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(54) MULTI-PIECE GOLF CLUB HEAD

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A63B 102/32 (2015.01)

(52) **U.S. Cl.**
CPC *A63B 53/0475* (2013.01); *A63B 53/0412* (2020.08); *A63B 2102/32* (2015.10)

(57) ABSTRACT

A method of making a golf club head includes interposing bonding tape between a first piece and a second piece of the golf club head such that the first piece is temporarily adhered to the second piece via a tackiness of the bonding tape. The method additionally includes positioning the first piece, the second piece, and the bonding tape, interposed between the first piece and the second piece, in a vacuum bag, and reducing a pressure within the vacuum bag, relative to a pressure external to the vacuum bag, such that the vacuum bag collapses onto the first piece and the second piece and compresses the bonding tape between the first piece and the second piece. The method also includes heating the bonding tape, at least to a curing temperature of the bonding tape, when the pressure within the vacuum bag is reduced.

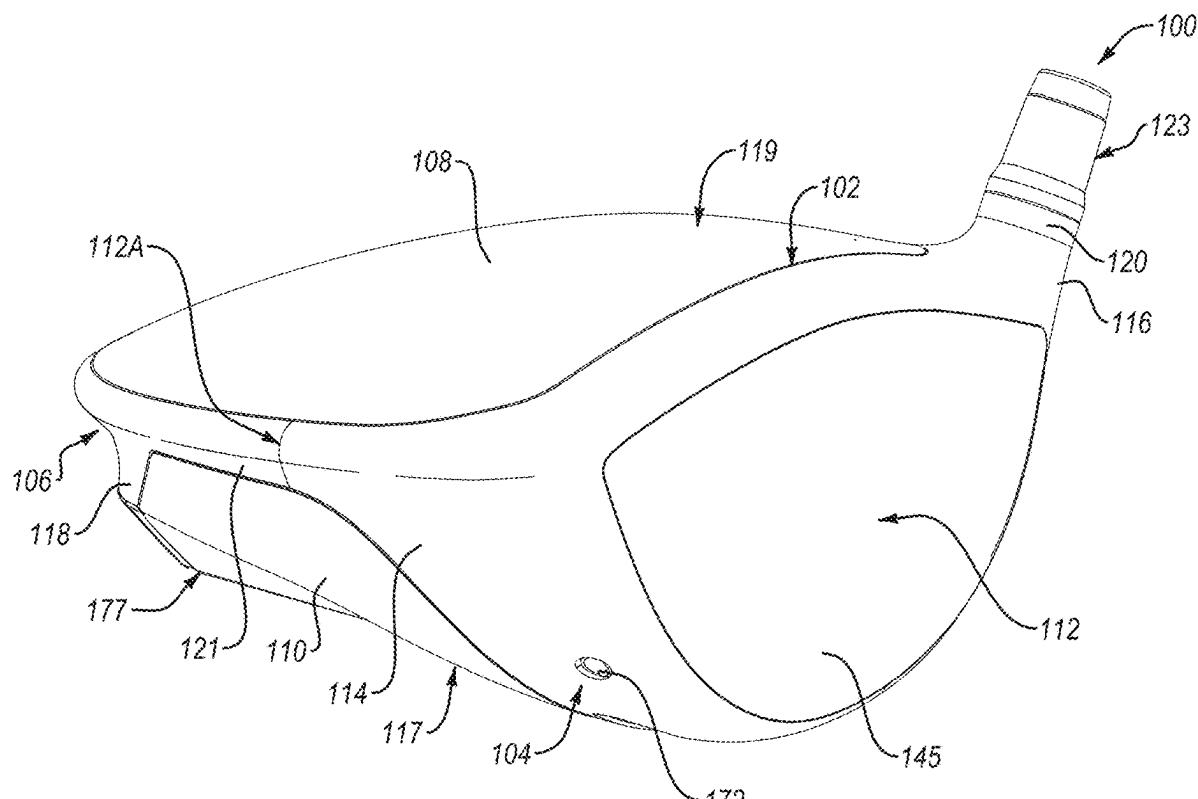


FIG. 1

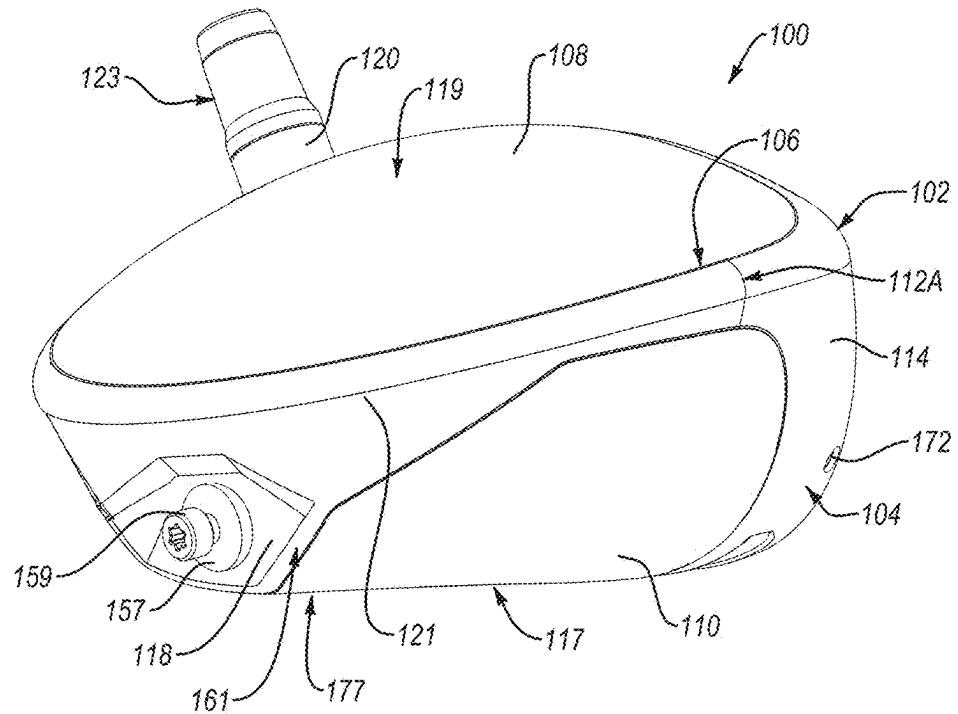
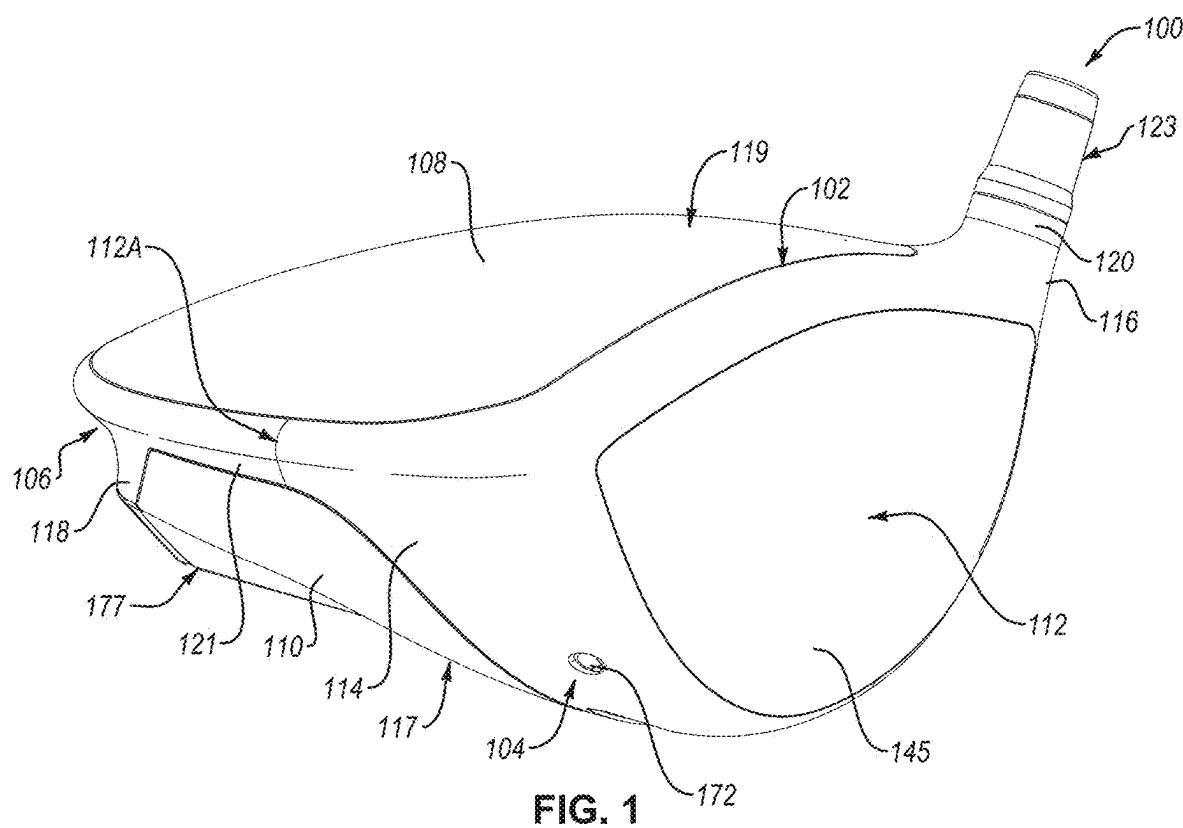
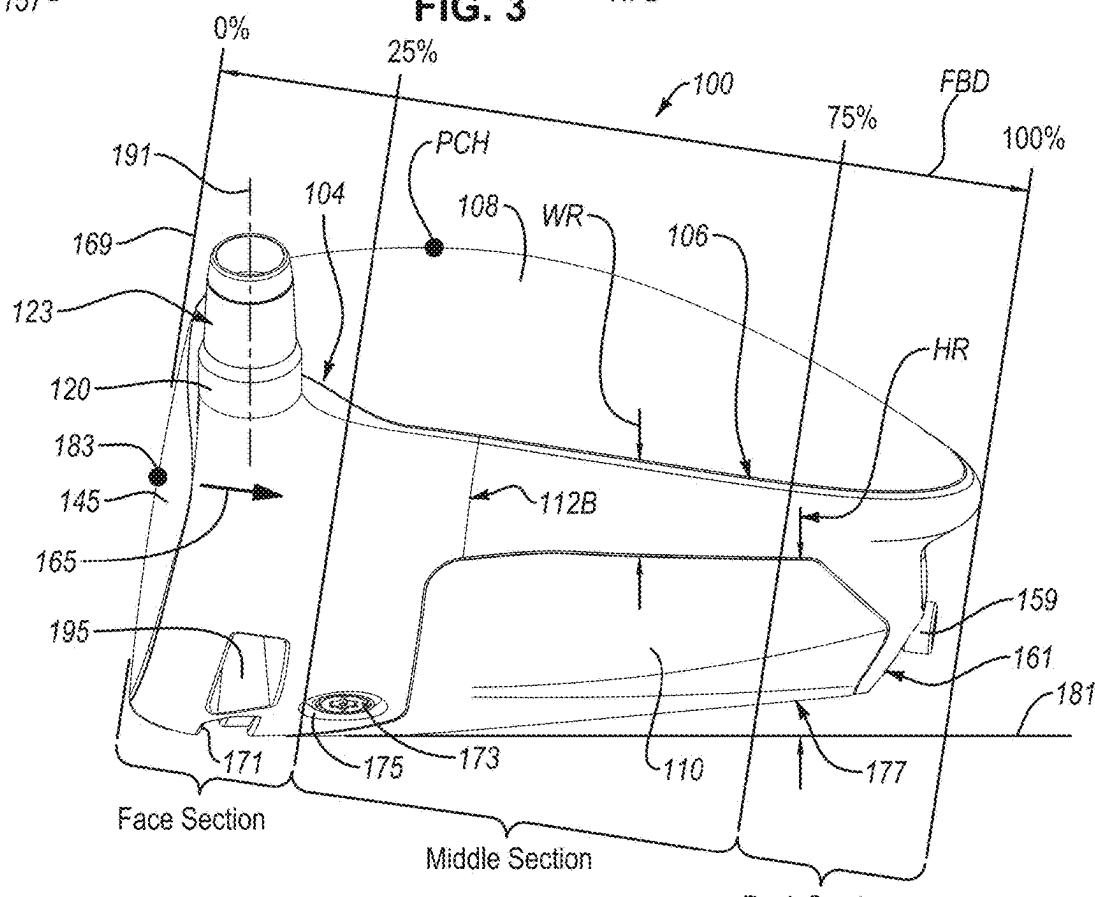
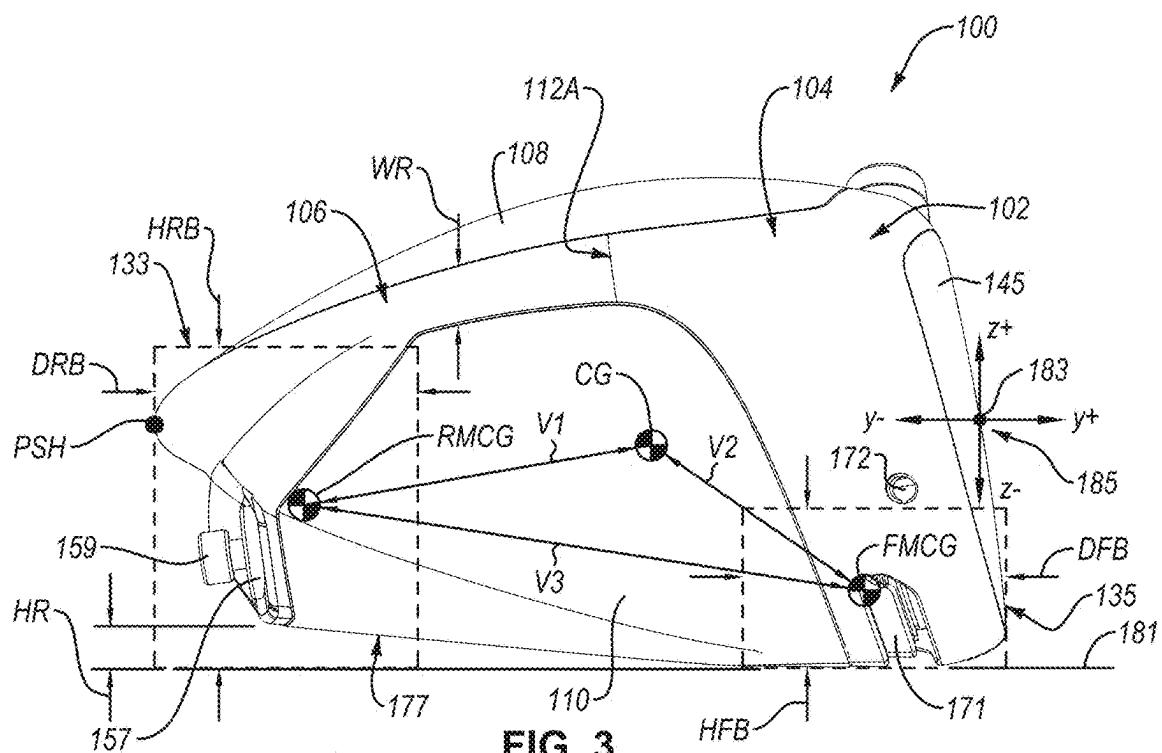


