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GOLF CLUB HEADS AND METHODS TO MANUFACTURE GOLF CLUB HEADS

Abstract

Embodiments of golf club heads and methods to manufacture golf club heads are generally described herein. In one example, a golf club head may include a body portion having a front portion, a rear portion, a toe portion, a heel portion, a top portion, a bottom portion, a face portion, and a periphery. The bottom portion may include a forward portion and a rear protrusion at or proximate the rear portion. A recessed portion is positioned between the forward portion and the rear protrusion and includes a plurality of contoured transition regions defining an opening. A shoulder portion is adjoined to the plurality of contoured transition regions. One or more connecting members extend across the opening to adjoin opposing portions of the shoulder portion. Other examples and embodiments may be described and claimed.

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Background/Summary

CROSS REFERENCE [0001] This application is a continuation of application Ser. No. 17/951,399, filed Sep. 23, 2022, which is a continuation of application Ser. No. 17/685,566, filed Mar. 3, 2022, now U.S. Pat. No. 11,484,756, which claims the benefit of U.S. Provisional Application No. 63/166,859, filed Apr. 26, 2021 [0002] U.S. application Ser. No. 17/951,399, filed Sep. 23, 2022, is a continuation-in-part of application Ser. No. 17/389,659, filed Jul. 30, 2021, now U.S. Pat. No. 11,654,337, which is a continuation of application Ser. No. 16/889,524, filed Jun. 1, 2020, now U.S. Pat. No. 11,103,755, which is a continuation of application Ser. No. 16/419,639, filed May 22, 2019, now U.S. Pat. No. 10,695,624. [0003] U.S. application Ser. No. 17/951,399, filed Sep. 23, 2022, is a continuation-in-part of application Ser. No. 17/400,516, filed Aug. 12, 2021, now U.S. Pat. No. 11,779,819, which is a continuation of application Ser. No. 16/930,716, filed Jul. 16, 2020, now U.S. Pat. No. 11,110,328, which is a continuation of application Ser. No. 16/422,661, filed May 24, 2019, now U.S. Pat. No. 10,722,765, which claims the benefit of U.S. Provisional Application No. 62/850,292, filed May 20, 2019. [0004] U.S. application Ser. No. 17/951,399, filed Sep. 23, 2022, is a continuation-in-part of application Ser. No. 17/198,906, filed Mar. 11, 2021, now U.S. Pat. No. 11,684,831, which is a continuation of application Ser. No. 16/813,453, filed Mar. 9, 2020, now U.S. Pat. No. 10,967,231. [0005] U.S. application Ser. No. 17/951,399, filed Sep. 23, 2022, is a continuation-in-part of application Ser. No. 17/198,770, filed Mar. 11, 2021, now U.S. Pat. No. 11,707,651, which is a continuation of application Ser. No. 16/807,591, filed Mar. 3, 2020, now U.S. Pat. No. 10,960,274, which claims the benefit of U.S. Provisional Application No. 62/837,592, filed Apr. 23, 2019, U.S. Provisional Application No. 62/873,773, filed Jul. 12, 2019, U.S. Provisional Application No. 62/897,015, filed Sep. 6, 2019, and U.S. Provisional Application No. 62/957,757, filed Jan. 6, 2020. [0006] U.S. application Ser. No. 17/951,399, filed Sep. 23, 2022, is a continuation-in-part of application Ser. No. 17/586,971, filed Jan. 28, 2022, now U.S. Pat. No. 12,064,670, which is a continuation of Application Ser. No. 17/149,954, filed Jan. 15, 2021, now U.S. Pat. No. 11,266,888, which claims the benefit of U.S. Provisional Application No. 62/963,430, filed Jan. 20, 2020. [0007] U.S. application Ser. No. 17/951,399, filed Sep. 23, 2022, is a continuation-in-part of application Ser. No. 17/407,025, filed Aug. 19, 2021, now U.S. Pat. No. 11,806,585, which is a continuation of application Ser. No. 17/225,414, filed Apr. 8, 2021, now U.S. Pat. No. 11,117,028, which claims the benefit of U.S. Provisional Application No. 63/057,252, filed Jul. 27, 2020, and claims the benefit of U.S. Provisional Application No. 63/010,036, filed Apr. 14, 2020. [0008] U.S. application Ser. No. 17/951,399, filed Sep. 23, 2022, is a continuation-in-part of application Ser. No. 17/528,436, filed Nov. 17, 2021, now abandoned, which claims the benefit of U.S. Provisional Application No. 63/117,182, filed Nov. 23, 2020. [0009] The disclosures of the above listed applications are incorporated by reference herein in their entirety.

FIELD
[0011] The present disclosure generally relates to sports equipment, and more particularly, to golf club heads and methods to manufacture golf club heads.

BACKGROUND
[0012] In golf, various factors may affect the distance and direction that a golf ball may travel. In particular, the center of gravity (CG) and/or the moment of inertia (MOI) of a golf club head may

affect the launch angle, the spin rate, and the direction of the golf ball at impact. Such factors may vary significantly based the type of golf swing.

Description

BRIEF DESCRIPTION OF THE DRA WINGS

[0013] FIG. **1** is top perspective view of an example golf club head according to an embodiment of the apparatus, methods, and articles of manufacture described herein.

[0014] FIG. **2** is a bottom perspective view of the golf club head of FIG. **1**.

[0015] FIG. **3** is a front view of the golf club head of FIG. **1**.

[0016] FIG. **4** is a rear view of the golf club head of FIG. **1**.

[0017] FIG. **5** is a top view of the golf club head of FIG. **1**.

[0018] FIG. **6** is a bottom view of the golf club head of FIG. **1**.

[0019] FIG. **7** is a heel side view of the golf club head of FIG. **1**.

[0020] FIG. **8** is a toe side view of the golf club head of FIG. **1**.

[0021] FIG. **9** is a cross-sectional view of the golf club head of FIG. **1** taken along section **9-9** of FIG. **5**.

[0022] FIG. **10** is a cross-sectional view of the golf club head of FIG. **1** taken along section **10-10** of FIG. **8**.

[0023] FIG. **11** is an exploded toe side view of the golf club head of FIG. **1**.

[0024] FIG. **12** is an exploded rear view of the golf club head of FIG. **1**.

[0025] FIG. **13** is an exploded rear perspective view of the golf club head of FIG. **1**.

[0026] FIG. **14** is a top view of an example golf club head according to an embodiment of the apparatus, methods, and articles of manufacture described herein.

[0027] FIG. **15** is a bottom view of the golf club head of FIG. **14**.

[0028] FIG. **16** is a heel side view of the golf club head of FIG. **14**.

[0029] FIG. **17** is a toc side view of the golf club head of FIG. **14**.

[0030] FIG. **18** is an exploded bottom heel side perspective view of the golf club head of FIG. **14**.

[0031] FIG. **19** is an exploded bottom toc side perspective view of the golf club head of FIG. **14**.

[0032] FIG. **20** is a bottom view of the golf club head of FIG. **14** with a sole insert portion removed to illustrate another example of a bottom portion of the golf club head.

[0033] FIG. **21** is a bottom view of the golf club head of FIG. **14** with the sole insert portion removed to illustrate yet another example of the bottom portion of the golf club head.

[0034] For simplicity and clarity of illustration, the drawing figures illustrate the general manner of construction, and descriptions and details of well-known features and techniques may be omitted to avoid unnecessarily obscuring the present disclosure. Additionally, elements in the drawing figures are not necessarily drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help improve understanding of embodiments of the present disclosure.

DESCRIPTION

[0035] The following U.S. Patents and Patent Publications, which are collectively referred to herein as “the incorporated by reference applications.” are incorporated by reference herein in their entirety: U.S. Pat. Nos. 9,199,140, 9,352,197, 9,399,158, 9,550,096, 9,555,295, 91430070, 9,636,554, 9,662,547, 96149270, 9,782,643, 9,795,842, 9,795,843, 9,802,087, 9,814,945, 9,821,200, 9,821,201, 9,833,667, 9,861,867, 9,895,582, 9,895,583, 9,914,029, 9,981,160, 9,987,526, 9,999,814, 10,010,770, 10,052,532, 10,099,093, 10,143,899, 10,195,101, 10,213,659, 10,232,234, 10,252,123, 10,293,220, 10,293,221, 103351445, 1031514754, 10,384,102, 10,413,787, 10,420,989, 10,420,990, 10,441,855, 10,532,257, 10,543,407, 10,583,336, 10,617,917, 10,617,918, 10,653,928, 10,695,623, 10,695,624, 10,709,942, 101522764, 101522765, 107861512,

10,821,334, 10,843,051, 10,898,766, 10,898,768, 10,926,142, 10,960,274, 10,960,275, 109615231, 10,981,037, 110001542, 11,103,755, 11,110,328, 111115028, and 111153356; and U.S. Patent Publication Numbers 20200206589, 20210121747, 20210128996, 20210138320, 202101915039, 202101915040, 20210205673, 20210228949, 20210354009, 202103150145, 20210379453, and 20220040542.

[0036] In general, golf club heads and methods to manufacture golf club heads are described herein. The apparatus, methods, and articles of manufacture described herein are not limited in this regard. In the example of FIGS. **1-13**, a golf club head **100** may include a body portion **110** with a top portion **130**, a crown portion **135**, a bottom portion **140**, a toc portion **150**, a heel portion **160**, a front portion **170**, and a rear portion **180**. The bottom portion **140** may include a skirt portion **190** defined as a side portion of the golf club head **100** between the top portion **130** and the bottom portion **140** excluding the front portion **170** and extending across a periphery of the golf club head **100** from the toe portion **150**, around the rear portion **180**, and to the heel portion **160**. Alternatively, the golf club head **100** may not include the skirt portion **190**. The front portion **170** may include a face portion **275** to engage a golf ball. The face portion **275** may be integral to the body portion **110** or may be a separate face portion that is coupled (e.g., welded) to the front portion **170** to enclose an opening in the front portion **170**. The body portion **110** may also include a hosel portion configured to receive a shaft portion (not shown). The hosel portion may be similar in many respects to any of the hosel portions described herein. The hosel portion may include an interchangeable hosel sleeve **126** and a fastener **127**. Alternatively, the body portion **110** may include a bore instead of the hosel portion. The body portion **110** may be made partially or entirely of an aluminum-based material, a magnesium-type material, a steel-based material, a titanium-based material, any combination thereof, or any other suitable material. In another example the body portion **110** may be made partially or entirely of a non-metal material such as a ceramic material, a composite material, any combination thereof, or any other suitable material. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0037] The golf club head **100** may have a club head volume greater than or equal to 300 cubic centimeters (cm.sup.3 or cc). In one example, the golf club head **100** may be about 460 cc. Alternatively, the golf club head **100** may have a club head volume less than or equal to 300 cc. In particular, the golf club head **100** may have a club head volume between 100 cc and 200 cc. The club head volume of the golf club head **100** may be determined by using the weighted water displacement method (i.e., Archimedes Principle). For example, procedures defined by golf standard organizations and/or governing bodies such as the United States Golf Association (USGA) and/or the Royal and Ancient Golf Club of St. Andrews (R&A) may be used for measuring the club head volume of the golf club head **100**. Although FIG. **1** may depict a particular type of club head (e.g., a driver-type club head), the apparatus, methods, and articles of manufacture described herein may be applicable to other types of club head (e.g., a fairway wood-type club head, a hybrid-type club head, an iron-type club head, a putter-type club head, etc.). The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0038] The top portion **130** may include a forward portion **131** extending a distance **134** between the front portion **170** and the crown portion **135**, as shown in FIG. **8**. In one example, the forward portion **131** may extend a distance **134** of at least 8 mm in a front-to-rear direction, resulting in the crown portion **135** being positioned at least 8 mm rearward of the face portion **275**. In another example, the forward portion **131** may extend a distance **134** of at least 12 mm in a front-to-rear direction. In another example, the forward portion **131** may extend a distance **134** of at least 16 mm in a front-to-rear direction. In yet another example, the forward portion **131** may extend a distance **134** of at least 20 mm in a front-to-rear direction. In still another example, the forward portion **131** may extend a distance **134** of between and including 12 mm and 20 mm in a front-to-rear direction. While the above examples may describe particular distances, the apparatus, methods, and articles of manufacture described herein may include a forward portion extending a distance less than 12

