second Average Coefficient of Friction Value of less than about 0.20, and

wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and

wherein said golf club head has a loft of less than about 10 degrees.

8. The golf club head of claim **7**, wherein first Average Coefficient of Friction Value is between about 0.30 and 0.40 and the second Average Coefficient of Friction Value is between about 0.10 and 0.20.

9. The golf club head of claim **7**, wherein the central region bottom portion comprises first micro-grooves having a first average groove depth of about 45 μm and 60 μm and the central region top portion comprises second micro-grooves having a second average groove depth of about 5 μm and 40 μm.

10. The golf club head of claim **7**, wherein the Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) is less than about 0.38 at the Reynolds Number of about 384,000.

11. The golf club head of claim **10**, wherein the Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) is less than about 0.36 the Reynolds Number of about 384,000.

12. A synergistic golf club and golf ball comprising:

a golf club head further comprising:

a club face located at a frontal portion of the golf club head, the club head further comprising;

an external surface, having an external surface roughness formed by a plurality of micro-grooves, and

wherein the external surface further comprises:

a central region occupying a central third of the club face, measured horizontally, and being comprised of a central region bottom portion adjacent a sole portion of the golf club head and a central region top portion adjacent a crown portion of the golf club head,

a toe region occupying a region toeward of the central region, and

a heel region occupying a region heelward of the central region,

wherein the central region bottom portion has a first Average Vertical Surface Roughness Value of greater than about 120 μin and the central region top portion has a second Average Vertical Surface Roughness Value of less than about 100 μin,

wherein the golf club head has a Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) of less than 0.40 at a Reynolds number of about 384,000, and

wherein said golf club head has a loft of less than about 10 degrees;

a golf ball comprising at least a core and a cover,

the golf ball having a weight of 1.600 ounces-1.620 ounces,

the golf ball having a diameter of 1.680 inches-1.700 inches,

the golf ball having a series of Coefficients of Drag (C_D) and a series of Coefficients of Lift (C_L) over a range of Reynolds numbers and spin ratios,

the cover comprising a plurality of dimples arranged in a dimple pattern having the following aerodynamic characteristics:

$0.230 \le C_D \le 0.250$ at a Reynolds number of 220,000 and a spin ratio of 0.070, and $0.230 \le C_D \le 0.250$ at a Reynolds number of 160,000 and a spin ratio of 0.095, and $0.230 \le C_D \le 0.250$ at a Reynolds number of 120,000 and a spin ratio of 0.100.

13. The synergistic golf club and golf ball of claim **12**, wherein the drag coefficient and the lift coefficient of the golf ball have the following relationship at a Reynolds number of 225,000 and a spin ratio of $0.070{:}1.400 \le C_D/C_L \le 1.800$.

14. The synergistic golf club and golf ball of claim **13**, wherein the dimple pattern has an integrated drag area (DA) defined by:

$$DA = \int_{160{,}000}^{225{,}000} C_D(Re)dRe$$

where $C_D(Re)$ is established at a setup condition including a golf ball speed of 182.0 mph, a launch angle of 10.0 degrees, and a spin rate of 2,700 rpm, and

wherein $14{,}500 \le DA \le 15{,}500$.

15. The synergistic golf club and golf ball of claim **12**, wherein the second Average Vertical Surface Roughness Value of less than about 80 μin.

16. The synergistic golf club and ball of claim **15**, wherein second Average Vertical Surface Roughness Value is between about 45 μin to 60 μin.

17. The synergistic golf club and ball of claim **16**, wherein the Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) is less than about 0.38 at the Reynolds Number of about 384,000.

18. The synergistic golf club and ball of claim **17**, wherein the Clubhead Coefficient of Drag ($C_{D\text{-}Clubhead}$) is less than about 0.36 the Reynolds Number of about 384,000.

19. The synergistic golf club and ball of claim **18**, wherein the golf club head has a CG-NA of between about −2.0 mm to about +2.0 mm.

20. The synergistic golf club and ball of claim **19**, wherein the golf club head has a CG-Z of less than about 30 mm.

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