FIG. 2



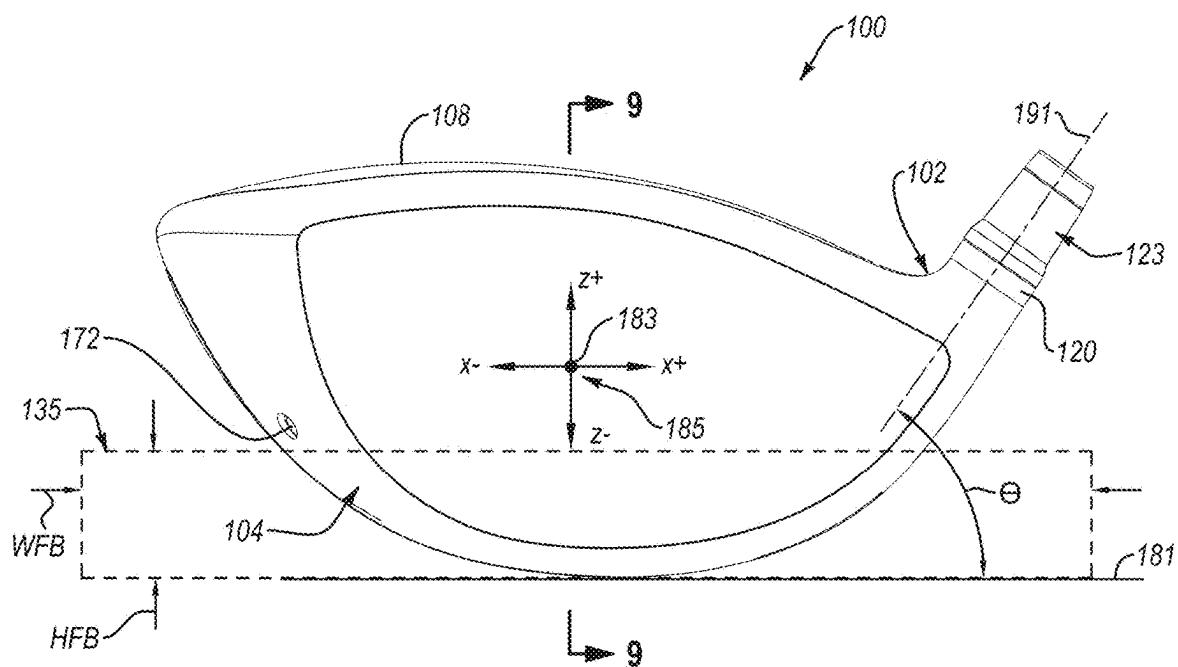


FIG. 5

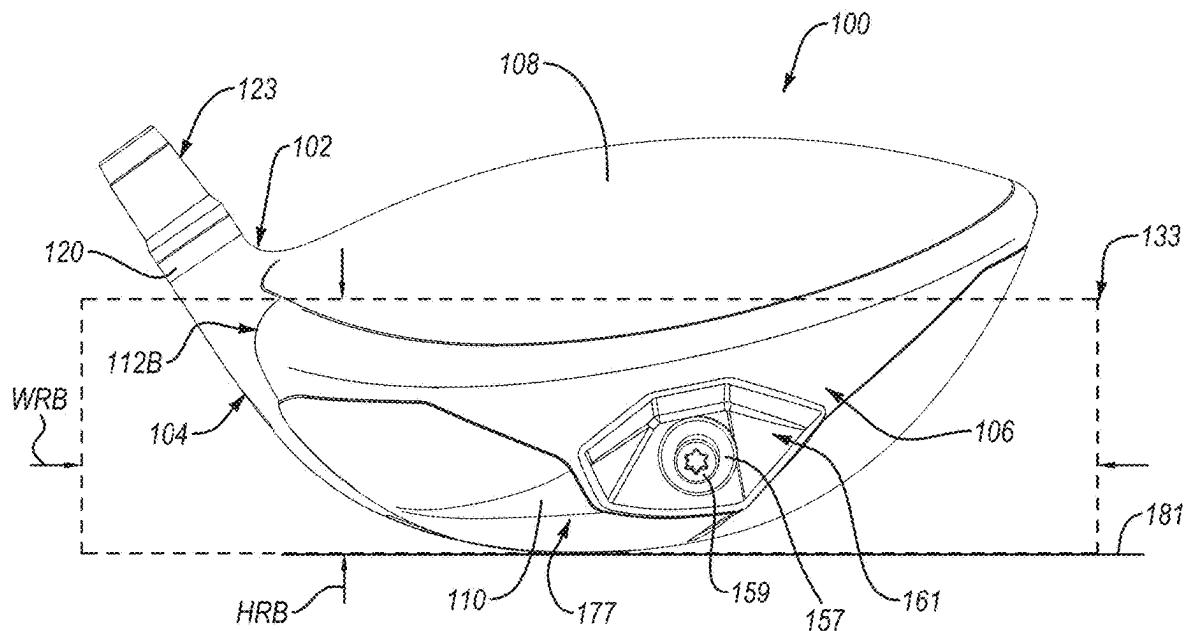
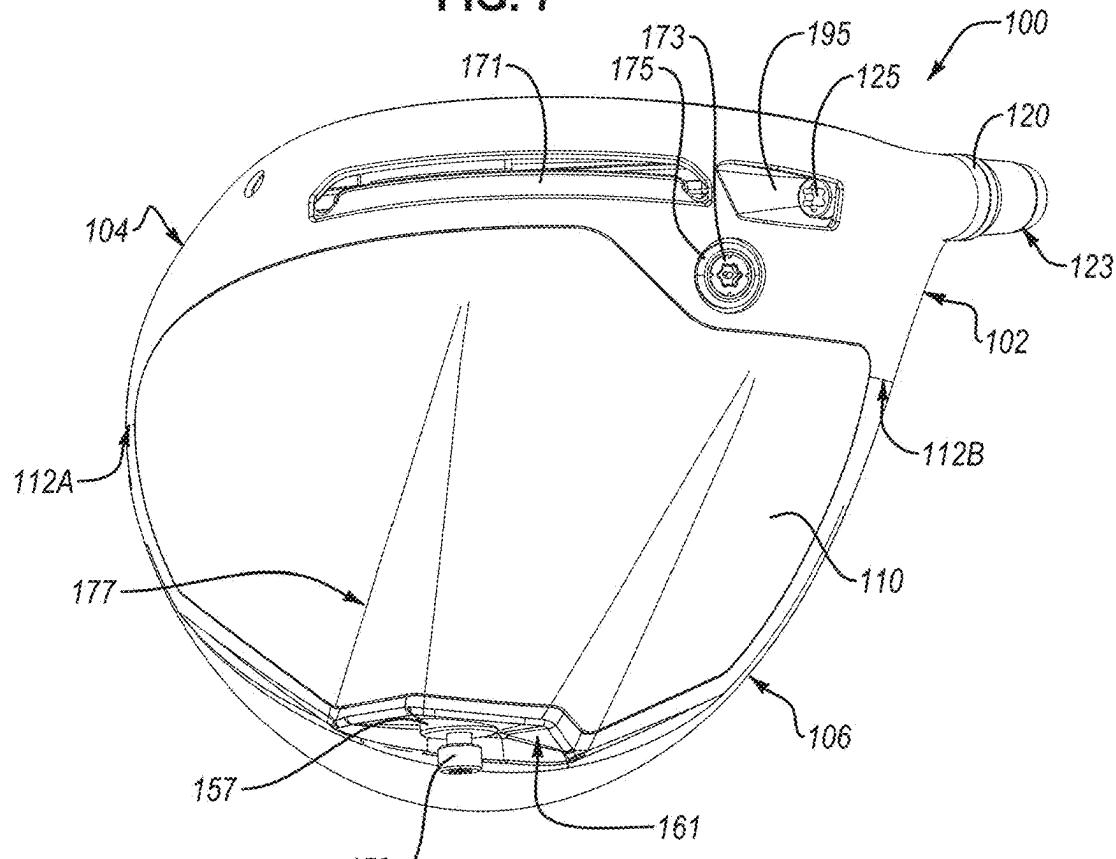
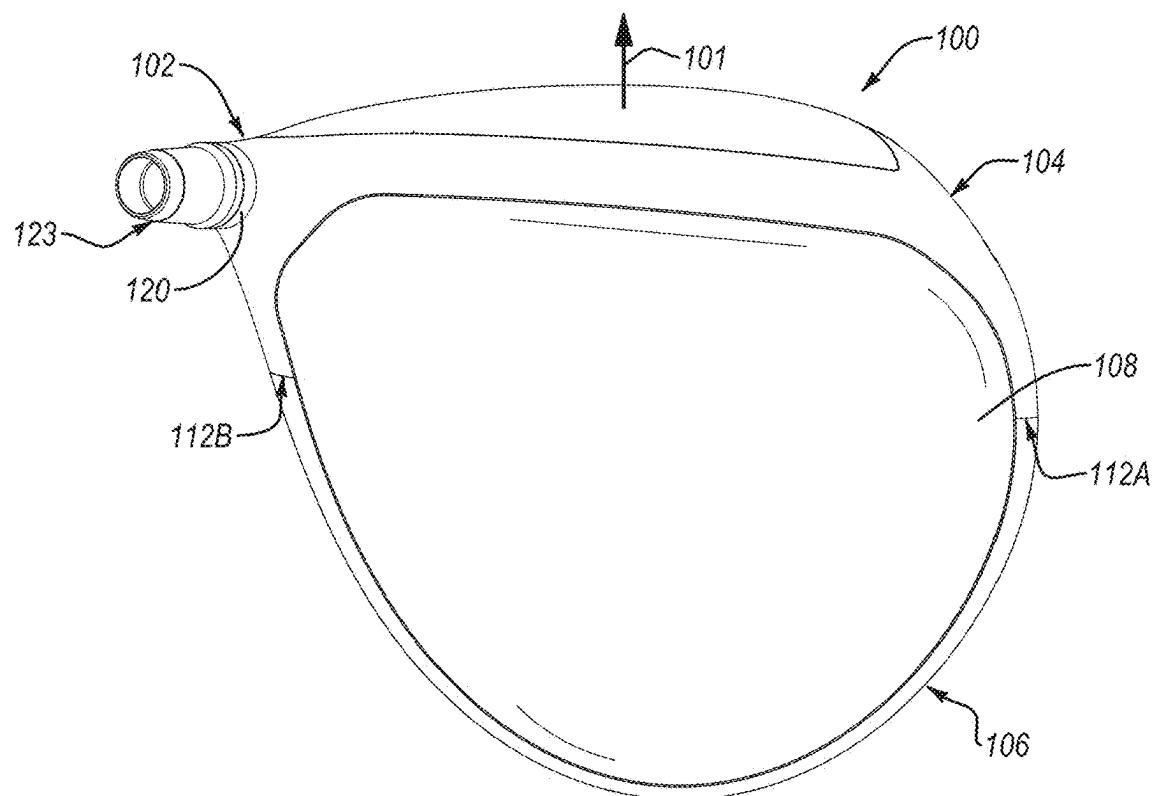
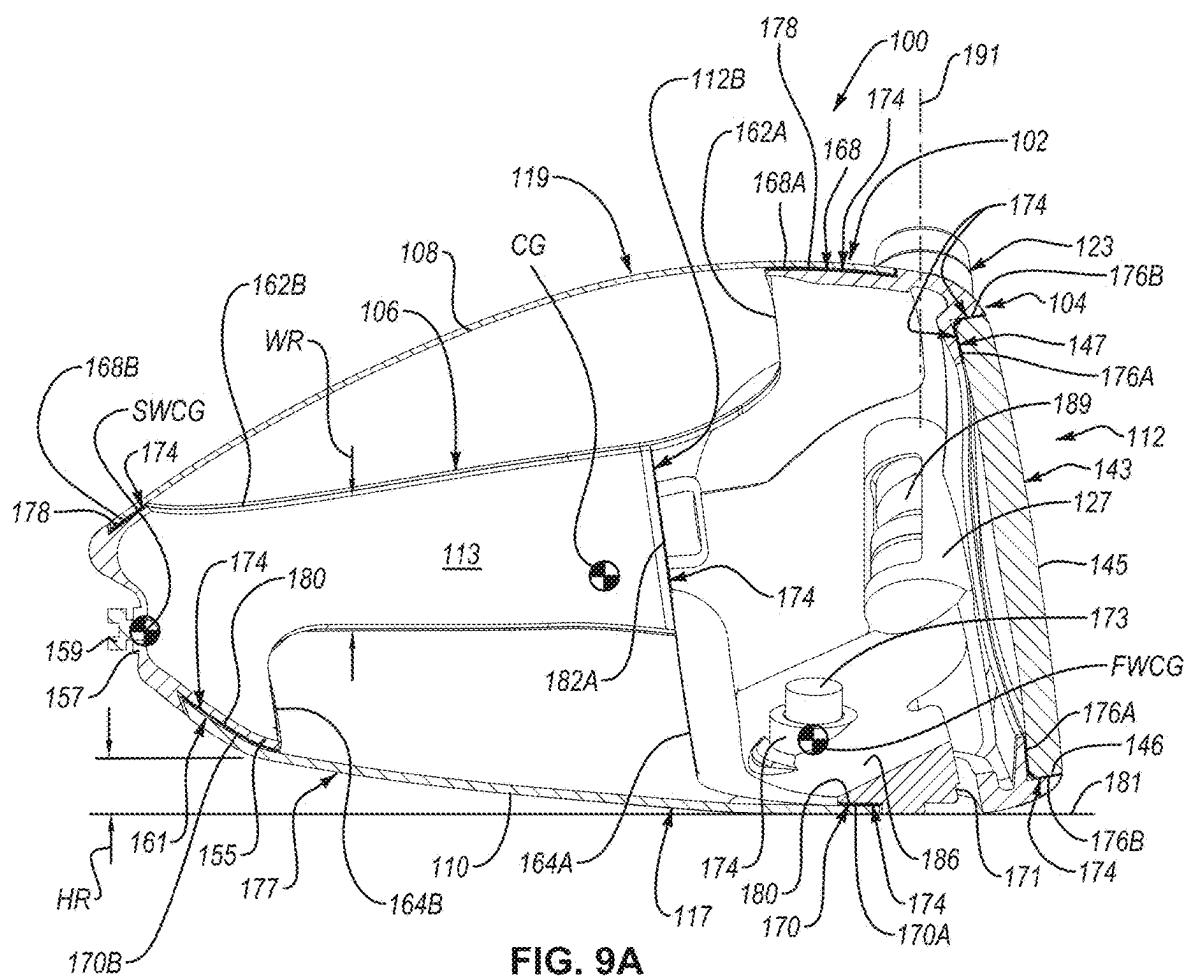
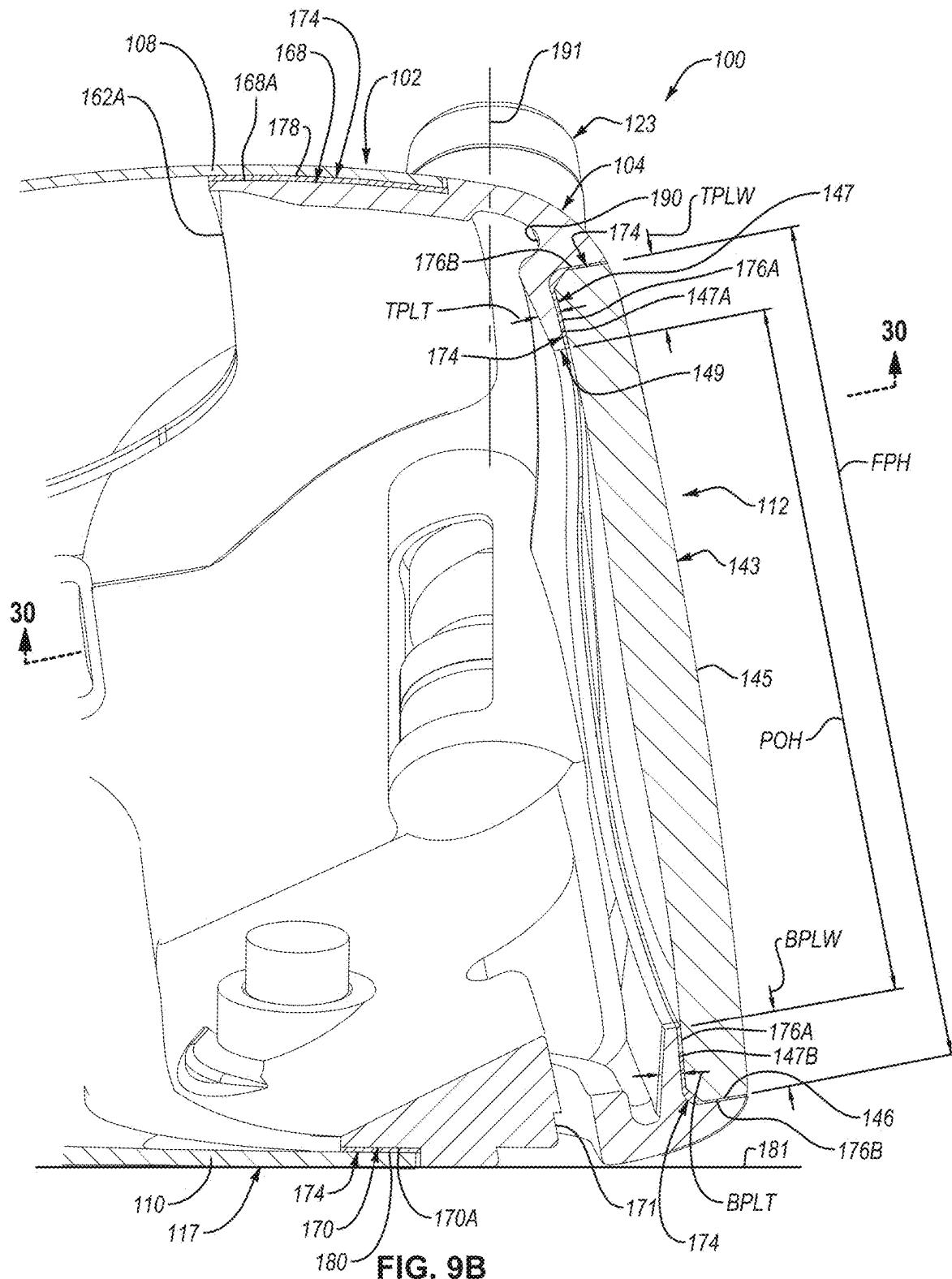