mm in a front-to-rear direction. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0039] The forward portion **131** may enhance structural integrity of the golf club head **100** and resist rearward deflection of the front portion **170** during impact with a golf ball. The forward portion **131** may transfer an impact force to the crown portion **135** during an impact with a golf ball. The forward portion **131** may distribute an impact force along a surface of the crown portion that abuts a junction **132** formed between the crown portion **135** and the forward portion **131** of the top portion **130**. The forward portion **131** may be an integral portion of the body portion **110**. In examples where the body portion **110** is formed through a metal (e.g. titanium) casting process, the forward portion **131** may be formed as an integral portion of the body portion during the casting process. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0040] The crown portion **135** may be a separate piece that may be attached to the top portion **130**. The crown portion **135** may enclose an opening **1201** in the top portion **130**. The crown portion **135** may include a heel-side perimeter **1131**, a front perimeter **1132**, a rear perimeter **1151**, and a toe-side perimeter **1133**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0041] As illustrated in FIGS. **12** and **13**, for example, the top portion **130** of the golf club head **100** may include an opening **1201** prior to installation of the crown portion **135**. The crown portion **135** may be constructed from one or more materials, and those materials may be the same or different from the material of the body portion **110**. In one example, the crown portion **135** may be at least partially constructed from a composite material such as a fiber-based composite material. The crown portion **135** may be attached to a shoulder portion **1204** of the top portion **130**. The shoulder portion **1204** may extend along an entire perimeter of the opening **1201** in the top portion **130** or a portion of the opening in the top portion **130**. The shoulder portion **1204** may support the crown portion **135**. The shoulder portion **1204** may provide a surface suitable for joining (e.g. adhering) the crown portion **135** to the top portion. In one example, the shoulder portion **1204** may extend a distance **1233** of at least 2 mm inward toward the opening **1201** in the top portion **130**. In another example, the shoulder portion **1204** may extend a distance **1233** of at least 6 mm. In yet another example, the shoulder portion **1204** may extend a distance **1233** of at least 8 mm. In still another example, the shoulder portion **1204** may extend a distance **1233** of between and including 2 mm and 8 mm. While the above examples may describe particular distances, the apparatus, methods, and articles of manufacture described herein may include a shoulder portion **1204** that extends a distance **1233** less than 2 mm inward toward the opening in the top portion **130**. The shoulder portion **1204** may be a continuous portion encircling the opening **1201** in the top portion **130**. Alternately, the shoulder portion **1204** may include one or more discrete shoulder portions arranged to support the crown portion **135**. In another example, the shoulder portion **1204** may include a plurality of tabs arranged to support the crown portion **135**. In still another example, the shoulder portion **1204** may be omitted, and the crown portion **135** may be adhered to an outer surface of the top portion **130** or to an inner surface of the top portion **130**. In yet another example, the shoulder portion **1204** may be omitted, and the crown portion **135** may include a protrusion extending from a bottom surface of the crown portion **135** that provides an interference fit with a perimeter edge of the opening **1201** in the top portion **130**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0042] In one example, the crown portion **135** may have a thickness of less than 1.0 mm. In another example, the crown portion **135** may have a thickness of less than 0.75 mm. In yet another example, the crown portion **135** may have a thickness of less than or equal to 0.65 mm. The crown portion **135** may be made of a composite material. While the above examples may describe particular thicknesses, the apparatus, methods, and articles of manufacture described herein may have a thickness greater than or equal to 1.0 mm. The apparatus, methods, and articles of

manufacture described herein are not limited in this regard.
[0043] In one example, the crown portion **135** may form at least 45% of an exterior surface area of the top portion **130**. In another example, the crown portion **135** may form at least 55% of an exterior surface area of the top portion **130**. In yet another example, the crown portion **135** may form at least 65% of an exterior surface area of the top portion **130**. While the above examples may describe particular percentages, the crown portion **135** may form less than 45% of the exterior surface area of the top portion **130**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0044] A top stiffening portion **136** may enhance stiffness of the top portion **130**. The top stiffening portion **136** may compensate for the presence of one or more relatively less stiff, thin, or lightweight regions elsewhere in the top portion **130** or crown portion **135**. The top stiffening portion **136** may enhance overall stiffness of the golf club head **100**. The top stiffening portion **136** may limit rearward deflection of the face portion **275** and/or forward portion **131** toward the rear portion **180** in response to the face portion **275** impacting a golf ball. The top stiffening portion **136** may resist physical compression of the crown portion **135** in a front-to-rear direction in response to the face portion **275** impacting a golf ball, which may reduce risk of cracking or delaminating of the crown portion **135** in examples where the crown portion **135** is constructed of two or more layers of composite material. The top stiffening portion **136** may be a raised portion of the top portion **130**. The top stiffening portion **136** may be part of a contoured portion of the top portion **130**. The top stiffening portion **136** may serve as a visual alignment aid for a golfer aligning a golf shot. The top stiffening portion **136** may improve acoustic response of the golf club head **100** in response to the face portion **275** impacting a golf ball. The top stiffening portion **136** may have a thickness greater than another region of the top portion **130** or the crown portion **135**. The top stiffening portion **136** may have a thickness greater than an average thickness of the crown portion **135**. The top stiffening portion **136** may be integral to the top portion **130**. The top stiffening portion **136** may be one or more separate portions adhered or joined to the top portion **130** to provide structural reinforcement. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0045] As mentioned above. the top portion **130** may include one or more top stiffening portions. In one example, the top stiffening portion **136** may include a first top stiffening portion **137**, a second top stiffening portion **138**, and a third top stiffening portion **139**, as shown in FIG. **1**. The first top stiffening portion **137** may be located adjacent to the forward portion **131** of the top portion **130**. The first top stiffening portion **137** may have a thickness greater than an average thickness of the crown portion **135**. In one example, the first top stiffening portion **137** may have a thickness of greater than 2 mm. In another example, the first top stiffening portion **137** may have a thickness of greater than or equal to 2.1 mm. In another example, the first top stiffening portion **137** may have a thickness of greater than or equal to 2.2 mm. In still another example, the first top stiffening portion **137** may have a thickness of greater than or equal to 2.4 mm. While the above examples may describe particular thickness, the apparatus, methods, and articles of manufacture described herein may include the first top stiffening portion **137** with a thickness of less than or equal to 2 mm. In one example, the first top stiffening portion **137** may have a length of at least 1.25 cm in a heel-to-toe direction. In another example, the first top stiffening portion **137** may have a length of at least 2 cm in a heel-to-toe direction. In yet another example, the first top stiffening portion **137** may have a length of at least 3 cm in a heel-to-toe direction. In still yet another example, the first top stiffening portion **137** may have a length of at least 4 cm in a heel-to-toe direction. In another example, the first top stiffening portion **137** may have a length of between and including 4 and 4.5 cm in a heel-to-toc direction. While the above examples may describe particular lengths, the apparatus, methods, and articles of manufacture describe herein may include the first top stiffening portion **137** having a length of less than 3 cm. The first top stiffening portion **137** may reduce aerodynamic drag of the golf club head **100**. The apparatus, methods, and articles of manufacture described herein are not

limited in this regard.
[0046] The second top stiffening portion **138** may extend from the first top stiffening portion **137** toward the rear portion **180**. The second top stiffening portion **138** may extend from the first top stiffening portion **137** toward the rear portion **180** and toward the toe portion **150**. The second top stiffening portion **138** may extend from a toc-side end of the first top stiffening portion **137** to a rear perimeter of the crown portion **135**. The second top stiffening portion **138** may extend from the first top stiffening portion **137** toward a weight port region on the bottom portion **140**. The second top stiffening portion **138** may extend from the first top stiffening portion **137** toward a weight port region on the bottom portion **140**, where the weight port region is closer to the toe portion **150** than other weight port regions on the bottom portion. The second top stiffening portion **138** may taper in width in a front-to-rear direction. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0047] The second top stiffening portion **138** may serve as a support structure between the forward portion **131** and the rear portion **180**. The second top stiffening portion **138** may oppose rearward deflection of the forward portion **131** in response to the face portion **275** impacting a golf ball. The second top stiffening portion **138** may have a thickness greater than an average thickness of the crown portion **135**. The second top stiffening portion **138** may have a thickness of greater than 2 mm. The second top stiffening portion **138** may have a thickness of greater than or equal to 2.1 mm. The second top stiffening portion **138** may have a thickness of greater than or equal to 2.2 mm. While the above examples may describe particular thicknesses, the apparatus, methods, and articles of manufacture described herein may include the second top stiffening portion **138** with a thickness of less than or equal to 2 mm. In one example, the second top stiffening portion **138** may have a length of at least 2 cm. In another example, the second top stiffening portion **138** may have a length of at least 4 cm. While the above examples may describe particular lengths, the apparatus, methods, and articles of manufacture describe herein may include a second top stiffening portion **138** having a length less than 2 cm. The second top stiffening portion **138** may reduce aerodynamic drag of the golf club head. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0048] The third top stiffening portion **139** may extend from the first top stiffening portion **137** toward the rear portion **180**. The third top stiffening portion **139** may extend from the first top stiffening portion **137** toward the rear portion **180** and toward the heel portion **160**. The third top stiffening portion **139** may extend from a heel-side end of the first top stiffening portion **137** to a rear perimeter of the crown portion **135**. The third top stiffening portion **139** may extend from the first top stiffening portion **137** toward a weight port region on the bottom portion **140**. The third top stiffening portion **139** may extend from the first top stiffening portion **137** toward a weight port region on the bottom portion **140**, where the weight port region is closer to the heel portion **160** than other weight port regions on the bottom portion. The third top stiffening portion **139** may taper in width in a front-to-rear direction. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0049] The third top stiffening portion **139** may serve as a support structure between the forward portion **131** and the rear portion **180**. The third top stiffening portion **139** may oppose rearward deflection of the forward portion **131** in response to the face portion **275** impacting a golf ball. The third top stiffening portion **139** may have a thickness greater than an average thickness of the crown portion **135**. The third top stiffening portion **139** may have a thickness of greater than 2 mm. The third top stiffening portion **139** may have a thickness of greater than or equal to 2.1 mm. The third top stiffening portion **139** may have a thickness of greater than or equal to 2.2 mm. While the above examples may describe particular thicknesses, the apparatus, methods, and articles of manufacture described herein may include the third top stiffening portion **139** with a thickness of less than or equal to 2 mm. The third top stiffening portion **139** may have a length of at least 2 cm. The third top stiffening portion **139** may have a length of at least 4 cm. The third top stiffening

portion **139** may reduce aerodynamic drag of the golf club head. While the above example may describe a particular number of top stiffening portions, the apparatus, methods, and articles of manufacture described herein may include more or fewer top stiffening portions. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0050] The top portion **130** may include a central top portion **101**, a toe-side top portion **102**, and a heel-side top portion **103**. The central top portion **101** may be a raised central top portion **101**. The raised central top portion **101** may be located between the heel-side top portion **103** and the toe-side top portion **102**. The raised central top portion **101** may have a maximum height greater than a maximum height of the toe-side top portion **102**, as shown in FIG. **8**. The raised central top portion **101** may have a maximum height greater than a maximum height of the heel-side top portion **103**, as shown in FIG. **7**. The raised central top portion **101** may serve as a visual alignment aid. The raised central top portion **101** may improve aerodynamic performance of the golf club head **100**. The raised central top portion **101** may stiffen the top portion **130** and reduce deflection (e.g. bulging) of the top portion **130** in response to the face portion **275** impacting a golf ball. Reducing bulging of the top portion **130** may be desirable to reduce shear stress on a joint (e.g. an adhesive bond) between the crown portion **135** and the shoulder portion **1204** of the opening **1201** in the top portion **130**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0051] The central top portion **101** may include a thin portion. The toe-side top portion **102** may include a thin portion. The heel-side top portion **103** may include a thin portion. Thin portions may be desirable to reduce overall mass of the top portion **130**, which may lower the CG of the golf club head **100**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0052] The top portion **130** may include a plurality of contoured surfaces. The plurality of contoured surfaces may generate turbulent flow across the top portion **130** of the golf club head **100** during a golf swing. The plurality of contoured surfaces may reduce aerodynamic drag of the golf club head **100**. The plurality of contoured surfaces may enhance rigidity of the golf club head **100**. The plurality of contoured surfaces may enhance structural integrity of the golf club head **100**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard

[0053] An outer surface **515** of the central top portion **101** may be elevated above an outer surface **516** of the toe-side top portion **102**. The outer surface **515** area of the central top portion **101** may be elevated above an outer surface **517** of the heel-side top portion **103**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard. The apparatus, methods, and articles of manufacture described herein are not limited in this regard

[0054] The top portion **130** may include a first contoured transition region **501** located between the central top portion **101** and the toe-side top portion **102**. The crown portion **135** may include a second contoured transition region **502** located between the central top portion **101** and the heel-side top portion **103**. The location of the first contoured transition region **501** may coincide with the location of the second top stiffening portion **138**. The location of the second contoured transition region **502** may coincide with the location of the third top stiffening portion **139**. Together, the central top portion **101**, toe-side top portion **102**, heel-side top portion **103**, first contoured transition region **501**, and second contoured transition region **502** may form a multi-level top portion **130**. Together, the central top portion **101**, toe-side top portion **102**, heel-side top portion **103**, first contoured transition region **501**, and second contoured transition region **502** may form a multi-thickness top portion **130**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0055] FIG. **9** depicts a cross-sectional toc side view of the example golf club head of FIG. **1** taken at section line **9-9** of FIG. **5**. The outer surface **515** of the central top portion **101** may be elevated above an outer surface **517** of the heel-side top portion **103**. In one example, the outer surface **515** of the central top portion **101** may be elevated above an outer surface **517** of the heel-side top

portion **103** by a height of greater than or equal to 0.5 mm. In another example, the outer surface **515** of the central top portion **101** may be elevated above an outer surface **517** of the heel-side top portion **103** by a height of greater than or equal to 1.0 mm. In yet another example, the outer surface **515** of the central top portion **101** may be elevated above an outer surface **517** of the heel-side top portion **103** by a height of greater than or equal to 2.0 mm. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0056] The outer surface **515** of the central top portion **101** may be elevated above an outer surface **516** of the toe-side top portion **102**. In one example, the outer surface **515** of the central top portion **101** may be elevated above an outer surface **516** of the toe-side top portion **102** by a height of greater than or equal to 0.5 mm. In another example, the outer surface **515** of the central top portion **101** may be elevated above an outer surface **516** of the toe-side top portion **102** by a height of greater than or equal to 1.0 mm. In yet another example, the outer surface **515** of the central top portion **101** may be elevated above an outer surface **516** of the toe-side top portion **102** by a height of greater than or equal to 2.0 mm. While the above examples may describe particular heights, the apparatus, methods, and articles of manufacture described herein may include outer surfaces with a difference in height of less than 0.5 mm. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0057] As shown in FIG. **7**, the outer surface **517** of the heel-side top portion **103** may be recessed below the forward portion **131** proximate to the junction **132**. Likewise, as shown in FIG. **8**, the outer surface **516** of the toe-side top portion **102** may be recessed below the forward portion **131** proximate the junction **132**. In one example, the outer surface **517** of the heel-side top portion **103** may be recessed below the forward portion **131** proximate to the junction **132** by a distance of greater than or equal to 0.5 mm. In another example, the outer surface **517** of the heel-side top portion **103** may be recessed below the forward portion **131** proximate to the junction **132** by a distance of greater than or equal to 1.0 mm. In yet another example, the outer surface **516** of the toe-side top portion **102** may be recessed below the forward portion **131** proximate the junction **132** by a distance of greater than or equal to 0.5 mm. The outer surface **516** of the toe-side top portion **102** may be recessed below the forward portion **131** proximate the junction **132** by a distance of greater than or equal to 1.0 mm. While the above examples may describe particular distances, the apparatus, methods, and articles of manufacture described herein may include outer surfaces recessed by distances of less than 0.5 mm. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0058] The central top portion **101** may be bounded by the first contoured transition region **501**, the second contoured transition region **502**, a rear perimeter **1151**, and a front perimeter **1132**, as shown in FIGS. **5** and **12**. The central top portion **101** may be bounded by the first contoured transition region **501**, the second contoured transition region **502**, a rear body perimeter **111**, and a front perimeter **1132**, as shown in FIG. **5**. The central top portion **101** may be bounded by the first top stiffening portion **137**, the second top stiffening portion **138**, the third top stiffening portion **139**, and the rear perimeter **1151**, as shown in FIG. **5**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0059] A front region of the central top portion **101** may have a symmetrical shape relative to a central vertical plane **593** that intersects the geometric center (e.g., at or proximate to a “sweet spot” of the golf club head **100**) on the face portion **275** and is normal to a front vertical plane. A front portion of the central top portion **101** may have a nonsymmetrical shape relative to the central vertical plane **593** that intersects the geometric center on the face portion **275** and is normal to the front vertical plane. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0060] In one example, the second top stiffening portion **138** and third top stiffening portion **139** may diverge in a front-to-rear direction, as shown in FIG. **5**. The central top portion **101** may have an irregular polygon-like shape (e.g., a quadrilateral-like shape). The distance between the second

and third top stiffening portions **138** and **139** at or proximate to the front portion **170** may be less than the distance between the second and third top stiffening portions **138** and **139** at or proximate to the rear portion **180**. In another example, the second top stiffening portion **138** and third top stiffening portion **139** may converge in a front-to-rear direction. A distance between the second and third top stiffening portions **138** and **139** at or proximate to the front portion **170** may be greater than a distance between the second and third top stiffening portions **138** and **139** at or proximate to the rear portion **180**. In yet another example, the second top stiffening portion **138** and third top stiffening portion **139** may converge and then diverge in a front-to-rear direction. In another example, the second top stiffening portion **138** and third top stiffening portion **139** may diverge and then converge in a front-to-rear direction. In still another example, the second top stiffening portion **138** and third top stiffening portion **139** may be substantially parallel in a front-to-rear direction. The distance between the second stiffening portion **138** and third top stiffening portion **139** at or proximate to the front portion **170** may be equal or substantially the same as the distance between the second and third top stiffening portions **138** and **139** at or proximate to the rear portion **180**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0061] In one example, as shown in FIG. **1**, the central top portion **101** may be raised relative to the toe-side top portion **102** and the heel-side top portion **103**, resulting in a raised central top portion **101**. Variations in relative heights of the central top portion **101**, toe-side top portion **102**, and heel-side top portion **103** may improve aerodynamic performance by reducing a drag coefficient associated with the golf club head **100**. Variations in relative heights of the central top portion **101**, toe-side top portion **102**, and heel-side top portion **103** may provide a visual alignment aid. Variations in relative heights of the central top portion **101**, toe-side top portion **102**, and heel-side top portion **103**, together with contoured transition regions (**501**, **502**) with integral ribs, may enhance structural integrity of the top portion **130**. In another example, the central top portion **101** may be depressed relative to the toe-side top portion **102** and the heel-side top portion **103**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0062] The total surface area of the top portion **130** may include surface areas of the central top portion **101**, toe-side top portion **102**, heel-side top portion **103**, first contoured transition region **501**, second contoured transition region **502**, and the forward portion **131**. In one example, the surface area of the central top portion **101** may be less than or equal to 40% of the total surface area of the top portion **130**. In another example, the surface area of the central top portion **101** may be at least 10% of the total surface area of the top portion **130**. In another example, the surface area of the central top portion **101** may be at least 20% of the total surface area of the top portion **130**. In yet another example, the surface area of the central top portion **101** may be at least 30% of the total surface area of the top portion **130**. In still yet another example, the surface area of the central top portion **101** may be at least 40% of the total surface area of the top portion **130**. In still yet another example, the surface area of the central top portion **101** may be at least 50% of the surface area of the top portion **130**. In another example, the surface area of the central top portion **101** may be at least 60% of the total surface area of the top portion **130**. In still yet another example, the surface area of the central top portion **101** may be at least 70% of the total surface area of the top portion **130**. In still yet another example, the surface area of the central top portion **101** may be at least 80% of the total surface area of the top portion **130**. In still yet another example, the surface area of the central top portion **101** may be at least 90% of the total surface area of the top portion **130**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0063] The toe-side top portion **102** may be bounded by the first contoured transition region **501**, a toe-side body perimeter **112**, and the forward portion **131**. In one example, the surface area of the toe-side top portion **102** may be at least 5% of the total surface area of the top portion **130**. In another example, the surface area of the toe-side top portion **102** may be at least 10% of the total surface area of the crown portion **135**. In yet another example, the surface area of the toe-side top portion **102** may be at least 15% of the total surface area of the top portion **130**. In still yet another

example, the surface area of the toe-side top portion **102** may be at least 20% of the surface area of the top portion **130**. In still yet another example, the surface area of the toe-side top portion **102** may be at least 25% of the total surface area of the top portion **130**. In still yet another example, the surface area of the toe-side top portion **102** may be at least 30% of the total surface area of the top portion **130**. In still yet another example, the surface area of the toe-side top portion **102** may be at least 35% of the total surface area of the top portion **130**. In still yet another example, the surface area of the toe-side top portion **102** may be at least 40% of the total surface area of the top portion **130**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0064] The heel-side top portion **103** may be bounded by the second contoured transition region **502**, a heel-side body perimeter **113**, and the forward portion **131**. In one example, the surface area of the heel-side top portion **103** may be at least 5% of the total surface area of the top portion **130**. In another example, the surface area of the heel-side top portion **103** may be at least 10% of the total surface area of the top portion **130**. In yet another example, the surface area of the heel-side top portion **103** may be at least 15% of the total surface area of the top portion **130**. In still yet another example, the surface area of the heel-side top portion **103** may be at least 20% of the total surface area of the top portion **130**. In still yet another example, the surface area of the heel-side top portion **103** may be at least 25% of the total surface area of the top portion **130**. In still yet another example, the surface area of the heel-side top portion **103** may be at least 30% of the total surface area of the top portion **130**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0065] In one example, the outer surface **515** area of the central top portion **101** may be greater than or equal to 40% of a total outer surface area of the top portion **130**, the outer surface **516** area of the toe-side top portion **102** may be less than or equal to 30% of the total outer surface area of the top portion **130**, and the outer surface **517** area of the heel-side top portion **103** be less than or equal to 15% of the total outer surface area of the top portion **130**. In another example, the outer surface area **515** of the central top portion **101** may be greater than or equal to 50% of a total outer surface area of the top portion **130**, the outer surface area of the toe-side top portion **102** may be greater than or equal to 15% of the total outer surface area of the top portion **130**, and the outer surface area of the heel-side top portion **103** be greater than or equal to 5% of the total outer surface area of the top portion **130**. In another example, the outer surface area **515** of the central top portion **101** may be greater than or equal to 30% of a total outer surface area of the top portion **130**, the outer surface area of the toe-side top portion **102** may be greater than or equal to 10% of the total outer surface area of the top portion **130**, and the outer surface area of the heel-side top portion **103** be greater than or equal to 5% of the total outer surface area of the top portion **130**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0066] FIG. **5** depicts a top view of the example golf club head **100** of FIG. **1** with a golf ball **550** proximate to the face portion **275**. The golf ball **550** may be in contact with and aligned with a geometric center **276** of the face portion **275**. The golf ball **550** may have a diameter of about 1.68 inches. A central vertical plane **593** bisects the golf ball **550** and the golf club head **100**. A toe-side bounding plane **591** bounds a toe-side of the golf club head **100**. A heel-side bounding plane **595** bounds a heel-side of the golf club head **100**. A toe-side dividing plane **592** divides the toe-side of the golf club head and bounds a toe-side of the golf ball **550**. A heel-side dividing plane **594** divides the heel-side of the golf club head and bounds a heel-side of the golf ball **550**. The top portion **130** may include a perimeter that includes a toe-side perimeter, heel-side perimeter, front perimeter, and rear perimeter. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0067] The top portion **130** of the golf club head **100** may include a plurality of integral ribs. The integral ribs may form the top stiffening portion **136**. The integral ribs (e.g., generally shown as **537**, **538**, and **539**) may provide embedded structural supports within the top portion **130**. Each

integral rib may be located in a top stiffening region adjacent to one or more thin portions. The top portion **130** may have contoured transition regions (e.g., generally shown as **501** and **502**) between the thin portions and the thicker top stiffening portions where the integral ribs reside. Contoured transition regions may prevent or mitigate unwanted stress concentrations within the top portion **130** by avoiding distinct edges between thin portions and adjacent thicker portions (e.g., such as **137**, **138**, or **139**). Stress concentrations may be undesirable as they may result in cracking or delaminating of layers of the top portion **130** during use of the golf club head **100**. For example, in an alternative embodiment having non-integral ribs attached to either an inner or outer surface of the top portion **130**, a distinct edge may exist at a junction formed between a non-integral rib and a surface of the top portion **130**, and that edge may introduce an unwanted stress concentration. After numerous ball strikes, presence of the stress concentration may result in cracking of the top portion **130** proximate to the non-integral rib. This physical deterioration of the top portion **130** may negatively impact performance of the golf club head **100**. For instance, as the top portion **130** physically deteriorates, shot-to-shot variability may increase. Shot-to-shot variability may be unacceptable to an individual who requires consistent performance from the golf club head **100**. Physical deterioration of the top portion **130** may also negatively affect appearance of the golf club head **100**. For the sake of long-term durability, consistency, and appearance, it is therefore desirable to have a top portion **130** with contoured transition regions (**501**, **502**) between the thin portions and the thicker portions containing integral ribs. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0068] The top portion **130** may include a toe-side integral rib **538**. The toe-side integral rib **538** may extend from the front perimeter **1132** of the crown portion **135** to the rear perimeter **1151** of the crown portion. The toe-side integral rib **538** may extend rearward from the forward portion **131**. The toe-side integral rib **538** may extend rearward from a starting location between the central vertical plane **593** and the toe-side dividing plane **592** and terminate at an ending location between the toe-side bounding plane **591** and the toe-side dividing plane **592**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0069] In one example, the toe-side integral rib **538** may have a maximum thickness between and including 1.0 mm and 2.0 mm. In another example, the toe-side integral rib **538** may have a maximum thickness greater than or equal to 1.0 mm. In another example, the toe-side integral rib **538** may have a maximum thickness greater than or equal to 2.0 mm. In another example, the toe-side integral rib **538** may have a maximum thickness greater than or equal to 2.1 mm. In yet another example, the toe-side integral rib **538** may have a maximum thickness greater than or equal to 2.2 mm. In yet another example, the toe-side integral rib **538** may have a maximum thickness greater than or equal to 2.4 mm. While the above examples may describe particular thicknesses, the apparatus, methods, and article of manufacture described herein may include the toe-side integral rib **538** with a maximum thickness of less than 2 mm. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0070] The top portion **130** may include a heel-side integral rib **539**. The heel-side integral rib **539** may extend from a front perimeter **1132** of the crown portion **135** to a rear perimeter **1151** of the crown portion. The heel-side integral rib **539** may extend rearward from the forward portion **131**. The heel-side integral rib **539** may extend rearward from a starting location between the central vertical plane **593** and the heel-side dividing plane **594** and terminate at an ending location between the heel-side bounding plane **595** and the heel-side dividing plane **594**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0071] In one example, the heel-side integral rib **539** may have a maximum thickness between and including 1.0 mm and 2.0 mm. In another example, the heel-side integral rib **539** may have a maximum thickness greater than or equal to 1.0 mm. In another example, the heel-side integral rib **539** may have a maximum thickness greater than or equal to 2.0 mm. In another example, the heel-side integral rib **539** may have a maximum thickness greater than or equal to 2.1 mm. In yet

another example, the heel-side integral rib **539** may have a maximum thickness greater than or equal to 2.4 mm. While the above examples may describe particular thicknesses, the apparatus, methods, and article of manufacture described herein may include the heel-side integral rib **539** with a maximum thickness of less than 2 mm. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0072] The top portion **130** may include a central integral rib **537**. The central integral rib **537** may extend along the front perimeter **1132** of the crown portion **135**. The central integral rib **537** may extend from the toe-side integral rib **538** to the heel-side integral rib **539**. The central integral rib **537** may extend from a forward-most end of the toe-side integral rib **538** to a forward-most end of the heel-side integral rib **539**. The central integral rib **537** may extend a distance of at least 3 centimeters beside the junction **132** formed between the front perimeter **1132** of the crown portion **135** and the forward portion **131** of the top portion **130**. The central integral rib **537** may be located between the toe-side dividing plane **592** and the heel-side dividing plane **594**. The central integral rib **537** and the face portion **275** may have parallel curves. In one example, the central integral rib **537** may have a maximum thickness greater than or equal to 2.0 mm. In another example, the central integral rib **537** may have a maximum thickness greater than or equal to 2.1 mm. In yet another example, the central integral rib **537** may have a maximum thickness greater than or equal to 2.4 mm. While the above examples may describe particular thicknesses, the apparatus, methods, and article of manufacture described herein may include the central integral rib **537** with a maximum thickness of less than 2 mm. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0073] The integral ribs (e.g., generally shown as **537**, **538**, and **539**) may enhance the flexural strength of the top portion **130**. The integral ribs may enhance the compressive strength of the top portion **130**. The integral ribs may reduce outward deflection (e.g., bulging) of the top portion **130** in response to an impact force transferred from the body portion **110** to the crown portion **135** during impact with a golf ball. The integral ribs may reduce deflection of the crown portion **135** inward toward in the interior cavity of the golf club head **100** in response to a downward force applied to an outer surface of the crown portion **135**. Inward deflection of the crown portion **135** may be easier to accurately measure in a test environment than outward deflection. In certain instances, resistance to inward deflection may correlate to resistance to outward deflection. Inward deflection may be measured by applying a downward force to an outer surface of the crown portion and measuring physical deflection of the crown portion with a suitable measuring device. In one example, when a downward force of 200 pound-force (lbf) is applied to the central top portion **101**, the central top portion **101** may deflect less than 0.025 inch. In another example, when a downward force of 200 lbf is applied to the central top portion **101**, the central top portion **101** may deflect less than 0.015 inch. In another example, when a downward force of 200 lbf is applied to the central top portion **101**, the central top portion **101** may deflect less than 0.012 inch. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0074] Certain rules or regulations imposed by the USGA or other governing bodies may limit a spring-like effect of certain designs, materials, or constructions of golf club heads. To ensure a club head **100** conforms to certain rules and regulations, it may therefore be desirable to minimize spring-like effects of certain aspects of the club head. For instance, it may be desirable to minimize a spring-like effect of the top portion **130** by reinforcing the crown portion to minimize deflection during use. The integral ribs may allow the top portion **130** to resist deflection better than a similar lightweight crown portion that lacks integral ribs. In one example, the top portion **130** with integral ribs may only deflect inward about 0.012 inch whereas a crown portion without integral ribs may deflect about 0.020 inch in response to applying a downward force of 200 lbf to the respective crown portions. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0075] As shown in FIG. **5**, the toe-side integral rib **538** and the heel-side integral rib **539** may

diverge in a front-to-rear direction along the top portion **130**. In another example, the toe-side integral rib **538** and heel-side integral rib **539** may converge in a front-to-rear direction along the top portion **130**. In yet another example, a toe-side integral rib **538** and a heel-side integral rib **539** may converge and then diverge in a front-to-rear direction along the top portion **130**. In another example, the toe-side integral rib **538** and heel-side integral rib **539** may be substantially parallel in a front-to-rear direction along the top portion **130**. The toe-side rib **538** may include one or more curved portions along its length. Similarly, the heel-side rib **539** may include one or more curved portions along its length. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0076] An outer surface of the top portion **130** may have an anti-glare finish. An outer surface of the top portion **130** may have a medium or low gloss appearance to reduce the amount of light reflected upward at an individual's eyes when aligning the golf club head **100** with a golf ball and performing a golf shot. A relative gloss value may be determined by projecting a beam of light at a fixed intensity and angle onto the outer surface of the top portion **130** and measuring the amount of light reflected at an equal but opposite angle upward at the individual. On a measurement scale, a specular reflectance of 0 gloss units (GU) may be associated with a perfectly matte surface, and a specular reflectance of 100 GU may be associated with a highly polished black glass material. Providing a top portion **130** with a relatively low specular reflectance may be desirable to reduce distraction perceived by the individual of the golf club head **100**, which may reduce mishits and thereby improve performance. In one example, an outer surface of the top portion **130** may have a specular reflectance of less than 55 GU. In another example, the outer surface of the top portion **130** may have a specular reflectance of less than 40 GU. In yet another example, the outer surface of the top portion **130** may have a specular reflectance of less than 25 GU. In still another example, the outer surface of the top portion **130** may have a specular reflectance of less than 10 GU. While the above examples may describe particular specular reflectance, the apparatus, methods, and article of manufacture may include the outer surface of the top portion **130** with a specular reflectance greater than or equal to 55 GU. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0077] In some examples, the outer surface of the top portion **130** may include an antireflective coating **133**. In one example, the antireflective coating **133** may have a specular reflectance of less than 55 GU. In another example, the antireflective coating **133** may have a specular reflectance of less than 40 GU. In yet another example, the antireflective coating **133** may have a specular reflectance of less than 25 GU. In still another example, the antireflective coating **133** may have a specular reflectance of less than 10 GU. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0078] The golf club head **100** may include a plurality of weigh port regions. Each weight port region may include a weight port. Each weight port may include a weight. As shown in FIG. **6**, a first weight port region **174** may be located closer to the rear portion **180** than the front portion **170**. A second weight port region **175** may be located closer to the toe portion **150** than the heel portion **160**. A third weight port region **176** may be located closer to the heel portion **160** than the toc portion **150**. A fourth weight port region **177** may be located closer to the front portion **170** than the rear portion **180**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0079] The first weight port region **174** may include a first weight port **154** containing a first weight portion **164**. The second weight port region **175** may include a second weight port **155** containing a second weight portion **165**. The third weight port region **176** may include a third weight port **156** containing a third weight portion **166**. The fourth weight port region **177** may include a fourth weight port **157** containing a fourth weight portion **167**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0080] The set of weight portions (e.g., generally shown as weight portions **164**, **165**, **166**, and **167**)