FIG. 6







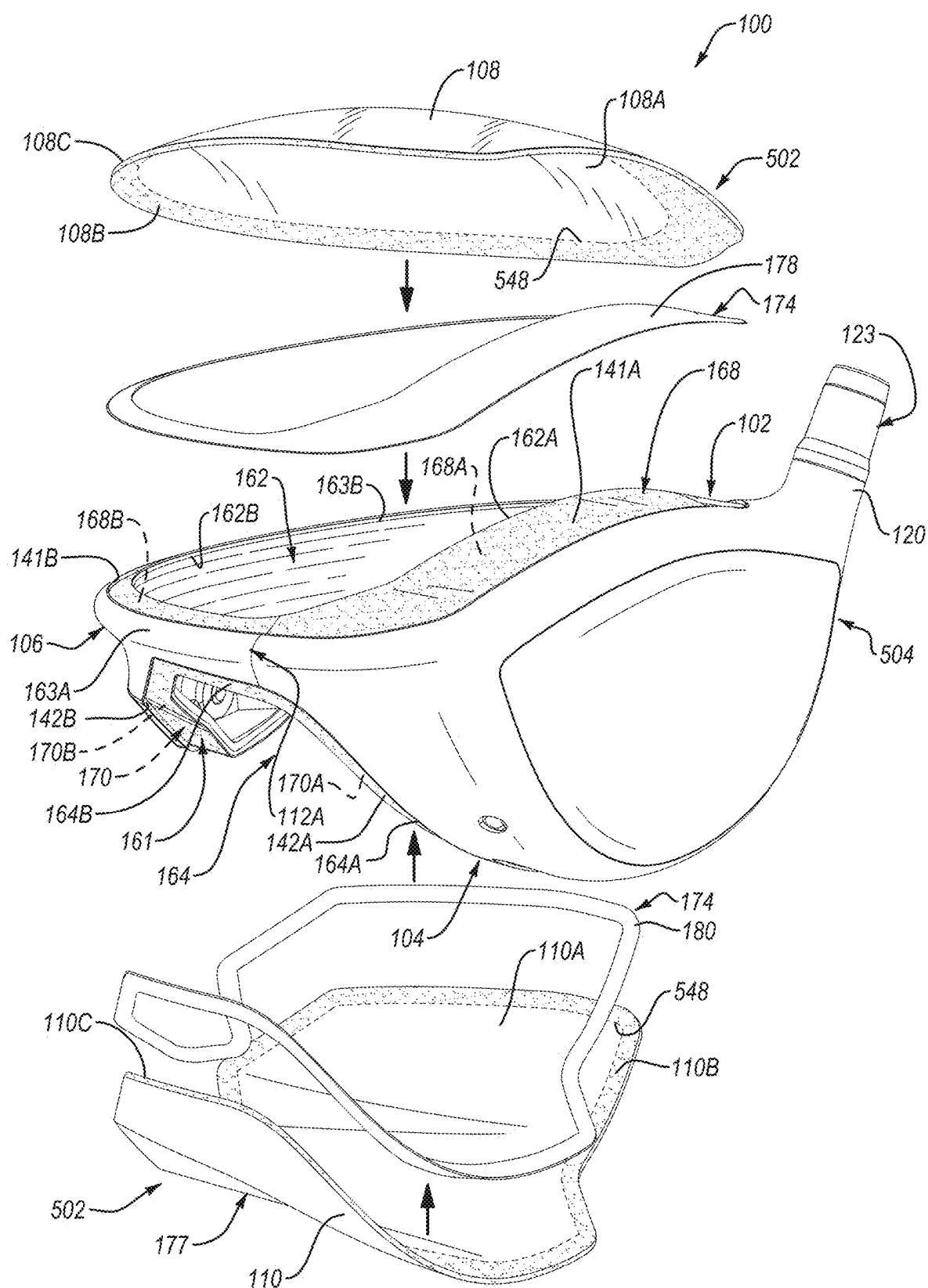


FIG. 10

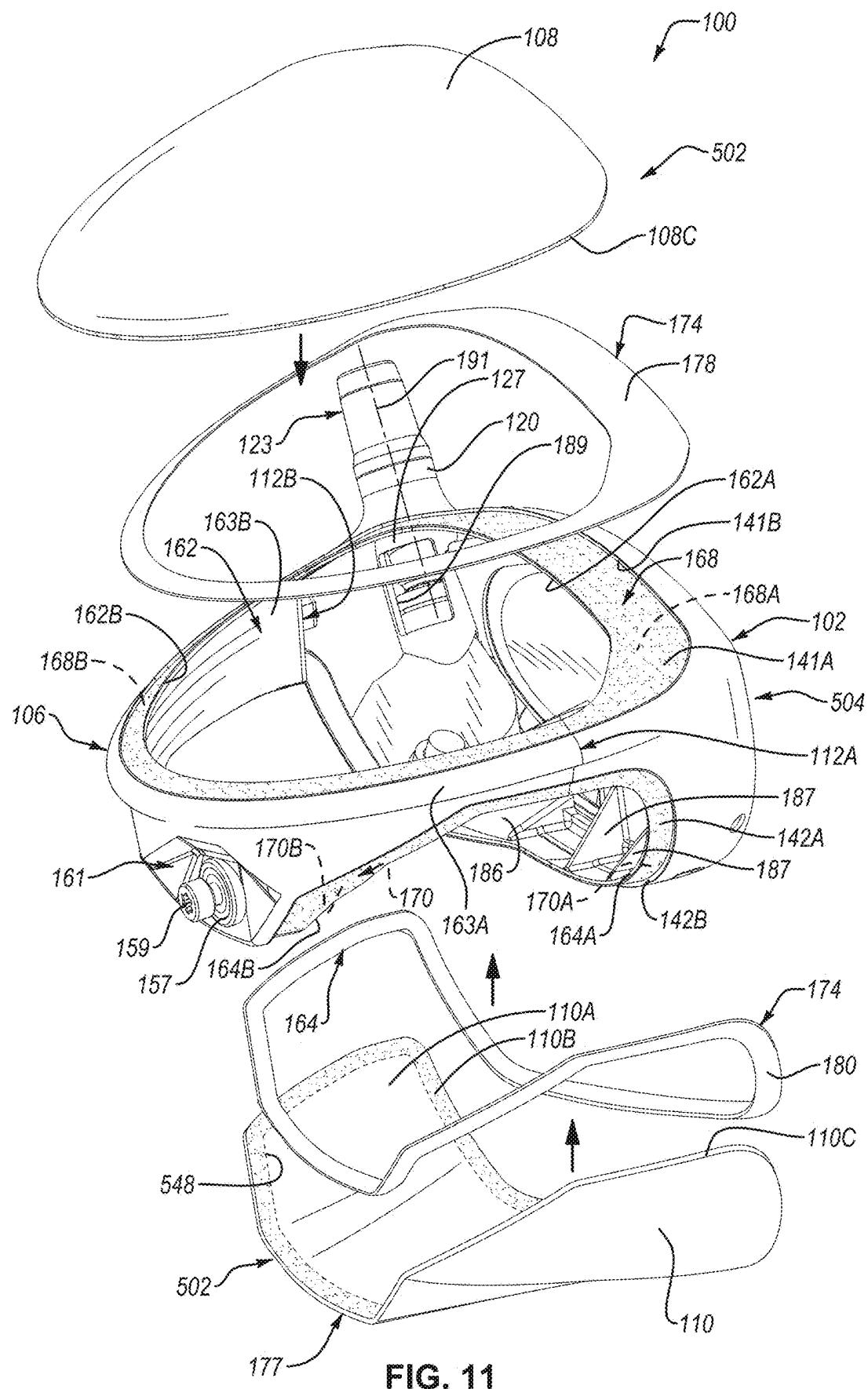


FIG. 11

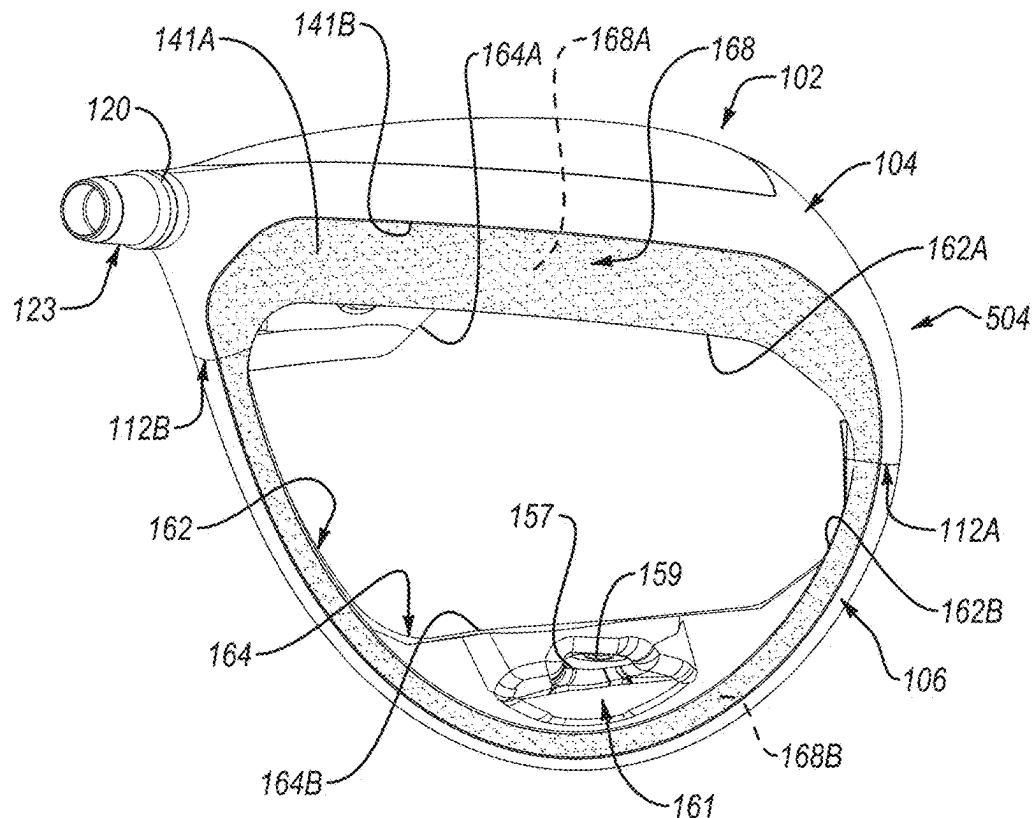


FIG. 12

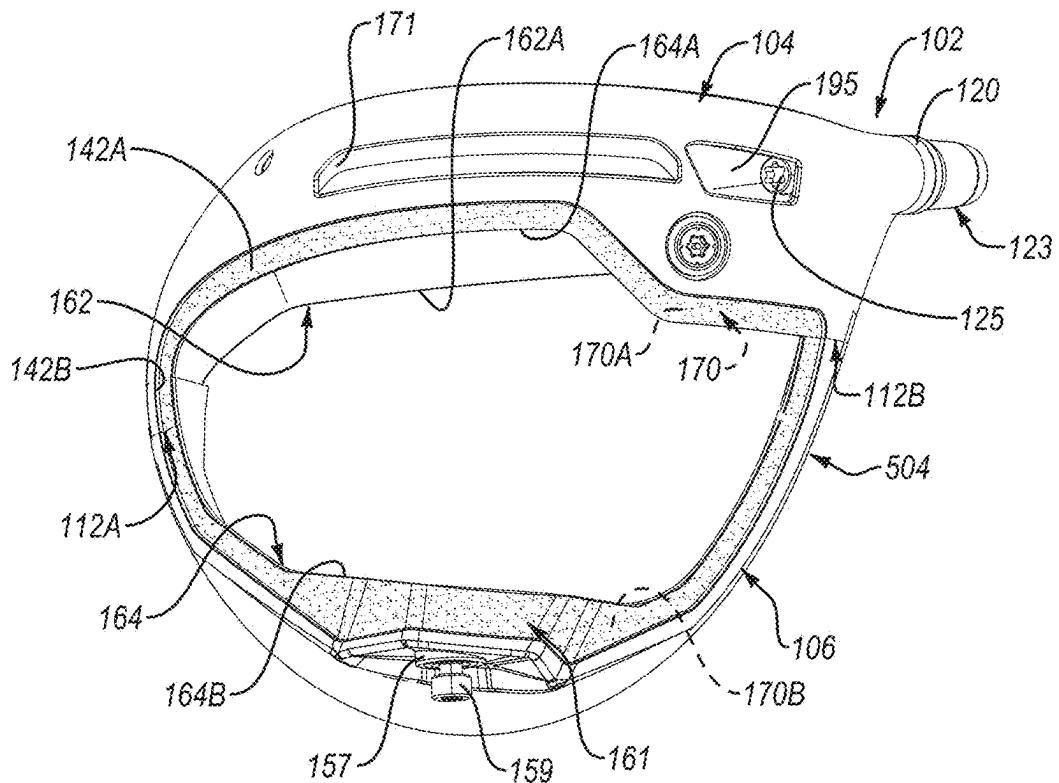


FIG. 13