may have similar or different masses. By using weight portions having similar or different masses in each of the weight ports, the overall mass in a weight port region and/or the mass distribution in the weight port regions may be adjusted to generally optimize and/or adjust the swing weight, center of gravity, moment of inertia, and/or an overall feel of the golf club head **100** for an individual using the golf club head **100**. In one example, the set of weight portions may collectively have a mass of at least 8 grams. In another example, the set of weight portions may collectively have a mass of at least 12 grams. In yet another example, the set of weight portions may collectively have a mass of between and including 8 grams and 13 grams. In still yet another example, the set of weight portions may collectively have a mass of between and including 12 grams and 16 grams. In still yet another example, the set of weight portions may collectively have a mass of between and including 15 grams and 19 grams. In still yet another example, the set of weight portions may collectively have a mass of between and including 18 grams and 22 grams. While the above examples may describe particular masses, the apparatus, methods, and articles of manufacture described herein may include the set of weight portions to have an aggregate mass of less than 8 grams or an aggregate mass of greater than 19 grams. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0081] The bottom portion **140** of the golf club head **100** may have in inner surface **142** and an outer surface **145**. The golf club head **100** may include one or more raised portions protruding outward from the outer surface **145**. Each raised portion may include a weight port region. Each weight port region may include a weight port. Each weight port may include a weight portion. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0082] The golf club head **100** may include a central protrusion **147** extending from the outer surface **145** of the bottom portion **140**. The central protrusion **147** may extend from the rear portion **180** toward the front portion **170**, as shown in FIG. **2**. The central vertical plane **593** may pass through the central protrusion **147**. The central vertical plane **593** may bisect the central protrusion **147**. The central protrusion **147** may be located between the toe-side dividing plane **592** and the heel-side dividing plane **594**, as shown in FIG. **6**. The central protrusion **147** may include the first weight port region **174**. The central vertical plane **593** may pass through the first weight port **154** and the first weight portion **164**. The central vertical plane **593** may bisect the first weight port **154** and the first weight portion **164**. The central protrusion **147** may include the fourth weight port region **177**. The central vertical plane **593** may pass through the fourth weight port **157** and the fourth weight portion **167**. The central vertical plane **593** may bisect the fourth weight port **157** and the fourth weight portion **167**. The central protrusion **147** may allow placement of weight portions (e.g. **164**, **167**) a greater distance from a center point of the golf club head **100** to increase perimeter weighting and MOI without increasing club head volume. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0083] The golf club head **100** may include a toe-side protrusion **148** extending from the outer surface **145** of the bottom portion **140**. The toe-side protrusion **148** may be located between the toe-side dividing plane **592** and the toe-side bounding plane **591**. The toe-side protrusion **148** may be located closer to the rear portion **180** than the front portion **170**. The toe-side protrusion **148** may include the second weight port region **175**. The toe-side protrusion **148** may allow placement of the weight portion **165** a greater distance from the center point of the golf club head **100** to increase perimeter weighting and MOI without increasing club head volume. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0084] The golf club head **100** may include a heel-side protrusion **149** extending from the outer surface **145** of the bottom portion **140**. The heel-side protrusion **149** may be located between the heel-side dividing plane **594** and the heel-side bounding plane **595**. The heel-side protrusion **149** may be located closer to the rear portion **180** than the front portion **170**. The heel-side protrusion **149** may include the third weight port region **176**. The heel-side protrusion **149** may allow placement of the weight portion **166** a greater distance from the center point of the golf club head

100 to increase perimeter weighting and MOI without increasing club head volume. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0085] The golf club head **100** may include an insert **1350**. The insert **1350** may be a vibration-dampening insert. The insert **1350** may be a sound-enhancing insert that attenuates certain frequencies. The insert **1350** may include a filler material. As shown in FIG. **9**, the insert **1350** may be located on the inner surface **142** of the bottom portion **140** of the golf club head **100**. The insert **1350** may be adjacent to one or more of the weight port regions. The insert **1350** may surround one or more of the weight ports. The insert **1350** may abut one or more of the weight port regions. The insert **1350** may abut the third weight port region **176**. The insert **1350** may be closer to the heel portion **160** than the toe portion **150**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0086] The insert **1350** may be located between the central vertical plane **593** and the heel-side bounding plane **595**. The insert **1350** may be located between the heel-side dividing plane **594** and the heel-side bounding plane **595**. The insert **1350** may be located between the central protrusion **147** and the heel-side bounding plane **595**. The insert **1350** may be located between the heel-side integral rib **539** and the inner surface **142** of the bottom portion **140**. The insert **1350** may extend from a front side of the third weight port **156** to a rear side of the third weight port, as shown in FIG. **10**. The insert **1350** may surround or partially surround the third weight port **156**. The insert **1350** may include a plurality of hexagonal recesses. The hexagonal recesses may define a honeycomb pattern. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0087] The filler material described herein may be an clastic polymer or elastomer material (e.g., a viscoelastic urethane polymer material such as Sorbothane® material manufactured by Sorbothane, Inc., Kent, Ohio), a thermoplastic elastomer material (TPE), a thermoplastic polyurethane material (TPU), and/or other suitable types of materials to absorb shock, isolate vibration, and/or dampen noise. In another example, the filler material may be a high density ethylene copolymer ionomer, a fatty acid modified ethylene copolymer ionomer, a highly amorphous ethylene copolymer ionomer, an ionomer of ethylene acid acrylate terpolymer, an ethylene copolymer comprising a magnesium ionomer, an injection moldable ethylene copolymer that may be used in conventional injection molding equipment to create various shapes, an ethylene copolymer that can be used in conventional extrusion equipment to create various shapes, and/or an ethylene copolymer having high compression and low resilience similar to thermoset polybutadiene rubbers. For example, the ethylene copolymer may include any of the ethylene copolymers associated with Dupont™ High-Performance Resin (HPF) family of materials (e.g., DuPont™ HPF AD1172, Dupont™ HPF AD1035, DuPont® HPF 1000 and Dupont™ HPF 2000), which are manufactured by E.I. du Pont de Nemours and Company of Wilmington, Delaware. The Dupont™ HPF family of ethylene copolymers are injection moldable and may be used with conventional injection molding equipment and molds, provide low compression, and provide high resilience. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.
[0088] In the example of FIGS. **14-21**, a golf club head **1400** may include a body portion **1410** with a top portion **1430**, a crown portion **1435**, a bottom portion **1440**, a toe portion **1450**, a heel portion **1460**, a front portion **1470**, and a rear portion **1480**. The top portion **1430** and the crown portion **1435** may be similar in many respects to the top portion **130** and the crown portion **135** of FIGS. **1-13**. The body portion **1410** may include a periphery **1490** defined as a side portion of the golf club head **1400** between the top portion **1430** and the bottom portion **1440** and extending around the body portion **1410** from the toe portion **1450**, around the rear portion **1480**, and to the heel portion **1460**. The front portion **1470** may include a face portion **1475** for impacting a golf ball. The face portion **1475** may be integral to the body portion **1410** or may be a separate face portion that is coupled (e.g., welded) to the front portion **1470** to close an opening in the front portion **1470**. The body portion **1410** may also include a hosel portion **1476** configured to receive a shaft portion **1474**

(e.g., FIG. **17**). The hosel portion **1476** may be similar in many respects to any of the hosel portions described herein. The hosel portion **1476** may be attached to the body portion **1410** via a fastener **1479**. Alternatively, the body portion **1410** may include a bore configured to receive a shaft portion **1474** instead of the hosel portion **1476**. The body portion **1410** may be made partially or entirely of an aluminum-based material, a magnesium-type material, a steel-based material, a titanium-based material, any combination thereof, or any other suitable material. In another example the body portion **1410** may be made partially or entirely of a non-metal material such as a ceramic material, a composite material, any combination thereof, or any other suitable material. The configuration of the body portion **1410** and/or the materials of construction of the body portion **1410** may be similar to the body portion and/or the materials of construction of any of the golf club heads described herein or in any of the incorporated by reference applications. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0089] The golf club head **1400** may include a plurality of weight ports at the bottom portion **1440**, which are shown in the illustrated example of FIGS. **14-21** as a first weight port **1501**, a second weight port **1502**, a third weight port **1503**, and a fourth weight port **1504**. In one example, as illustrated in FIGS. **14-21**, the first weight port **1501** may be located at or proximate to the front portion **1470**, the second weight port **1502** may be located at or proximate to the toe portion **1450**, the third weight port **1503** may be located at or proximate to the heel portion **1460**, and the fourth weight port **1504** may be located at or proximate to the rear portion **1480**. In one example, the plurality of weight ports may be threaded cylindrical ports of similar circumference and depth. One or more of the plurality of weight ports (e.g., the first weight port **1501** and the fourth weight port **1504**) may communicate with an interior cavity **1411** of the golf club head **1400** via one or more openings (e.g., openings **1841** and **1842**) through which an adhesive (not shown) may be applied to interior structures of the body portion **1410**. The adhesive may be applied via a hot melt process and may function to improve feel, dampen sound, collect debris, and/or add weight to the golf club head **1400** at certain locations in the interior cavity **1411**. In another example, the interior cavity **1411** may be partially or fully filled with one or more polymer materials via the openings **1841** and **1842**. In yet another example, the interior cavity **1411** may include one or more filler inserts coupled to the interior walls of the body portion **1410**. The configuration of the weight ports and presence, insertion, or injection of any adhesives and/or filler materials in the interior cavity may be similar in many respects to the weight ports, adhesives, and/or filler materials of any of the golf club heads described herein or described in any of the incorporated by reference applications. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0090] In the example of FIGS. **14-21**, the golf club head **1400** may be characterized by a vertical plane system while at an address position. The vertical plane system may include a plurality of parallel vertical planes shown as a longitudinal vertical plane **1510**, a toe-side bounding plane **1511**, a heel-side bounding plane **1512**, a toe-side dividing plane **1513**, and a heel-side dividing plane **1514**. The vertical plane system may also include a lateral vertical plane **1515** perpendicular to each of the plurality of parallel vertical planes. The longitudinal vertical plane **1510** may bisect the golf club head **1400** and may intersect a geometric center (e.g., at or proximate to a “sweet spot” of the golf club head **1400**) on the face portion **1475**. The toe-side bounding plane **1511** may be parallel with the longitudinal vertical plane **1510** and may bound a toe-side of the golf club head **1400** or may be tangent to the outermost extent of the of the toe side of the golf club head **1400**. The heel-side bounding plane **1512** may be parallel with the longitudinal vertical plane **1510** and may bound a heel-side of the golf club head **1400** or may be tangent to the outermost extent of the of the heel side of the golf club head **1400**. The toe-side dividing plane **1513** may be parallel with the longitudinal vertical plane **1510** and may be equidistant from the longitudinal vertical plane **1510** and the toc-side bounding plane **1511**. The heel-side dividing plane **1514** may be parallel with the longitudinal vertical plane **1510** and may be equidistant from the longitudinal vertical plane **1510** and the heel-side bounding plane **1512**. The lateral vertical plane **1515** may be located