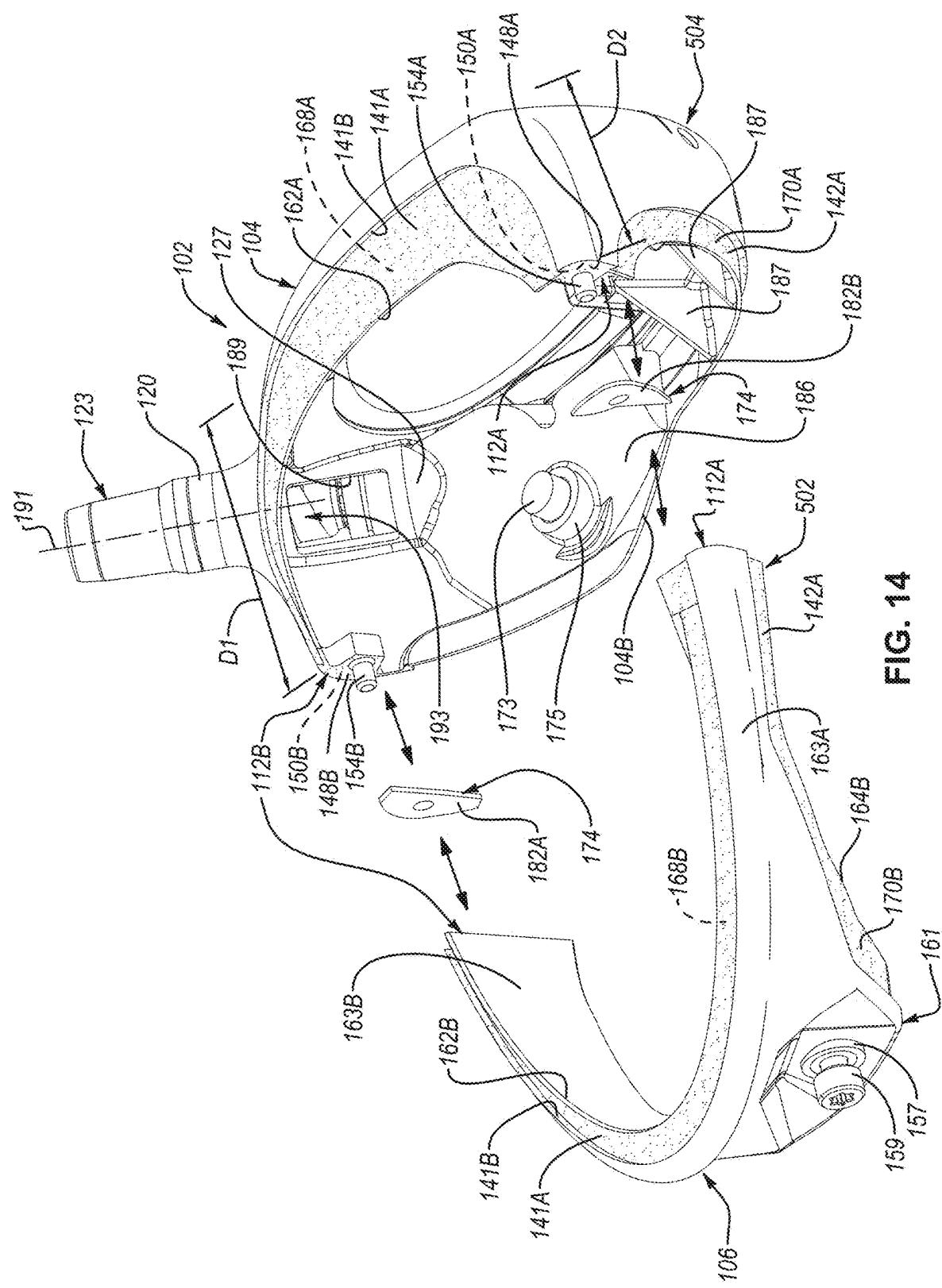


FIG. 14

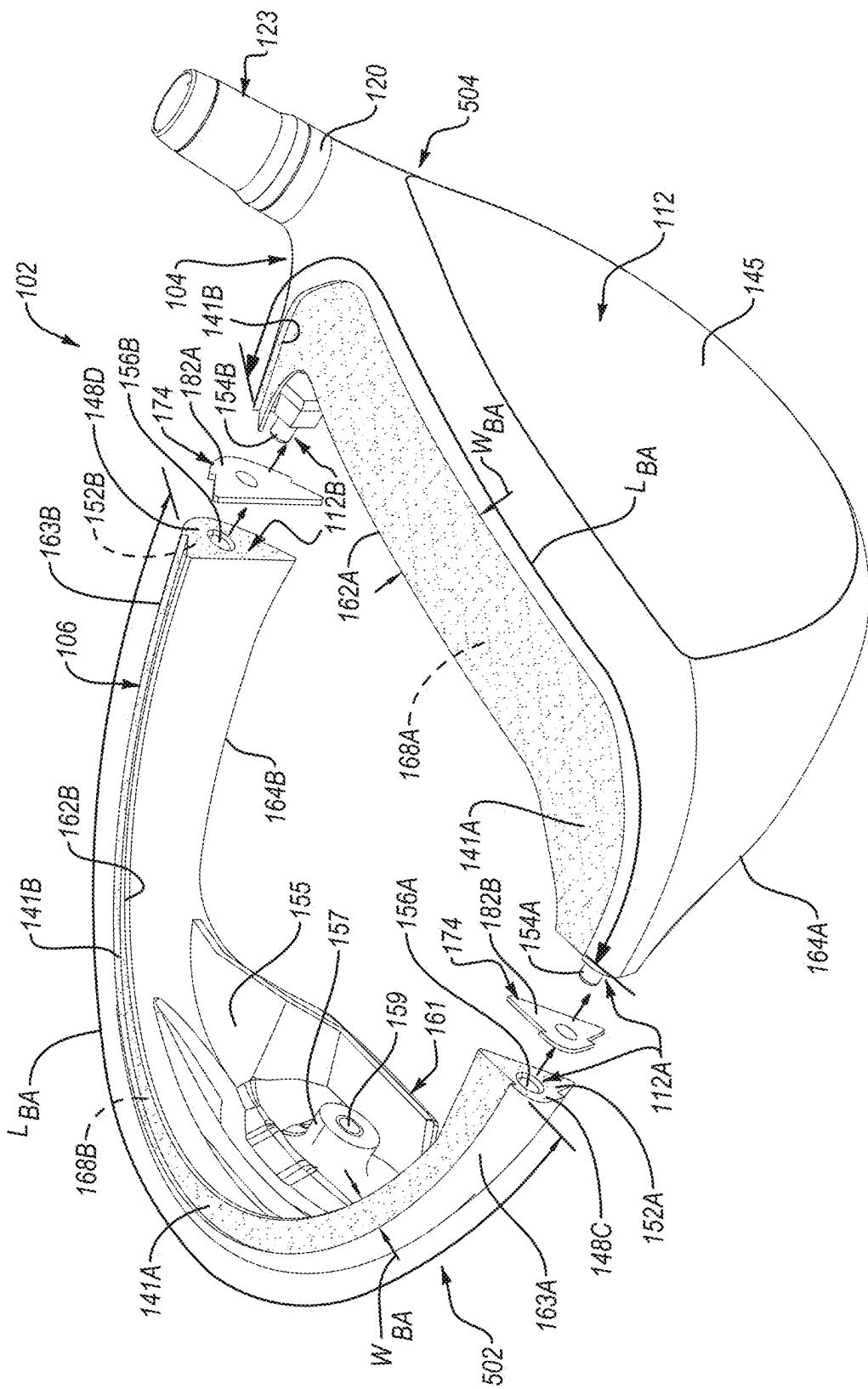
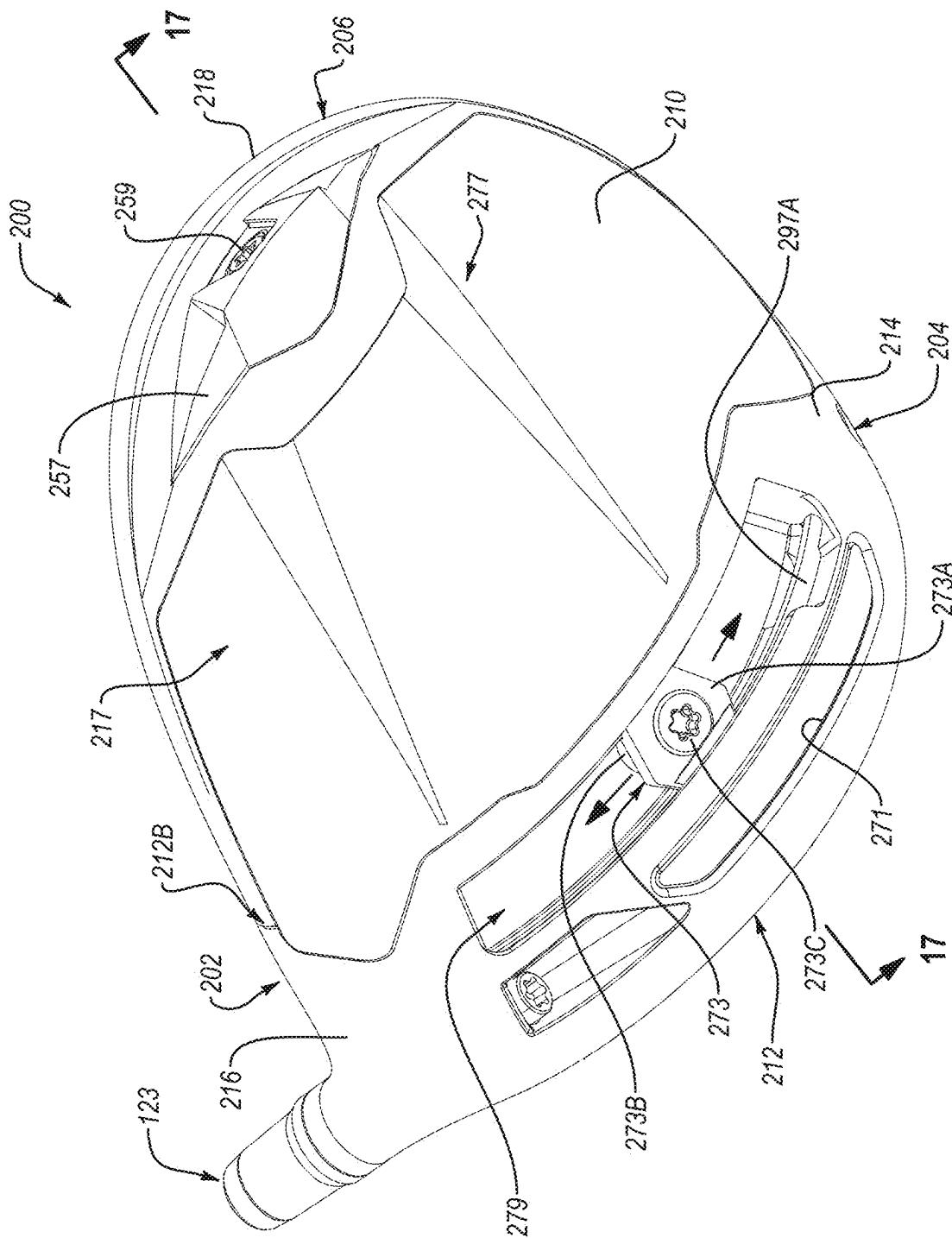
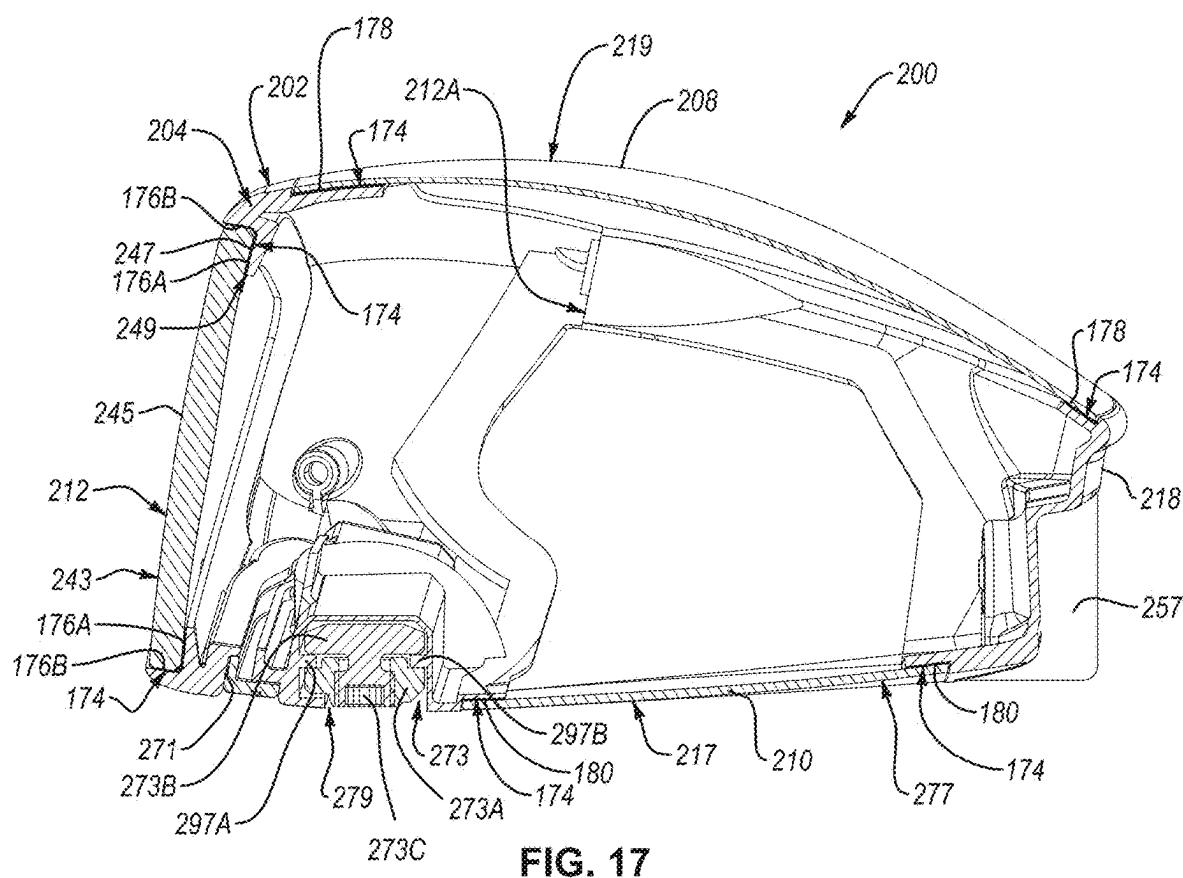
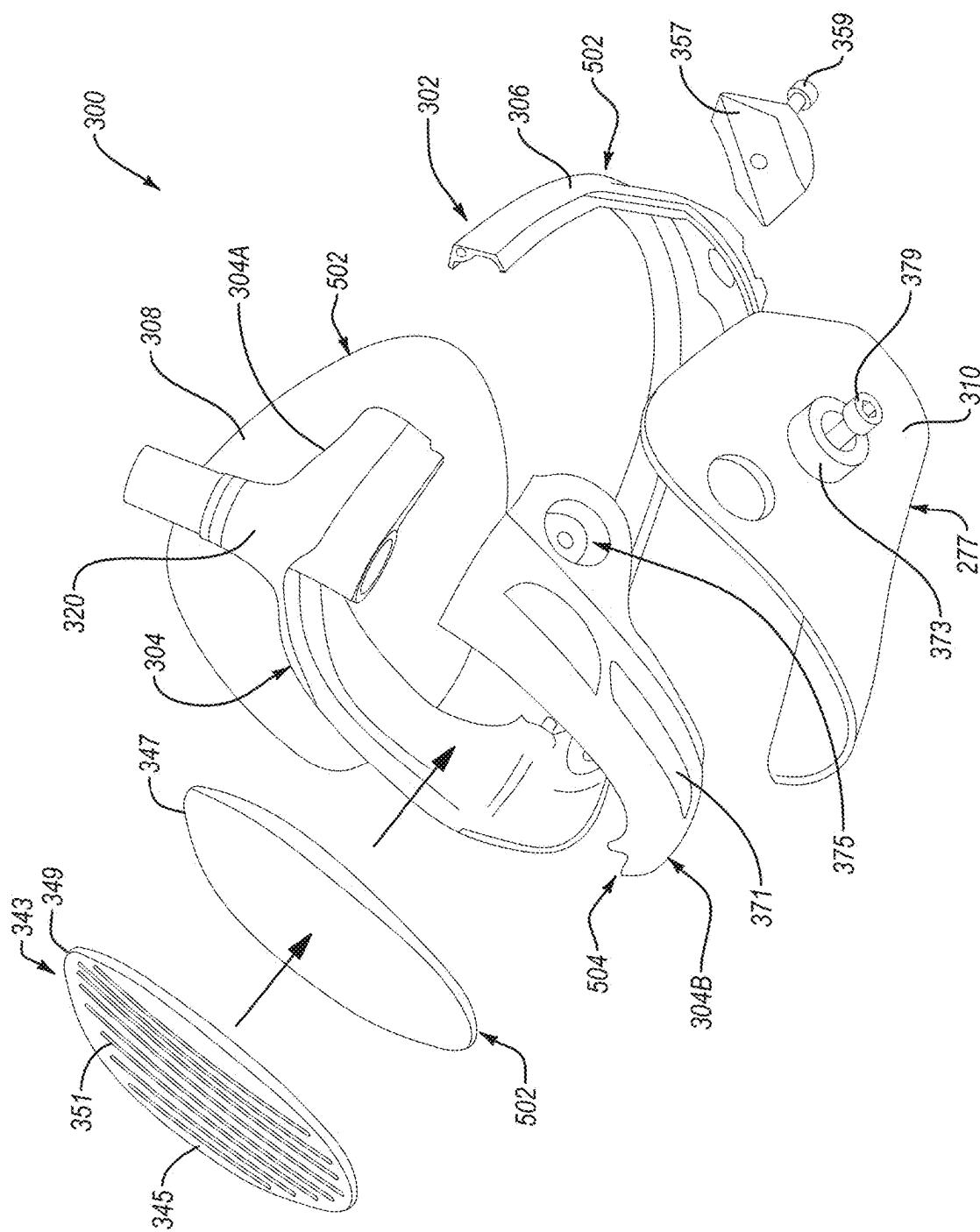


FIG. 15

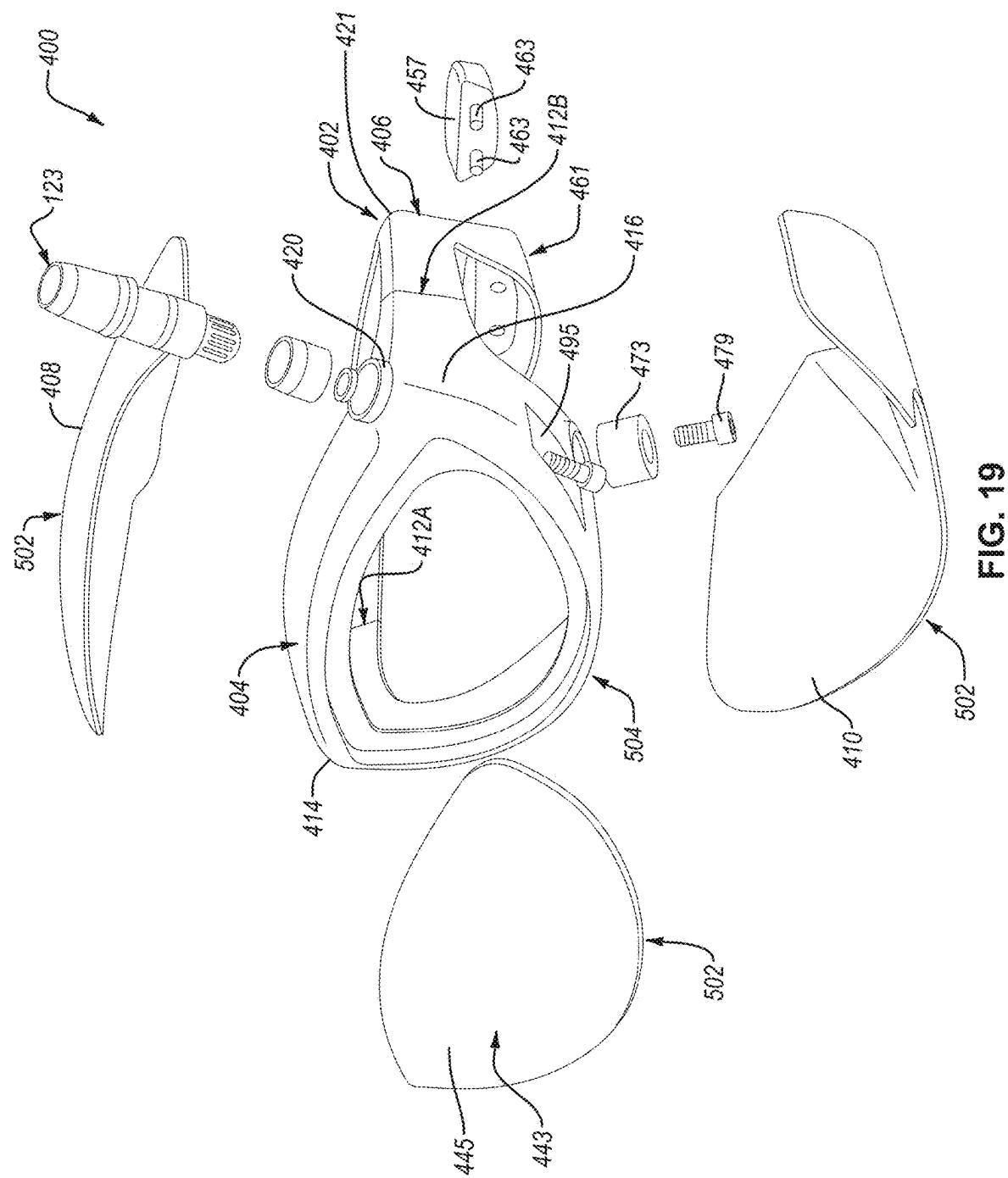


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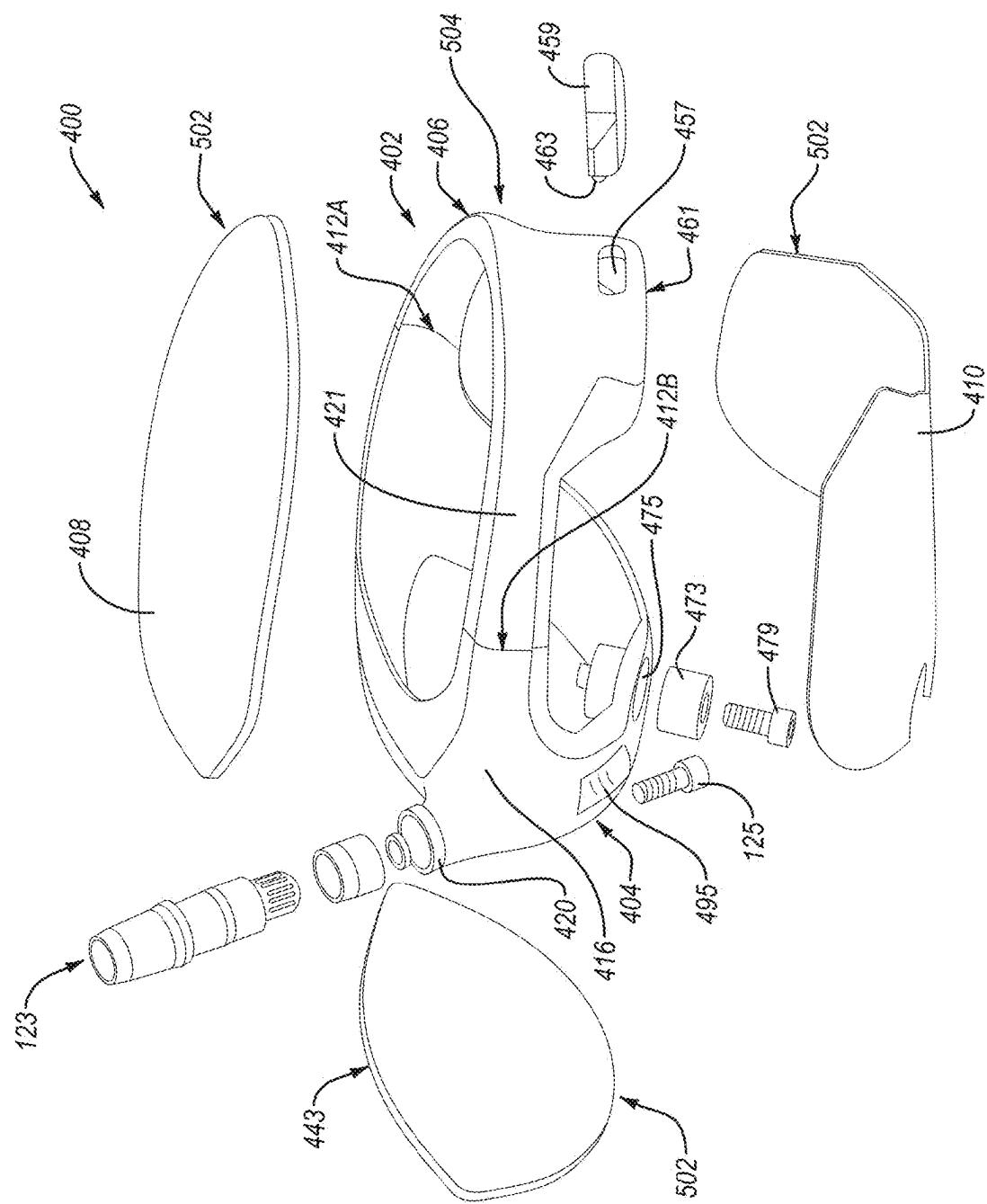