halfway between the frontmost and rearmost extents of the body portion **1410**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0091] In one example, the first and fourth weight ports **1501** and **1504** may be bisected by the longitudinal vertical plane **1510** and may be located between the toe-side dividing plane **1513** and the heel-side dividing plane **1514**. The second weight port **1502** may be located between the toe-side bounding plane **1511** and the toc-side dividing plane **1513**. The third weight port **1503** may be located between the heel-side bounding plane **1512** and the heel-side dividing plane **1514**. The first, second, and third weight ports **1501**, **1502**, and **1503** may be located at a forward portion **641** of the bottom portion **1440**. The fourth weight port **1504** may be located at a rear protrusion **1442** located at or proximate the rear portion **1480**. The rear protrusion **1442** may intersect the longitudinal vertical plane **1510** and may be located between the toe-side dividing plane **1513** and the heel-side dividing plane **1514**. The rear protrusion **1442** may project downward from the periphery **1490** and may extend along the longitudinal vertical plane **1510**. In one example, as illustrated in FIGS. **14-21**, the rear protrusion **1442** may be wedge shaped and may extend longitudinally in a rear-to-front direction from the rear portion **1480** toward the front portion **1470**. The rear protrusion **1442** may end short of the lateral vertical plane **1515**. In another example, the rear protrusion **1442** may extend in the rear-to-front direction and end at the lateral vertical plane **1515** or may intersect and extend past the lateral vertical plane **1515**. A width of the rear protrusion **1442** may vary or be uniform in a rear-to-front direction. In one example, as illustrated in FIGS. **14-21**, the rear protrusion **1442** may decrease in width in the rear-to-front direction. In another example, the rear protrusion **1442** may have a uniform width in the rear-to-front direction. In yet another example, the rear protrusion **1442** may have an increase in width in the rear-to-front direction. In one example, as illustrated in FIGS. **14-21**, the rear protrusion **1442** may decrease in height in the rear-to-front direction. In another example, the rear protrusion **1442** may have a uniform height in the rear-to-front direction. In yet another example, the rear protrusion **1442** may have an increase in height in the rear to front direction. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0092] In the example of FIGS. **14-21**, a set of weight portions shown as a first weight portion **1505**, a second weight portion **1506**, a third weight portion **1507**, and a fourth weight portion **1508** may be coupled to the plurality of weight ports. In one example, the first weight portion **1505** may be coupled to the first weight port **1501**, the second weight portion **1506** may be coupled to the second weight port **1502**, the third weight portion **1507** may be coupled to the third weight port **1503**, and the fourth weight portion **1508** may be coupled to the fourth weight port **1504**. The set of weight portions may have similar or different masses to generally optimize and/or adjust the swing weight, center of gravity, moment of inertia, and/or an overall feel of the golf club head **1400** for an individual using the golf club head **1400**. The set of weight portions may individually and/or collectively have a mass similar to any of the weight portion masses described herein with respect to other example golf club heads (e.g., golf club head **100**). In one example, the set of weight portions may be interchangeable and may have similar or different masses. The configuration of the weight portions and the coupling thereof to the weight ports may be similar in many respects to the weight portions and the weight ports of any of the golf club heads described herein or described in any of the incorporated by reference applications. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0093] In the example of FIGS. **14-21**, the bottom portion **1440** of the golf club head **1400** may include a recessed portion **1520** located rearward of the first weight port **1501**, the second weight port **1502** and the third weight port **1503**. With respect to the rear-to-front direction, a greater portion (e.g., greater than 50%) of the recessed portion **1520** may be located rearward of the lateral vertical plane **1515**. With respect to a toe-to-heel direction, a greater portion of the recessed portion **1520** may be located toe-ward of the longitudinal vertical plane **1510**. The recessed portion **1520** may have a perimeter defined by the rear protrusion **1442** and a plurality of contoured transition

regions exemplarily shown as a first contoured transition region **1521**, a second contoured transition region **1522**, a third contoured transition region **1523**, a fourth contoured transition region **1524**, and a fifth contoured transition region **1525**. Any of the plurality of contoured transition regions may be linear, curved, curvilinear, and/or have any other shape. Any of the plurality of contoured transition regions may have single stepped (e.g., a single wall), multiple stepped or gradual transitions. In one example, as illustrated in FIGS. **14-21**, the first contoured transition region **1521** may be located rearward of the first weight port **1501** and may be positioned adjacent or proximate to the first weight port **1501**. The first contoured transition region **1521** may be bisected by the longitudinal vertical plane **1510** and may be located forward of the lateral vertical plane **1515**. The first contoured transition region **1521** may extend linearly in a lateral direction between the toe-side dividing plane **1513** and the heel-side dividing plane **1514** and may be parallel to the lateral vertical plane **1515**. In the illustrated example of FIGS. **14-21**, the second contoured transition region **1522** may extend linearly from the first contoured transition region **1521** in a rearward diagonal direction toward the toe portion **1450**. In the illustrated example of FIGS. **14-21**, the second contoured transition region **1522** may extend from the first contoured transition region **1521** to a location rearward of the second weight port **1502** and adjacent or proximate to the second weight port **1502**. The second contoured transition region **1522** may intersect the lateral vertical plane **1515** and the toe-side dividing plane **1513** and may extend up to the periphery **1490** of the body portion **1410**. The third contoured transition region **1523** may extend linearly from the first contoured transition region **1521** in a rearward diagonal direction toward the heel portion **1460**. In the illustrated example of FIGS. **14-21**, the third contoured transition region **1523** may extend from the first contoured transition region **1521** to a location rearward of the third weight port **1503** and adjacent or proximate to the third weight port **1503**. The third contoured transition region **1523** may intersect the lateral vertical plane **1515** and the heel-side dividing plane **1514** and may extend up to the periphery **1490** of the body portion **1410**. The first and second contoured transition regions **1521** and **1522** may be joined to define a first elbow **1526** and the first and third contoured transition regions **1521** and **1523** may be joined to define a second a second elbow **1527**. In one example, the first and second elbows **1526** and **1527** may point in a forward direction (e.g., toward the face portion **1475**). In such an arrangement, the first contoured transition region **1521** may be set further back, forming a pocket structure, to allow the first weight port **1501** to be positioned further rearward and closer to a center portion **647** of the bottom portion **1440**. In so doing, the first weight portion **1505** may lower the center of gravity (CG) of the golf club head **1400**. In another example, the first and second elbows **1526** and **1527** may point in a rearward direction (e.g., toward the rear portion **1480**). The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0094] In the example of FIGS. **14-21**, the fourth contoured transition region **1524** may extend between the longitudinal vertical plane **1510** and the toe-side bounding plane **1511**. The fourth contoured transition region **1524** may be located rearward of the lateral vertical plane and may intersect the toc-side dividing plane **1513**. In one example, as illustrated in FIGS. **14-21**, the fourth contoured transition region **1524** may extend curvilinearly from the second contoured transition region **1522** in a rearward direction about the periphery **1490** and may adjoin a toe-side portion **1444** of the rear protrusion **1442**. Accordingly, the fourth contoured transition region **1524** may define or partially define a rear-toe portion **1491** of the periphery **1490** of the body portion **1410**. In one example, as illustrated in FIGS. **14-21**, the fifth contoured transition region **1525** may extend between the longitudinal vertical plane **1510** and the heel-side bounding plane **1512**. The fifth contoured transition region **1525** may be located rearward of the lateral vertical plane **1515** and may intersect the heel-side dividing plane **1514**. In one example, the fifth contoured transition region **1525** may extend curvilinearly from the third contoured transition region **1523** in a rearward direction about the periphery **1490** and may adjoin a heel-side portion **1445** of the rear protrusion **1442**. Accordingly, the fifth contoured transition region **1525** may define or partially define a rear-

heel portion **1492** of the periphery **1490** of the body portion **1410**. The heel-side portion **1445** and the toe-side portion **1444** of the rear protrusion **1442** may be joined together by a front-side portion **1446** of the rear protrusion **1442**. In one example, as illustrated in FIGS. **14-21**, the front-side portion **1446** of the rear protrusion **1442** and the first contoured transition region **1521** may be arranged in parallel to face one another and may extend a same distance laterally across the bottom portion **1440**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0095] In the illustrated example of FIGS. **14-21**, the perimeter of the recessed portion **1520** may define an opening **1528** leading into the interior cavity **1411** of the golf club head **1400**. The recessed portion **1520** may further include a shoulder portion **1529** extending inward toward the opening **1528** and adjoined to the perimeter of the recessed portion **1520** or a portion(s) of the recessed portion **1520**. In one example, the shoulder portion **1529** may be adjoined to the first contoured transition region **1521**, the second contoured transition region **1522**, the third contoured transition region **1523**, the fourth contoured transition region **1524**, the fifth contoured transition region **1525**, and the rear protrusion **1442** (e.g., the toe-side portion **1444**, the heel-side portion **1445**, and the front-side portion **1446**). The shoulder portion **1529** may be configured as a ledge structure and may extend a certain distance inward into the opening **1528**. In one example, the shoulder portion **1529** may extend into the opening by a distance of greater than or equal to 2 millimeters (mm) and less than or equal to 4 mm. In another example, the shoulder portion **1529** may extend into the opening by a distance of greater than or equal to 4 mm and less than or equal to 6 mm. In another example, the shoulder portion **1529** may extend into the opening by a distance of greater than or equal to 6 mm and less than or equal to 8 mm. In another example, the shoulder portion **1529** may extend into the opening by a distance of greater than or equal to 2 mm and less than or equal to 5 mm. In yet another example, the shoulder portion **1529** may extend into the opening by a distance of greater than or equal to 3 mm and less than or equal to 9 mm. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0096] As described herein, the shoulder portion **1529** may be a continuous or discontinuous support structure encircling the entire opening **1528** or a portion thereof. In one example, as illustrated in FIGS. **14-19**, opposing portions of the opening **1528** may not be connected by any structures (i.e., the opening may be unobstructed). In another example, as illustrated in FIG. **20**, the shoulder portion **1529** may include one or more connecting members (e.g., shown as connecting members **1531**, **1532**, and **1533**) that extend across the opening **1528** and adjoin opposing portions of the shoulder portions **1529**. In another example, as shown in FIG. **21**, the shoulder portion **1529** may be configured as a plurality of interconnected and intersecting support ribs **1535** or support structures defining a lattice. In another example (not shown), the shoulder portion **1529** may be configured as a mesh. In yet another example (not shown), the shoulder portion **1529** may be configured as discrete support structures such as a plurality of equal and/or variable length tabs that may be arranged around the opening in an equidistant or variable spacing configuration. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0097] In the example of FIGS. **14-21**, the recessed portion **1520** may further include a sole insert portion **1540** coupled (e.g., adhered) to the shoulder portion **1529** to cover the opening **1528**. The sole insert portion **1540** may be asymmetric about the longitudinal vertical plane **1510** and may extend between the toe portion **1450** and the heel portion **1460**. The sole insert portion **1540** may be recessed relative to the forward portion **641** and may include a central intermediate portion **1541** located between the first contoured transition region **1521** and the front-side portion **1446** of the rear protrusion **1442**. The sole insert portion **1540** may also include a first wing portion **1542** connected to the central intermediate portion **1541** and located between the second contoured transition region **1522**, the fourth contoured transition region **1524**, and the toe-side portion **1444** of the rear protrusion **1442**. The first wing portion **1542** may fan out or increase in outer surface area in a rearward direction from the central intermediate portion **1541** toward the rear-toe portion **1491**