FIG. 20

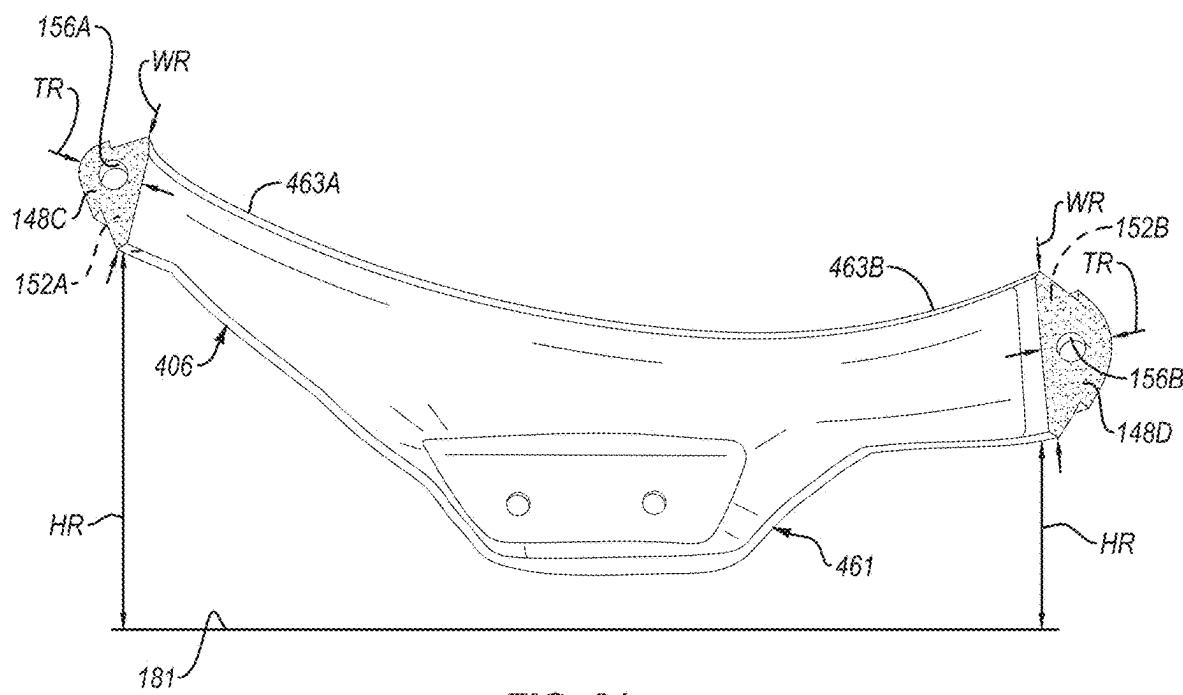


FIG. 21

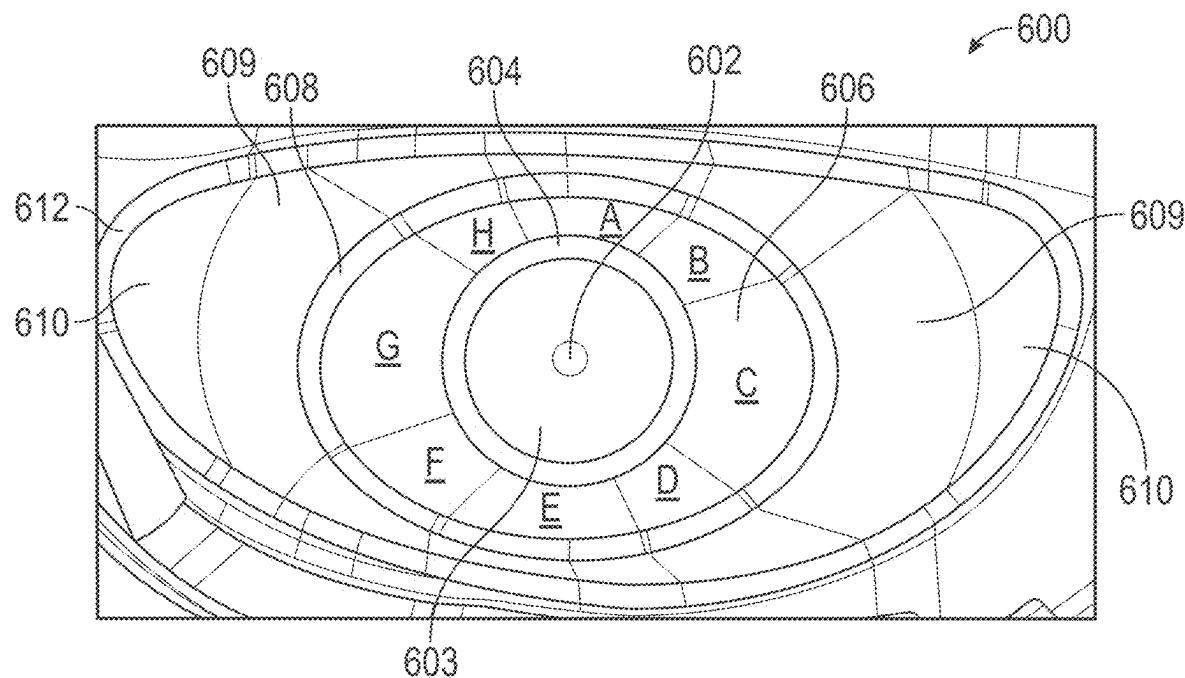


FIG. 22

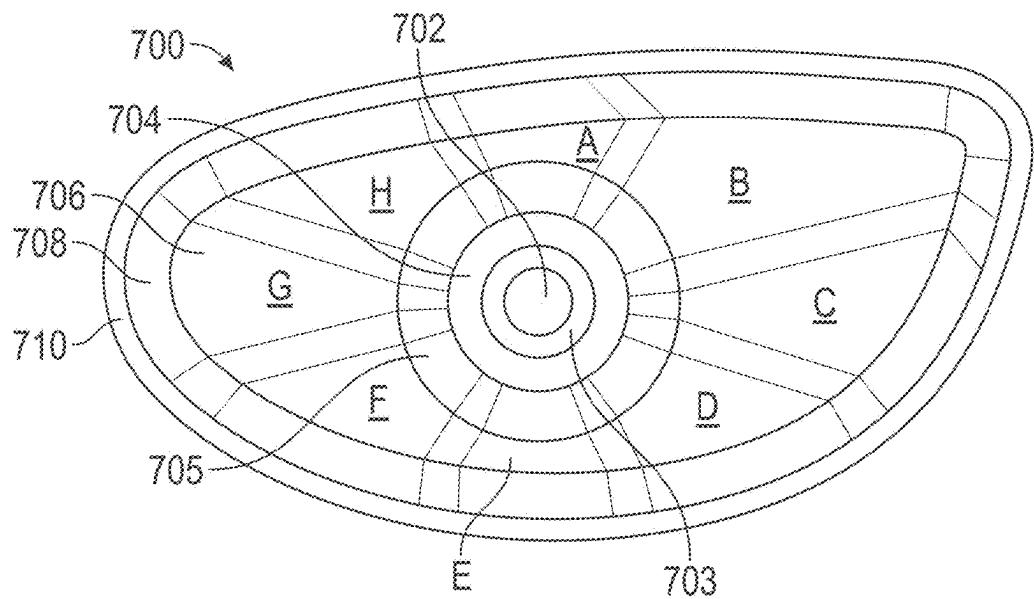


FIG. 23

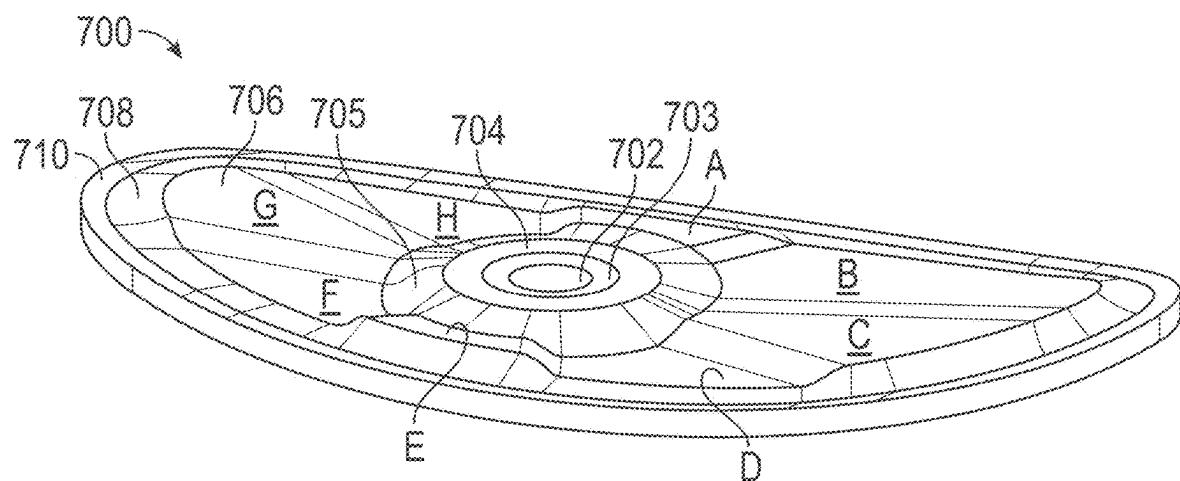


FIG. 24

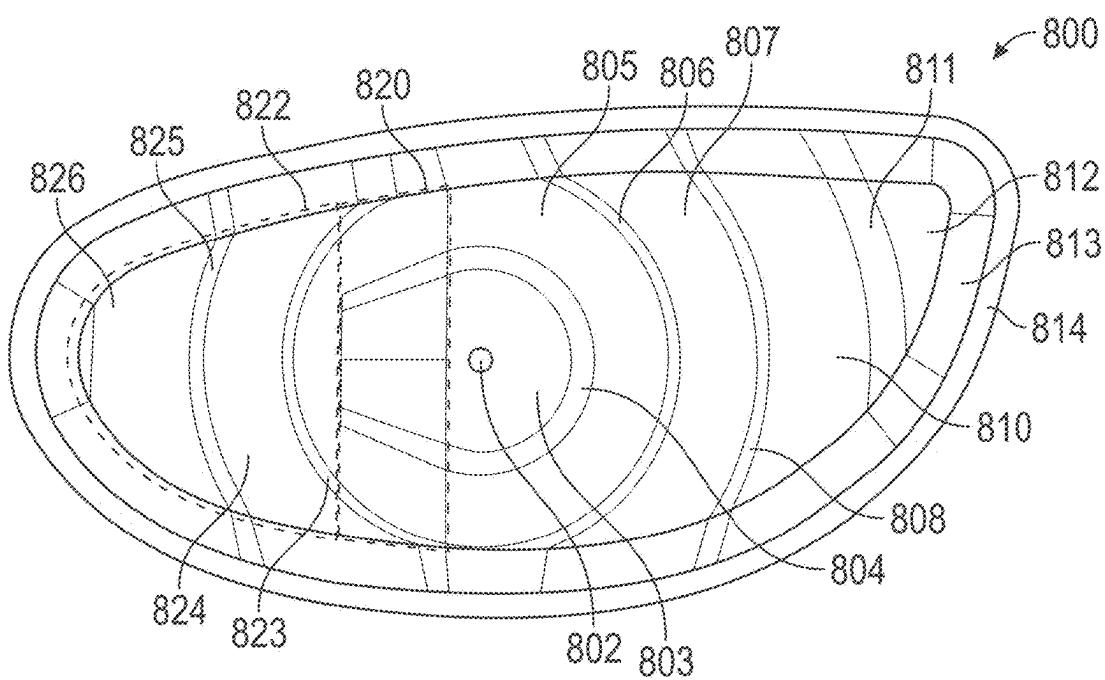


FIG. 25

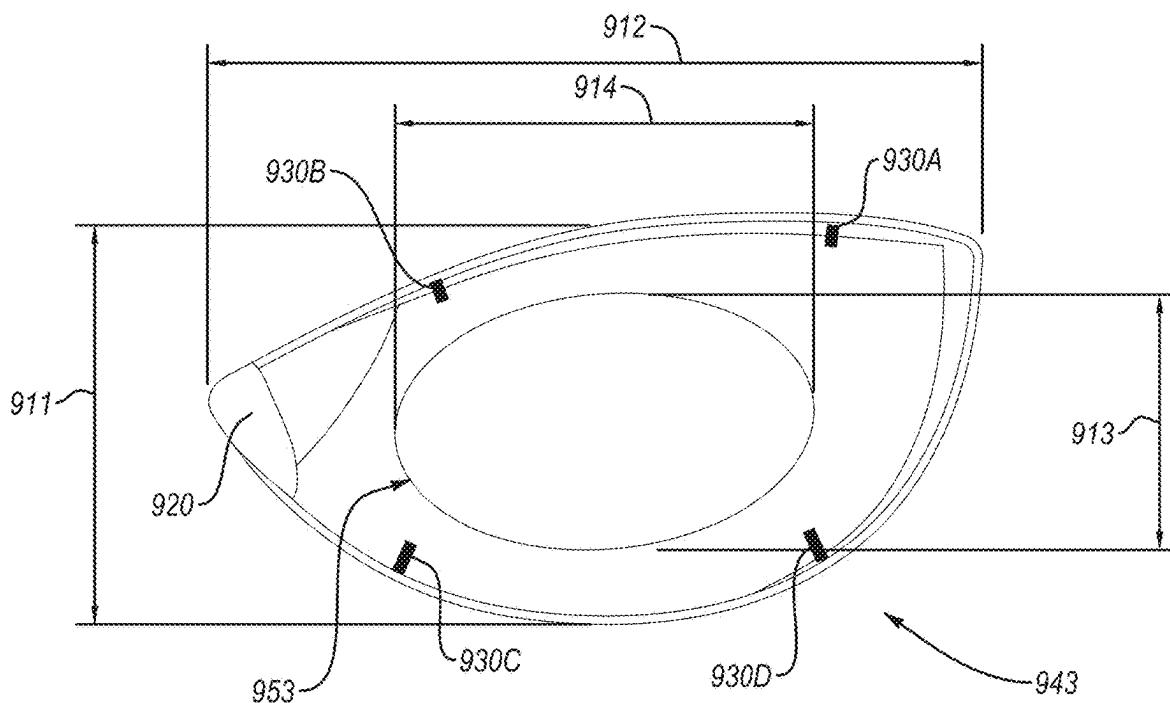


FIG. 26

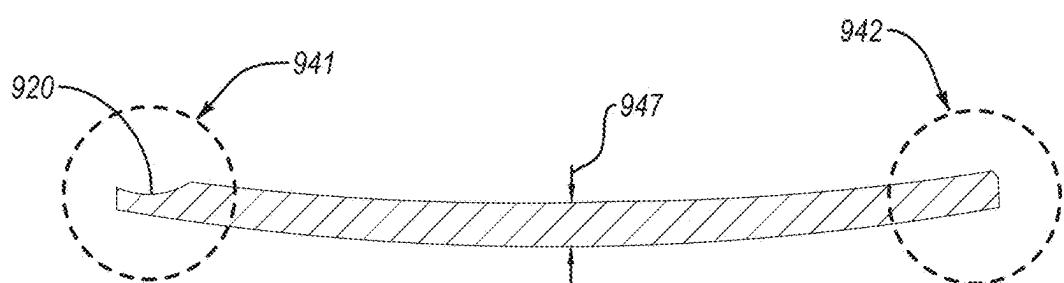


FIG. 27

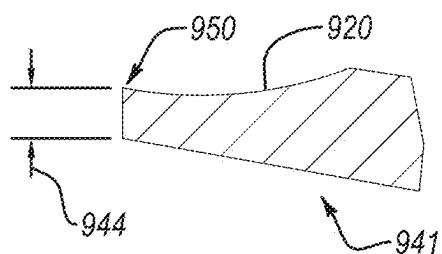


FIG. 28A

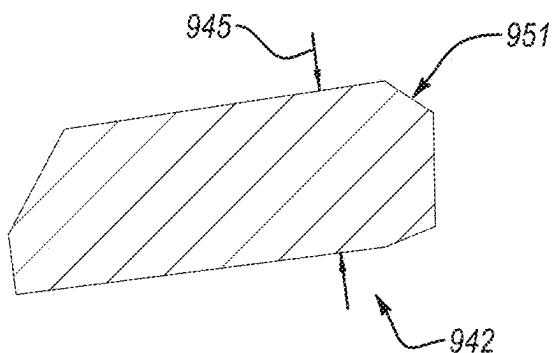


FIG. 28B

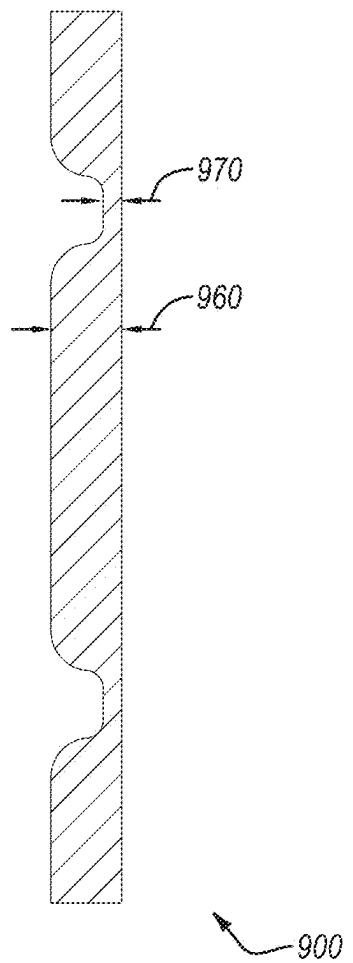


FIG. 29

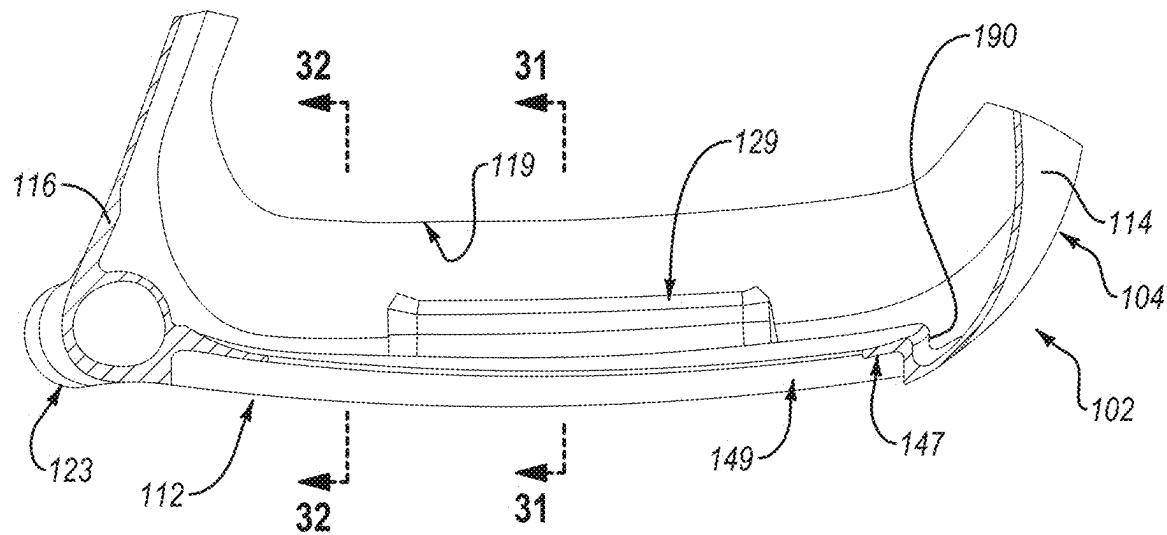


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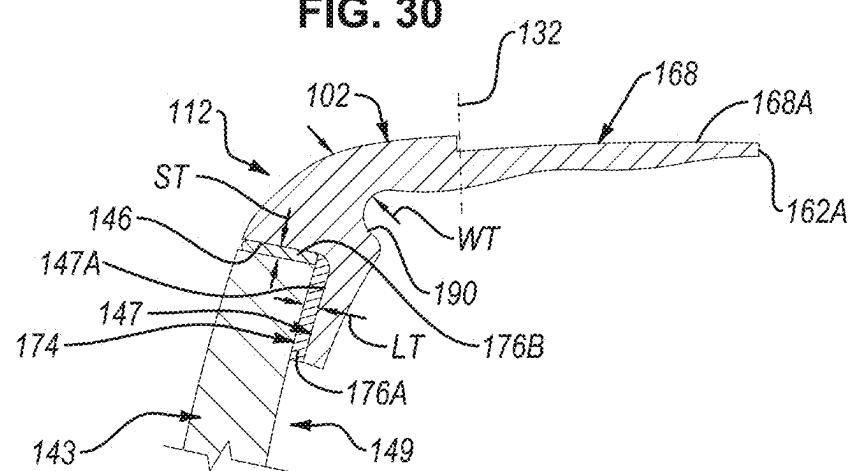


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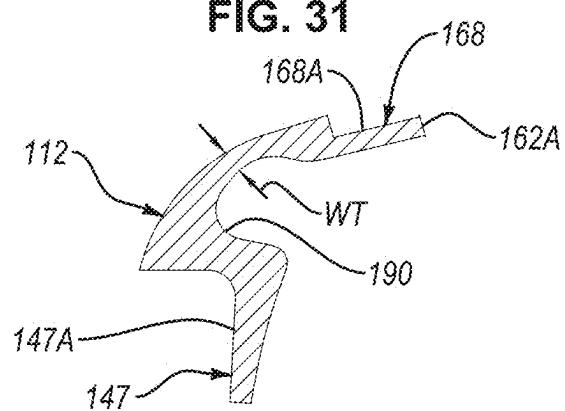


FIG. 32

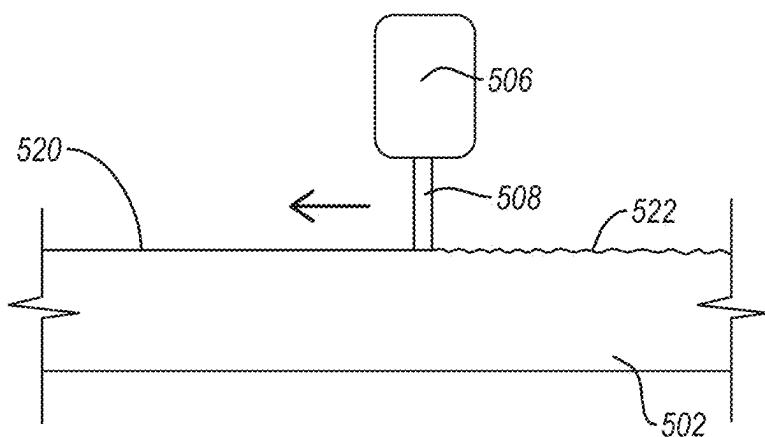


FIG. 33

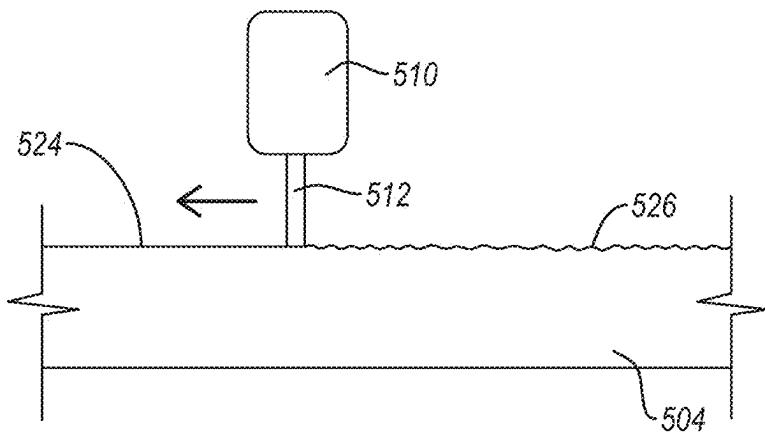


FIG. 34

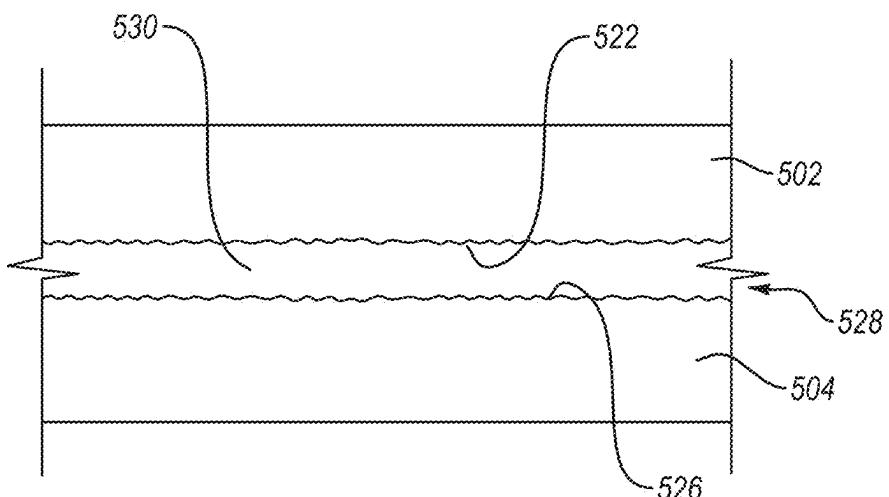
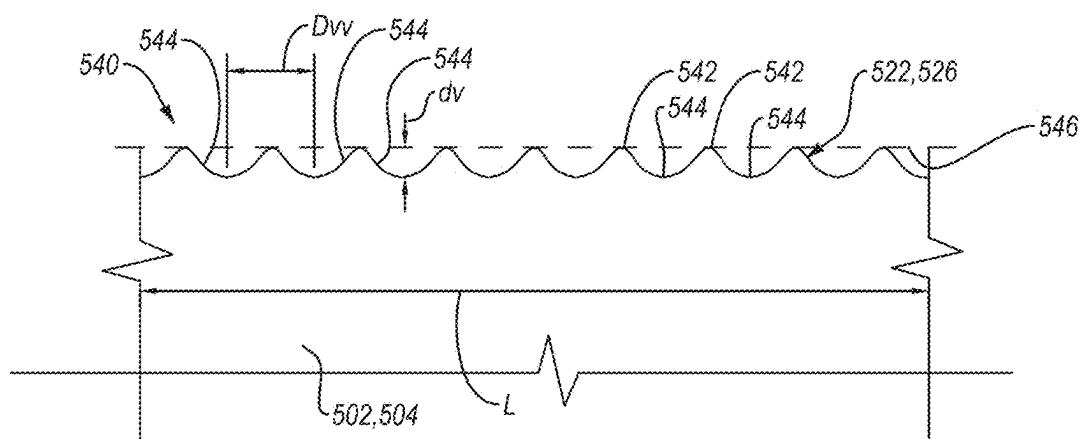
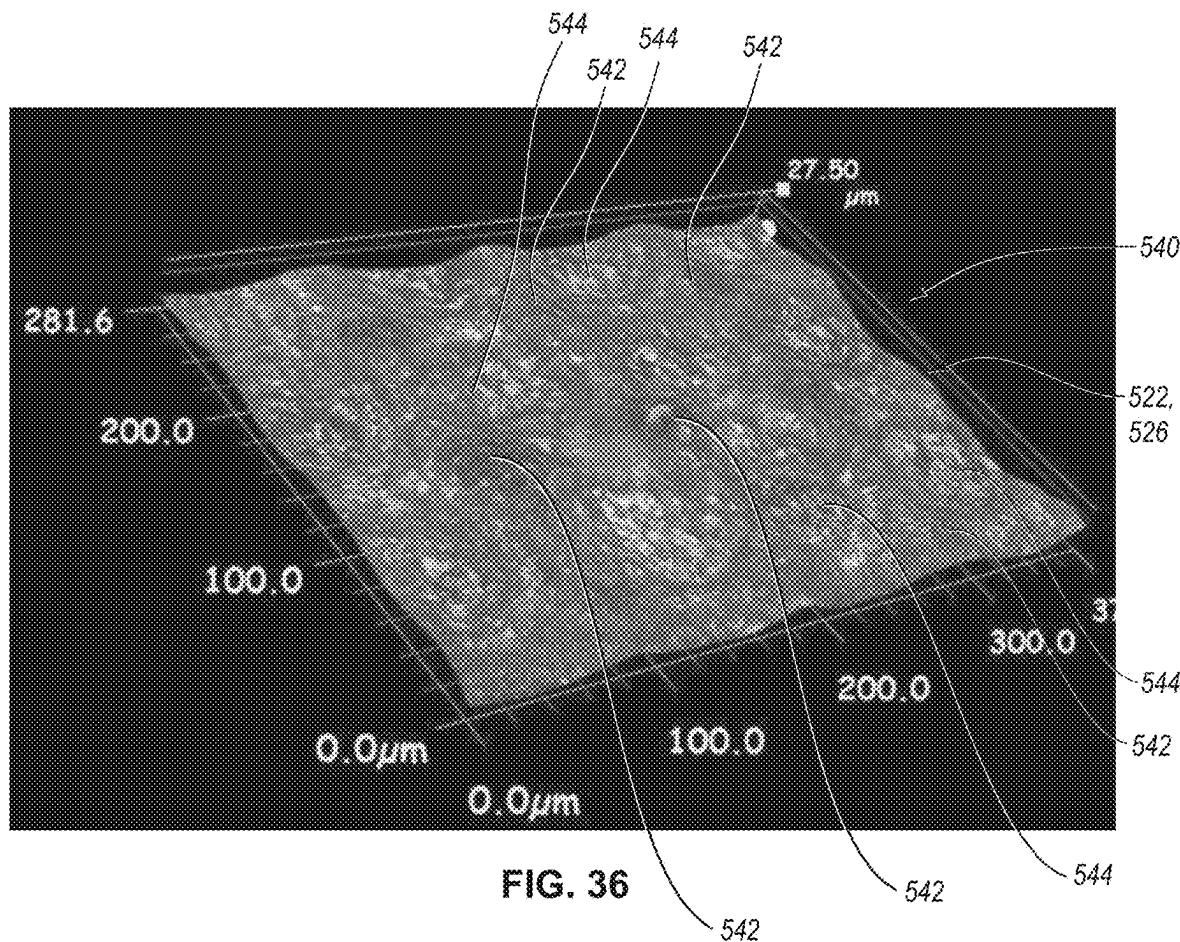