of the periphery **1490**. The sole insert portion **1540** may further include a second wing portion **1543** connected to the central intermediate portion **1541** and located between the third contoured transition region **1523**, the fifth contoured transition region **1525**, and the heel-side portion **1445** of the rear protrusion **1442**. The second wing portion **1543** may fan out or increase in outer surface area in a direction from the central intermediate portion **1541** toward the rear-heel portion **1492** of the periphery **1490**. In one example, the first wing portion **1542** may have a larger outer surface area than the second wing portion **1543**, which may in turn have a larger outer surface area than the central intermediate portion **1541**. In another example, the first wing portion **1542** may have a smaller outer surface area than the second wing portion **1542**. In yet another example, the first wing portion **1542** and the second wing portion **1542** may have about the same outer surface area. The first and second wing portions **1542** and **1543** may be configured in a variety of shapes that increase in outer surface toward the toe portion **1450** and the heel portion **1460**, respectively. In one example, as illustrated in FIGS. **14-21**, the sole insert portion **1540** may be a unitary structure. In another example, the sole insert portion **1540** may be defined by two or more separate structures. For example, the central intermediate portion **1541**, the first wing portion **1542**, and the second wing portion **1543** may each be provided as separate pieces. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0098] In the example of FIGS. **14-21**, the sole insert portion **1540** may define greater than 30% and less than 40% of a total outer surface area of the bottom portion **1440**. In another example, the sole insert portion **1540** may define greater than 25% and less than 50% of the total outer surface area of the bottom portion **1440**. In yet another example, the sole insert portion **1540** may define greater than 20% and less than 60% of the total outer surface area of the bottom portion **1440**. The sole insert portion **1540** may have a total outer surface area that is greater than a total outer surface area of the rear protrusion **1442** and a total outer surface area of the forward portion **641** of the bottom portion **1440**. The forward portion **1441** may be defined as the portion(s) of the bottom portion **1440** bounded by the first contoured transition region **1521**, the second contoured transition region **1522**, the third contoured transition region **1523**, the front portion **1470** (e.g., the face portion **1475**), and the top portion **1430**. In one example, the sole insert portion **1540** may have a uniform or variable thickness ranging from 0.250 mm to 1.250 mm. In another example, any portion of the sole insert portion **1540** may have a thickness of greater than or equal to 0.1 mm and less than or equal to 1.0 mm. In yet another example, any portion of the sole insert portion **1540** may have a thickness of greater than or equal to 0.2 mm and less than or equal to 2.0 mm. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0099] The sole insert portion **1540** may be made from a material having a lower density than a density of one or more materials of certain or all portions of the body portion **1410** while providing sufficient stiffness or structural support for the bottom portion **1440**. In one example, all or portions of the body portion **1410** may be constructed from steel and the sole insert portion **1540** may be constructed from titanium. In another example, all of portions of the body portion **1410** may be constructed from steel and the sole insert portion **1540** may be constructed from a composite material. In yet another example, all of portions of the body portion **1410** may be constructed from steel and the sole insert portion **1540** may be constructed from a polymer material. The presence of one or more connecting members (e.g., connecting members **1531** and **1532**) or any structural support members in the opening **1528** may affect the physical properties and the materials of construction of the sole insert portion **1540**. In one example, due to the presence of the connecting members **1531**, **1532**, and **1533** in the opening **1528** of the golf club head **1400** of FIG. **20**, a sole insert portion **1540** for the golf club head **1400** of FIG. **20** may not have to provide as much structural support for the bottom portion **1440** as a sole insert portion **1540** for the golf club head **1400** of FIGS. **14-19**. In another example, due to the presence of the mesh structure in the opening **1528** of the golf club head **1400** of FIG. **21**, a sole insert portion **1540** for the golf club head **1400** of FIG. **21** may not have to provide as much structural support for the bottom portion **1440** as a

sole insert portion **1540** for the golf club head **1400** of FIG. **20**. In yet another example, the mesh structure of the golf club head **1400** of FIG. **21** may provide sufficient structural support for the golf club head **1400** such that the sole insert portion **1540** may be constructed from a polymer material (e.g., thermoplastic or thermoset material). Thus, the materials of construction of the sole insert portion **1540** and other physical properties of the sole insert portion **1540** may be determined to provide optimal performance characteristics for the golf club head **1400** while structurally supporting the body portion **1410**. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0100] In one example, as illustrated in FIGS. **14-21**, the sole insert portion **1540** may be constructed from one or more layers of a composite material so as to have a lower density than the density of the body portion **1410** and provide sufficient structural support for the bottom portion **1440**. A sole insert portion **1540** constructed from one or more composite materials may provide sound and vibration dampening for the golf club head **1400**. Additionally, the mass savings provided by a sole insert portion **1540** constructed from one or more composite materials may provide an increase in a moment of inertia (MOI) of the golf club head **1400** by enabling more mass to be concentrated toward the periphery **1490** (e.g., via the set of weight portions). In one example, more mass may be concentrated toward the rear portion **1480** (e.g., via the fourth weight portion **1508**) in effect increasing spin and imparting higher launch to a golf ball struck by the golf club head **1400**. Accordingly, the golf club head **1400** may provide greater forgiveness to the benefit of most golfers. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0101] As described herein, the sole insert portion **1540** may include a single layer of composite material or a plurality of layers of composite material. The plurality of layers of composite materials may include different material and/or physical properties. In one example, the entire sole insert portion **1540** may include the same configuration of composite materials and/or layers. In another example, certain portions of the sole insert portion **1540** may include a greater number of composite material layers to provide additional stiffness (i.e., additional layers forming stiffening ribs) at certain locations on the sole insert portion. In one example, the sole insert portion **1540** may include one or more layers of composite material that may be arranged in parallel or substantially parallel planes. In another example, the sole insert portion **1540** may include one or more layers of composite material that may be arranged in nonparallel planes. The tensile strength of the sole insert portion **1540**, as determined along certain axes, may be enhanced by having layers of composite material that are arranged in nonparallel planes (i.e., nonuniform orientations). The number of composite material layers of the sole insert portion **1540**, the material and physical properties of each composite layer of the sole insert portion **1540**, and/or construction of the sole insert portion **1540** may be similar in many respects to construction of composite golf club head parts (e.g., composite crown) of any of the golf club heads described herein or described in any of the incorporated by reference applications. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0102] The plurality of composite layers may include a plurality of layers of composite materials in a stacked arrangement. A layer of composite material may include a layer of fabric combined with an amount of resin. The fabric may be constructed from graphite fiber (commonly referred to as “carbon fiber”), glass fiber, aramid fiber, carbon nanotubes, or any other suitable high-performance fiber, combination of fibers, or material. In some examples, the fabric may be a hybrid of two or more types of fibers, such as a hybrid fabric made of carbon fibers and aramid fibers. Examples of aramid fibers include KEVLAR, TWARON, NOMEX, NEW STAR, TECHNORA, and TEIJINCONEX fibers. The fabric may be constructed as a woven, knitted, stitched, or nonwoven (e.g. uni-directional) fabric. Examples of suitable woven fabrics include Style 71525 Bi-directional E-Glass (Item No. 1094), Twill Weave Carbon Fiber Fabric (Item No. 1069), and KEVLAR Plain Weave Fabric (Item No. 2469), all available from Fibre Glast Developments Corporation of

Brookville, Ohio. The resin may be a thermosetting resin, such as an epoxy resin, vinyl-ester resin, polyester resin, or other suitable resin. Resin selection may be based, at least in part, on fabric compatibility and the characteristics of the composite layers. Epoxy resins are suitable since they may be used to form a strong, lightweight composite sole insert portion **1540** that is dimensionally stable. A suitable epoxy resin is System 2000 Epoxy Resin (Item No. 2000-A) available from Fibre Glast Developments Corporation. The number of composite material layers of the sole insert portion **1540**, the material and physical properties of each composite layer of the sole insert portion **1540**, and/or construction of the sole insert portion **1540** may be similar in many respects to construction of composite golf club head parts (e.g., composite crown) of any of the golf club heads described herein or described in any of the incorporated by reference applications. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0103] Manufacturing and assembly of one or more parts of the golf club head **1400** including the weight portions and/or injection or placement of any filler materials in the interior cavity **1411** may be similar in many respects to the manufacturing and assembly of similar parts of any of the golf club heads described herein or described in any of the incorporated by reference applications. After manufacturing the body portion **1410**, the sole insert portion **1540** may be adhered or otherwise affixed to the shoulder portion **1529**. In one example, a sole insert portion **1540** that is constructed from a metal or metal alloy may be attached to the shoulder portion **1529** by one or more adhesives, one or more bonding agents, welding, soldering, mechanical locking, and/or one or more fasteners. In another example, as shown in FIGS. **14-21**, a sole insert portion **1540** that is constructed from a composite material may be attached to the shoulder portion **1529** by one or more adhesives, one or more bonding agents, mechanical locking, and/or one or more fasteners. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0104] While each of the above examples may describe a certain type of golf club head, the apparatus, methods, and articles of manufacture described herein may be applicable to other types of golf club heads (e.g., a driver-type golf club head, a fairway wood-type golf club head, a hybrid-type golf club head, an iron-type golf club head, a putter-type golf club head, etc.).

[0105] Procedures defined by golf standard organizations and/or governing bodies such as the United States Golf Association (USGA) and/or the Royal and Ancient Golf Club of St. Andrews (R&A) may be used for measuring the club head volume of any of the golf club heads described herein. For example, a club head volume may be determined by using the weighted water displacement method (i.e., Archimedes Principle). Although the figures may depict particular types of club heads (e.g., a driver-type club head or iron-type golf club head), the apparatus, methods, and articles of manufacture described herein may be applicable to other types of club head (e.g., a fairway wood-type club head, a hybrid-type club head, a putter-type club head, etc.). Accordingly, any golf club head as described herein may have a volume that is within a volume range corresponding to certain type of golf club head as defined by golf governing bodies. A driver-type golf club head may have a club head volume of greater than or equal to 300 cubic centimeters (cm3 or cc). In another example, a driver-type golf club head may have a club head volume of 460 cc. A fairway wood golf club head may have a club head volume of between 100 cc and 300 cc. In one example, a fairway wood golf club head may have a club head volume of 180 cc. An iron-type golf club head may have a club head volume of between 25 cc and 100 cc. In one example, an iron-type golf club head may have a volume of 50 cc. Any of the golf clubs described herein may have the physical characteristics of a certain type of golf club (i.e., driver, fairway wood, iron, etc.), but have a volume that may fall outside of the above-described ranges. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0106] Any of the golf club heads and/or golf clubs described herein may include one or more sensors (e.g., accelerometers, strain gauges, etc.) for sensing linear motion (e.g., acceleration) and/or forces in all three axes of motion and/or rotational motion (e.g., angular acceleration) and rotational forces about all three axes of motion. In one example, the one or more sensors may be

internal sensors that may be located inside the golf club head, the hosel, the shaft, and/or the grip. In another example, the one or more sensors may be external sensors that may be located on the grip, on the shaft, on the hosel, and/or on the golf club head. In yet another example, the one or more sensors may be external sensors that may be attached by an individual to the grip, to the shaft, to the hosel, and/or to the golf club head. In one example, data collected from the sensors may be used to determine any one or more design parameters for any of the golf club heads and/or golf clubs described herein to provide certain performance or optimum performance characteristics. In another example, data from the sensors may be collected during play to assess the performance of an individual. The apparatus, methods, and articles of manufacture described herein are not limited in this regard.

[0107] Any of the apparatus, methods, or articles of manufacture described herein may include one or more visual identifiers such as alphanumeric characters, colors, images, symbols, logos, and/or geometric shapes. For example, one or more visual identifiers may be manufactured with one or more portions of a golf club such as the golf club head (e.g., casted or molded with the golf club head), painted on the golf club head, etched on the golf club (e.g., laser etching), embossed on the golf club head, machined onto the golf club head, attached as a separate badge or a sticker on the golf club head (e.g., adhesive, welding, brazing, mechanical lock(s), any combination thereof, etc.), or any combination thereof. The visual identifier may be made from the same material as the golf club head or a different material than the golf club head (e.g., a plastic badge attached to the golf club head with an adhesive). Further, the visual identifier may be associated with manufacturing and/or brand information of the golf club head, the type of golf club head, one or more physical characteristics of the golf club head, or any combination thereof. In particular, a visual identifier may include a brand identifier associated with a manufacturer of the golf club (e.g., trademark, trade name, logo, etc.) or other information regarding the manufacturer. In addition, or alternatively, the visual identifier may include a location (e.g., country of origin), a date of manufacture of the golf club or golf club head, or both.

[0108] The visual identifier may include a serial number of the golf club or golf club head, which may be used to check the authenticity to determine whether or not the golf club or golf club head is a counterfeit product. The serial number may also include other information about the golf club that may be encoded with alphanumeric characters (e.g., country of origin, date of manufacture of the golf club, or both). In another example, the visual identifier may include the category or type of the golf club head (e.g., 5-iron, 7-iron, pitching wedge, etc.). In yet another example, the visual identifier may indicate one or more physical characteristics of the golf club head, such as one or more materials of manufacture (e.g., visual identifier of “Titanium” indicating the use of titanium in the golf club head), loft angle, face portion characteristics, mass portion characteristics (e.g., visual identifier of “Tungsten” indicating the use of tungsten mass portions in the golf club head), interior cavity and filler material characteristics (e.g., one or more abbreviations, phrases, or words indicating that the interior cavity is filled with a polymer material), any other information that may visually indicate any physical or play characteristic of the golf club head, or any combination thereof. Further, one or more visual identifiers may provide an ornamental design or contribute to the appearance of the golf club, or the golf club head.

[0109] Any of the golf club heads described herein may be manufactured by casting from metal such as steel. However, other techniques for manufacturing a golf club head as described herein may be used such as 3D printing or molding a golf club head from metal or non-metal materials such as ceramics.

[0110] All methods described herein may be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. Although a particular order of actions may be described herein with respect to one or more processes, these actions may be performed in other temporal sequences. Further, two or more actions in any of the processes described herein may be performed sequentially, concurrently, or simultaneously.

[0111] The terms “and” and “or” may have both conjunctive and disjunctive meanings. The terms “a” and “an” are defined as one or more unless this disclosure indicates otherwise. The term “coupled,” and any variation thereof, refers to directly or indirectly connecting two or more elements chemically, mechanically, and/or otherwise. The phrase “removably connected” is defined such that two elements that are “removably connected” may be separated from each other without breaking or destroying the utility of either element.
[0112] The term “substantially” when used to describe a characteristic, parameter, property, or value of an element may represent deviations or variations that do not diminish the characteristic, parameter, property, or value that the element may be intended to provide. Deviations or variations in a characteristic, parameter, property, or value of an element may be based on, for example, tolerances, measurement errors, measurement accuracy limitations and other factors. The term “proximate” is synonymous with terms such as “adjacent,” “close,” “immediate,” “nearby,” “neighboring,” etc., and such terms may be used interchangeably as appearing in this disclosure.
[0113] Recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless otherwise indicated herein, each individual value is incorporated into the specification as if it were individually recited herein. A numerical range defined using the word “between” includes numerical values at both end points of the numerical range. A spatial range defined using the word “between” includes any point within the spatial range and the boundaries of the spatial range. A location expressed relative to two spaced apart or overlapping elements using the word “between” includes (i) any space between the elements, (ii) a portion of each element, and/or (iii) the boundaries of each element.
[0114] The use of any and all examples, or exemplary language (e.g., “such as”) provided herein is intended merely for clarification and does not pose a limitation on the scope of the present disclosure. No language in the specification should be construed as indicating any non-claimed element essential to the practice of any embodiments discussed herein.
[0115] Groupings of alternative elements or embodiments disclosed herein are not to be construed as limitations. Each group member may be referred to and claimed individually or in any combination with other members of the group or other elements disclosed herein. One or more members of a group may be included in, or deleted from, a group for reasons of convenience and/or patentability. When any such inclusion or deletion occurs, the specification is deemed to contain the group as modified thus fulfilling the written description of all Markush groups used in the appended claims.
[0116] While different features or aspects of an embodiment may be described with respect to one or more features, a singular feature may comprise multiple elements, and multiple features may be combined into one element without departing from the scope of the present disclosure. Further, although methods may be disclosed as comprising one or more operations, a single operation may comprise multiple steps, and multiple operations may be combined into one step without departing from the scope of the present disclosure.
[0117] The apparatus, methods, and articles of manufacture described herein may be implemented in a variety of embodiments, and the foregoing description of some of these embodiments does not necessarily represent a complete description of all possible embodiments. Instead, the description of the drawings, and the drawings themselves, disclose at least one embodiment, and may disclosure alternative embodiments.
[0118] As the rules of golf may change from time to time (e.g., new regulations may be adopted or old rules may be eliminated or modified by golf standard organizations and/or governing bodies such as the USGA, the R&A, etc.), golf equipment related to the apparatus, methods, and articles of manufacture described herein may be conforming or non-conforming to the rules of golf at any particular time. Accordingly, golf equipment related to the apparatus, methods, and articles of manufacture described herein may be advertised, offered for sale, and/or sold as conforming or non-conforming golf equipment. The apparatus, methods, and articles of manufacture described

herein are not limited in this regard.
[0119] Further, while the above examples may be described with respect to golf clubs, the apparatus, methods and articles of manufacture described herein may be applicable to other suitable types of sports equipment such as a fishing pole, a hockey stick, a ski pole, a tennis racket, etc.
[0120] Although certain example apparatus, methods, and articles of manufacture have been described herein, the scope of coverage of this disclosure is not limited thereto. On the contrary, this disclosure covers all apparatus, methods, and articles of articles of manufacture fairly falling within the scope of the appended claims cither literally or under the doctrine of equivalents.

Claims

1. A golf club head comprising: a body portion comprising a front portion, a rear portion, a toe portion, a heel portion, a top portion, a bottom portion, a face portion, and a periphery, the bottom portion comprising: a forward portion; a rear protrusion at or proximate the rear portion, the rear protrusion extending longitudinally in a rear-to-front direction, the rear protrusion comprising: a front-side portion; a toe-side portion extending rearwardly from the front-side portion towards the rear portion and positioned on a first side of a longitudinal vertical plane bisecting the golf club head and intersecting a geometric center of the face portion; and a heel-side portion extending rearwardly from the front-side portion towards the rear portion and positioned on a second side of the longitudinal vertical plane; a recessed portion between the forward portion and the rear protrusion, the recessed portion comprising a plurality of contoured transition regions defining an opening; a shoulder portion adjoined to the plurality of contoured transition regions; and one or more connecting members extending across the opening to adjoin opposing portions of the shoulder portion, wherein the one or more connecting members are configured as a plurality of intersecting support ribs.
2. A golf club head as defined in claim 1, wherein at least one of the plurality of intersecting support ribs is positioned rearwardly of a lateral vertical plane, and wherein the lateral vertical plane is perpendicular to the longitudinal vertical plane and located halfway between a frontmost extent and a rearmost extent of the body portion.
3. A golf club head as defined in claim 1, wherein at least one of the plurality of intersecting support ribs is positioned forward of the front-side portion.
4. A golf club head as defined in claim 1, wherein a first rib of the plurality of intersecting support ribs is perpendicular to a second rib of the plurality of intersecting support ribs.
5. A golf club head as defined in claim 1, further comprising a sole insert portion coupled to the shoulder portion to cover the opening, wherein the one or more connecting members are positioned between the sole insert portion and an interior cavity of the body portion.
6. A golf club head as defined in claim 1, further comprising a sole insert portion configured to cover the opening, wherein the sole insert portion is made from a polymeric material.
7. A golf club head as defined in claim 1, further comprising a weight port defined by the rear protrusion, the weight port configured to receive a weight portion.
8. A golf club head comprising: a body portion comprising a front portion, a face portion at the front portion, a rear portion, a toe portion, a heel portion, a top portion, a bottom portion, and a periphery; a vertical plane system characterizing the golf club head at an address position, the vertical plane system comprising: a longitudinal vertical plane bisecting the golf club head and intersecting a geometric center of the face portion, the longitudinal vertical plane dividing the golf club head into a toe side and a heel side; a toe-side bounding plane parallel with the longitudinal vertical plane and bounding a toe-side of the golf club head; a heel-side bounding plane parallel with the longitudinal vertical plane and bounding a heel-side of the golf club head; a toe-side dividing plane parallel with the longitudinal vertical plane and equidistant from the longitudinal vertical plane and the toe-side bounding plane; a heel-side dividing plane parallel with the

longitudinal vertical plane and equidistant from the longitudinal vertical plane and the heel-side bounding plane; and a lateral vertical plane perpendicular to the longitudinal vertical plane and located halfway between a frontmost extent and a rearmost extent of the body portion; a rear protrusion at the bottom portion and located at or proximate the rear portion, the rear protrusion extending longitudinally in a rear-to-front direction; an opening located between the face portion and the rear protrusion; a shoulder portion encircling at least a portion of the opening; and a first connecting member extending across the opening on opposing sides of the shoulder portion, the first connecting member positioned rearward of the lateral vertical plane.

9. A golf club head as defined in claim 8, further comprising a second connecting member extending across the opening on opposing sides of the shoulder portion, wherein the first connecting member is positioned on one of the toe side or the heel side of the longitudinal vertical plane, and wherein the second connecting member is positioned on the other one of the toe side or the heel side of the longitudinal vertical plane.

10. A golf club head as defined in claim 8, further comprising a second connecting member extending across the opening on opposing sides of the shoulder portion, the second connecting member positioned rearward of the lateral vertical plane.

11. A golf club head as defined in claim 8, further comprising a second connecting member extending across the opening on opposing sides of the shoulder portion, wherein the first connecting member extends in a first diagonal direction, and wherein the second connecting member extends in a second diagonal direction different from the first diagonal direction.

12. A golf club head as defined in claim 8, further comprising a third connecting member extending across the opening on opposing sides of the shoulder portion, the third connecting member positioned forward of the lateral vertical plane.

13. A golf club head as defined in claim 8, further comprising a third connecting member extending across the opening on opposing sides of the shoulder portion, wherein the third connecting member coincides with the longitudinal vertical plane.

14. A golf club head as defined in claim 8, further comprising a sole insert portion coupled to the shoulder portion to cover the opening, wherein the first connecting member is positioned between the sole insert portion and an interior cavity of the body portion.

15. A golf club head comprising: a body portion comprising a front portion, a face portion at the front portion, a rear portion, a toe portion, a heel portion, a top portion, a bottom portion, and a periphery, the bottom portion comprising: a forward portion at or proximate the front portion; a rear protrusion at or proximate the rear portion, the rear protrusion extending longitudinally in a rear-to-front direction, the rear protrusion comprising: a front-side portion; a toe-side portion extending rearwardly from the front-side portion towards the rear portion and positioned on a first side of a longitudinal vertical plane bisecting the golf club head and intersecting a geometric center of the face portion; and a heel-side portion extending rearwardly from the front-side portion towards the rear portion and positioned on a second side of the longitudinal vertical plane; an opening located between the face portion and the rear protrusion; and a first connecting member extending across the opening from the front-side portion to the forward portion, the first connecting member positioned forward of a lateral vertical plane perpendicular to the longitudinal vertical plane and located halfway between a frontmost extent and a rearmost extent of the body portion.

16. A golf club head as defined in claim 15, further comprising a second connecting member extending across the opening, the second connecting member positioned rearward of the lateral vertical plane and on a first side of the longitudinal vertical plane.

17. A golf club head as defined in claim 15, further comprising a third connecting member extending across the opening, the third connecting member positioned rearward of the lateral vertical plane and on a second side of the longitudinal vertical plane.

18. A golf club head as defined in claim 15, further comprising a second connecting member extending across the opening, wherein a length of the first connecting member is different from a

length of the second connecting member.

19. A golf club head as defined in claim 15, further comprising a sole insert portion coupled to the bottom portion to cover the opening.

20. A golf club head as defined in claim 15, further comprising a first weight port at the forward portion and a second weight port at the rear protrusion, wherein the first weight port is configured to receive a first weight portion, and wherein the second weight port is configured to receive a second weight portion.