FIG. 35



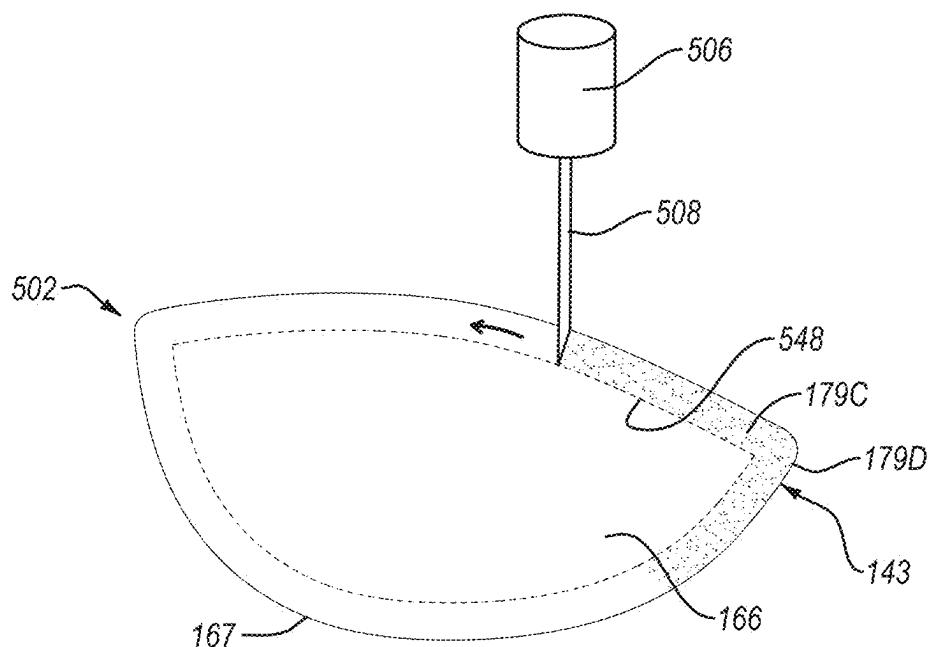


FIG. 38

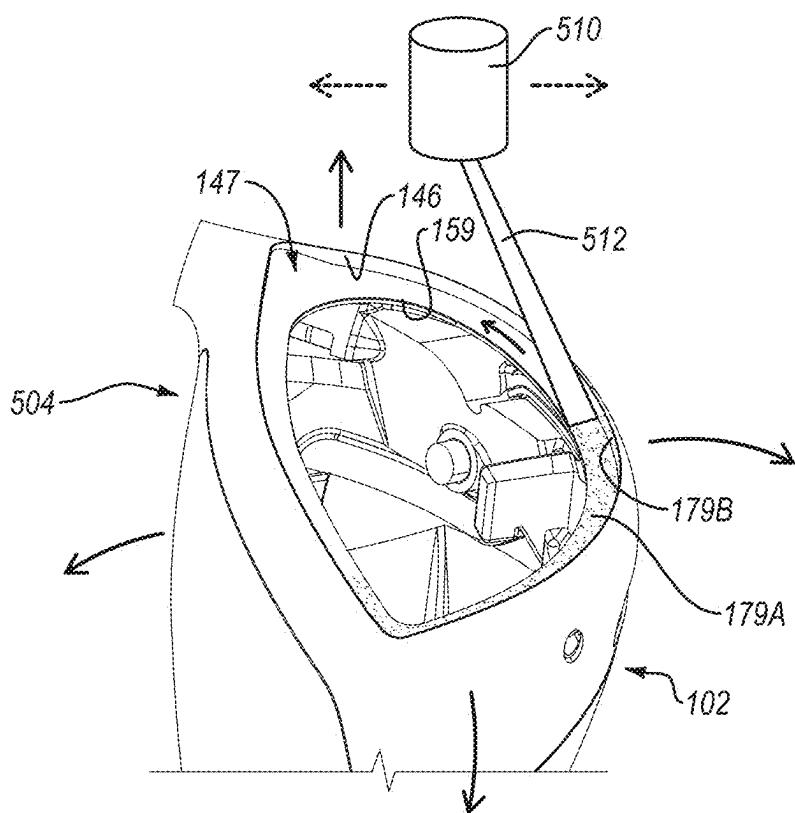


FIG. 39

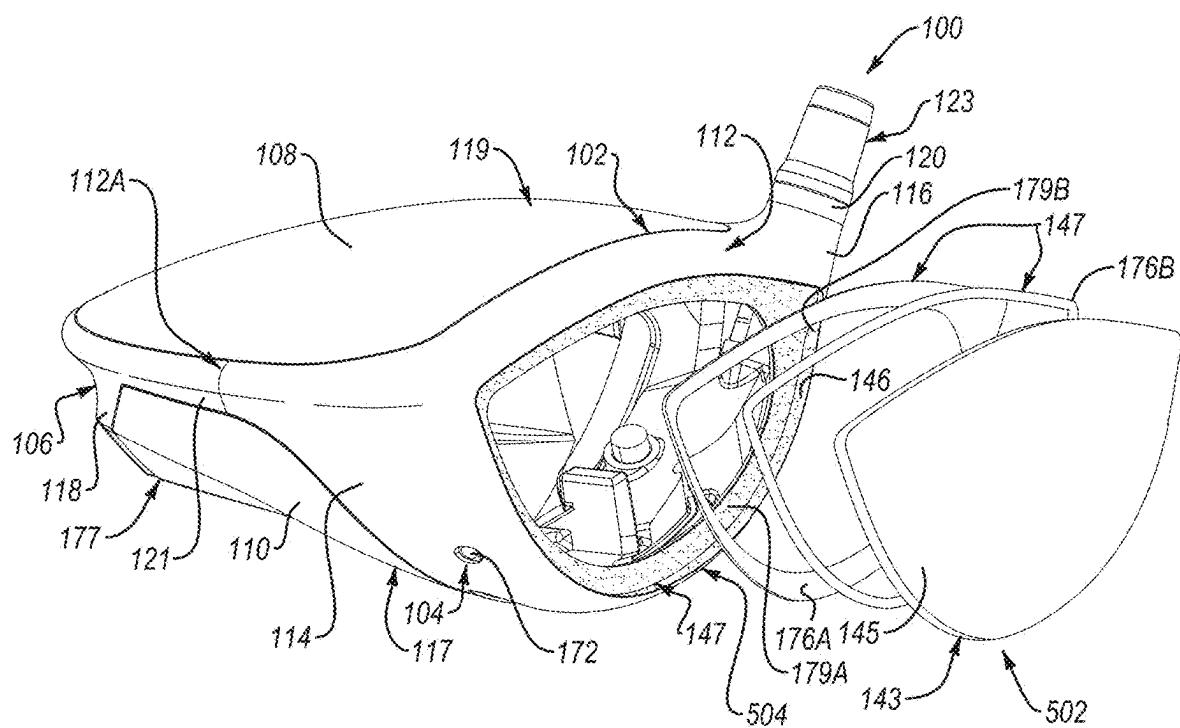


FIG. 40

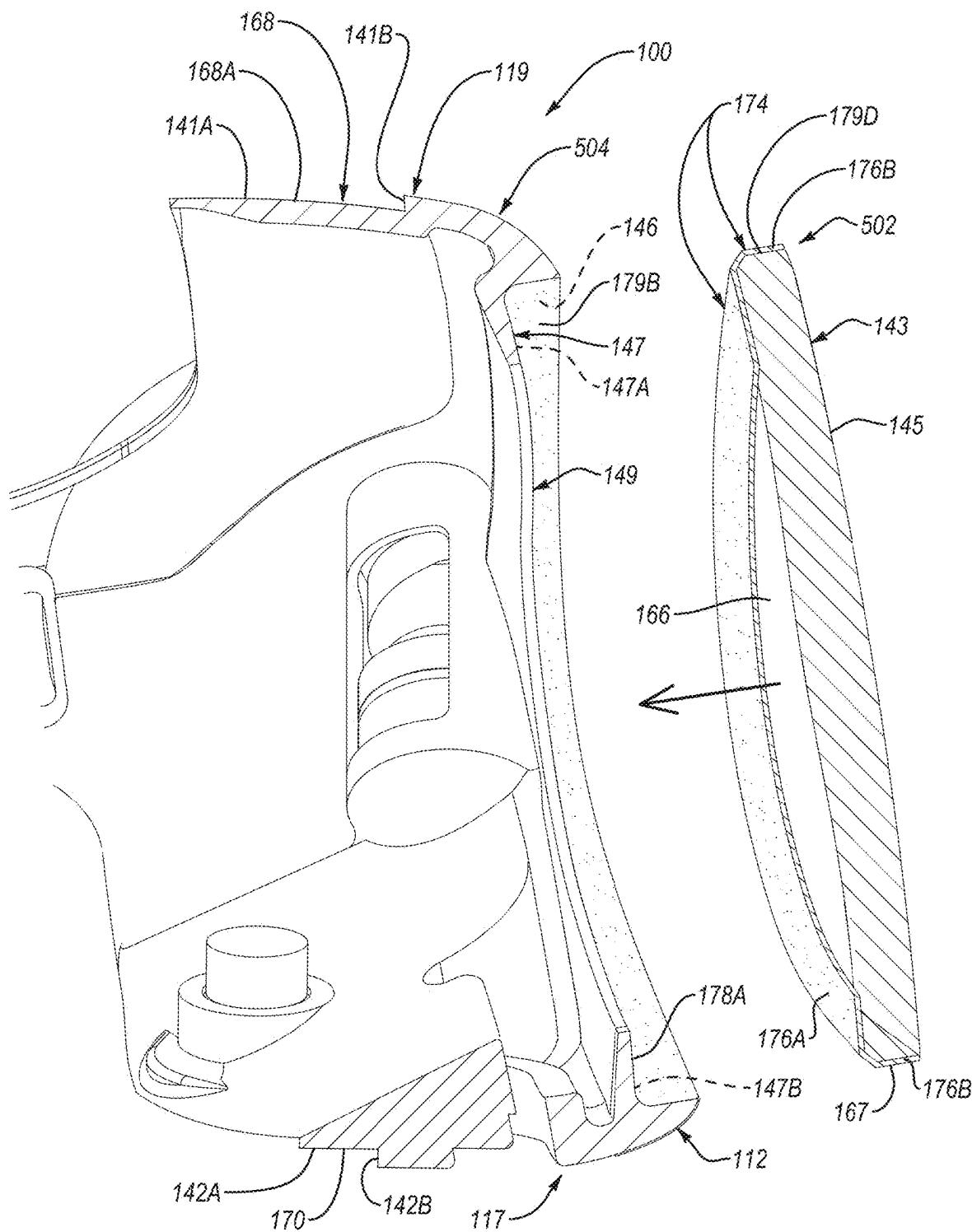


FIG. 41

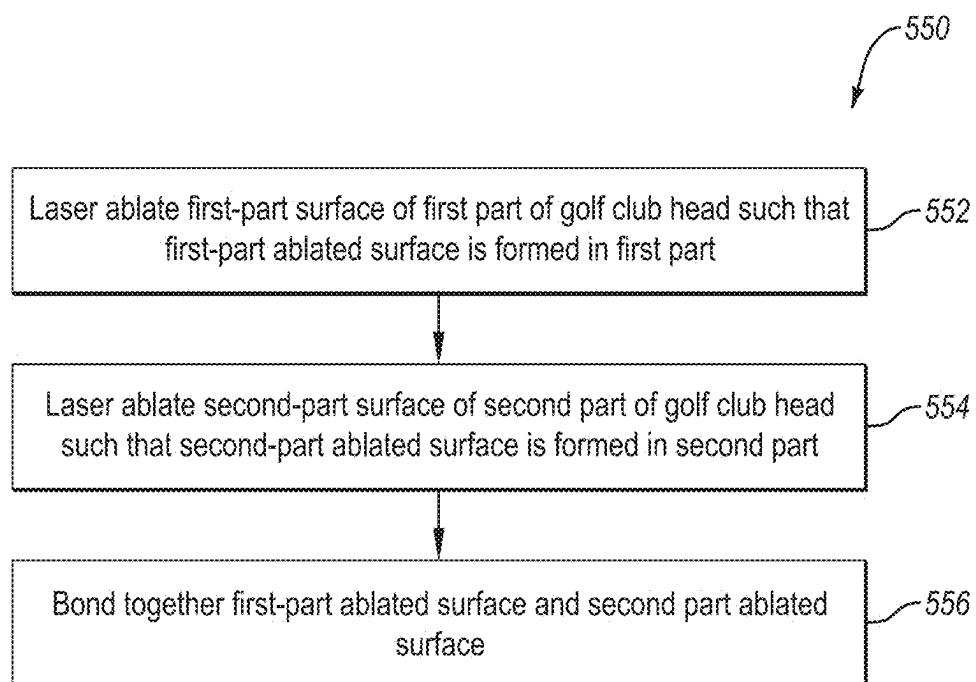


FIG. 42

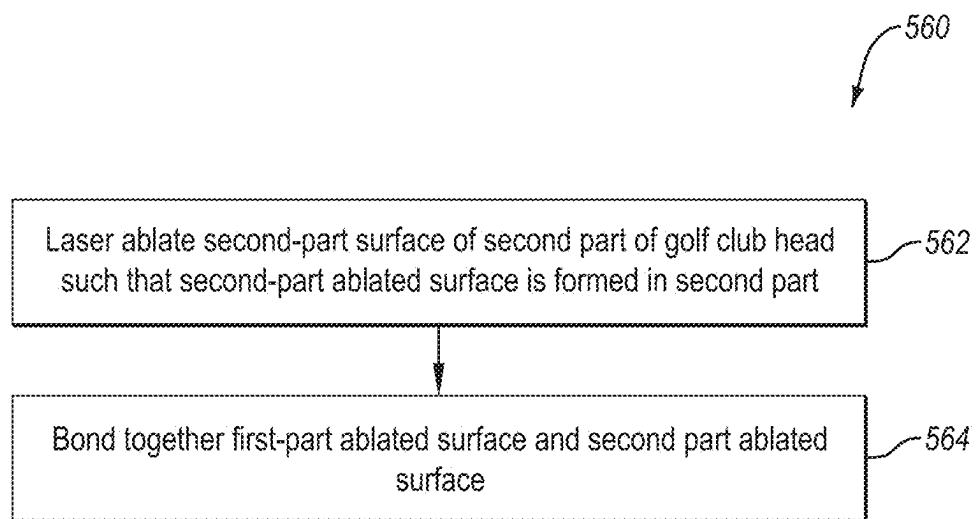


FIG. 43

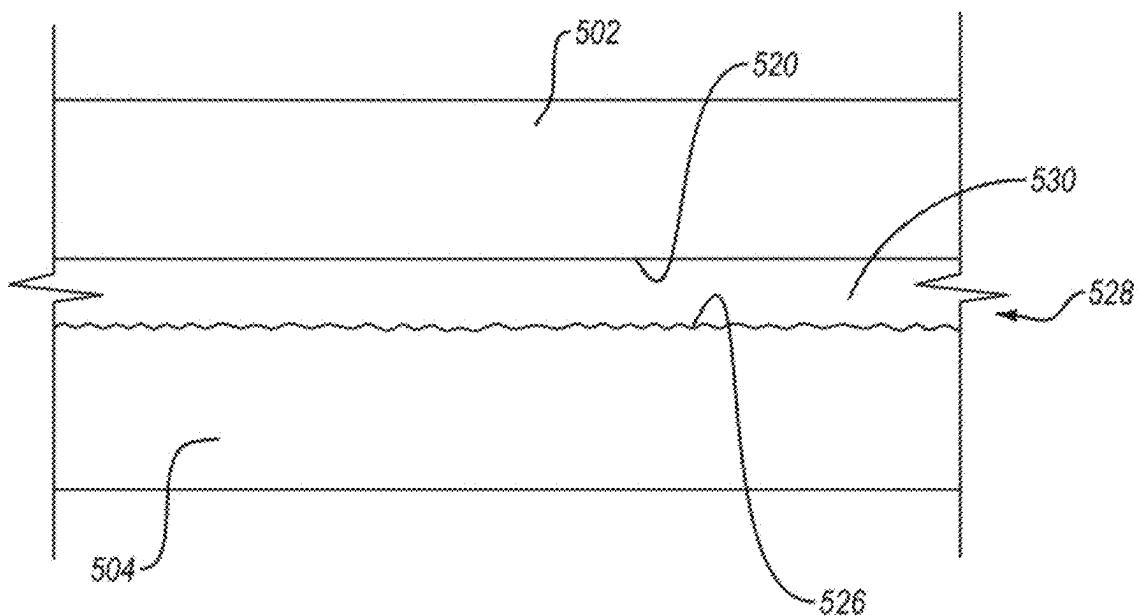


FIG. 44

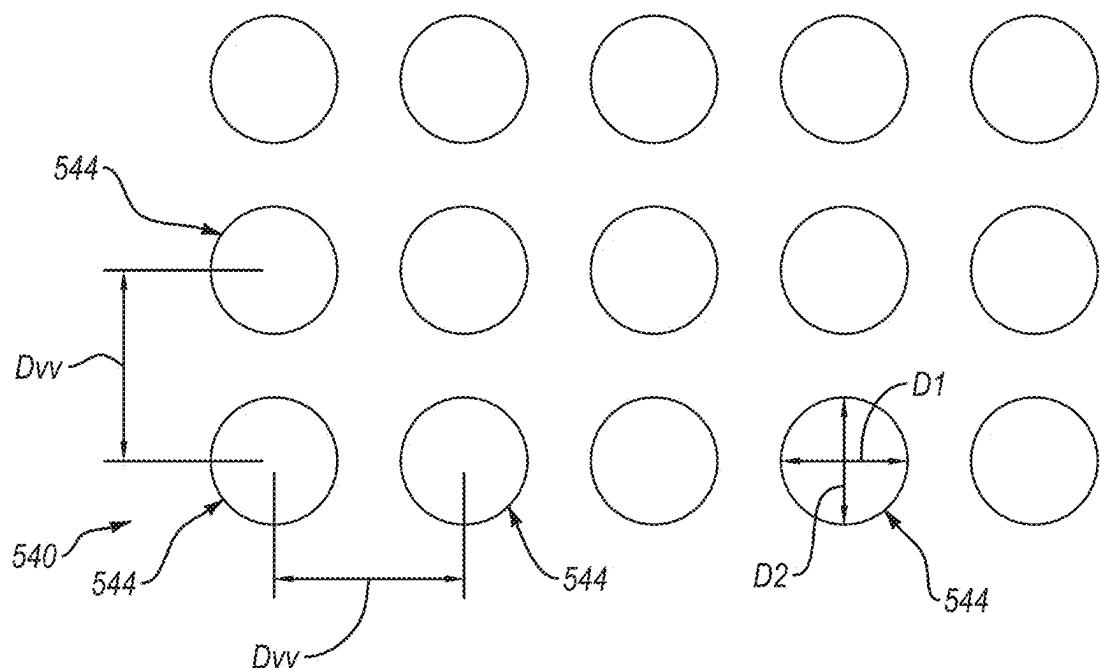


FIG. 45

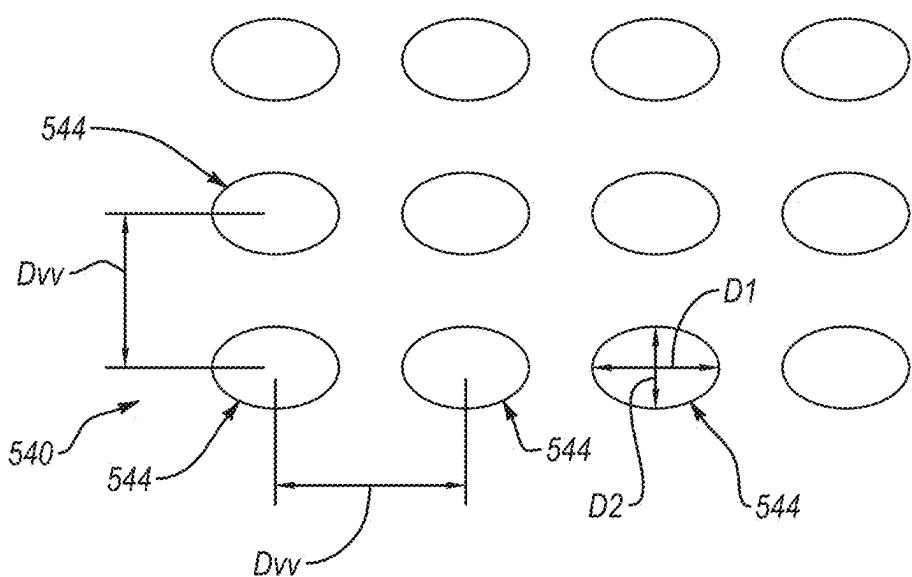
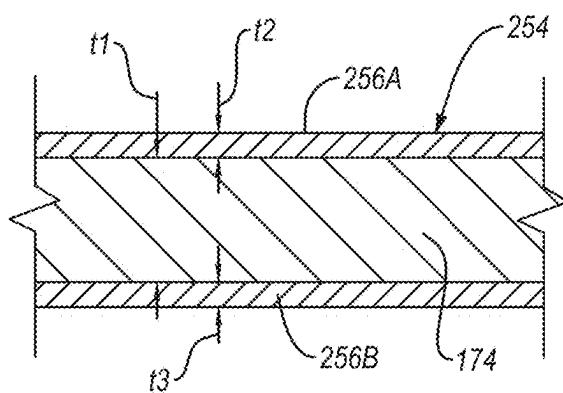
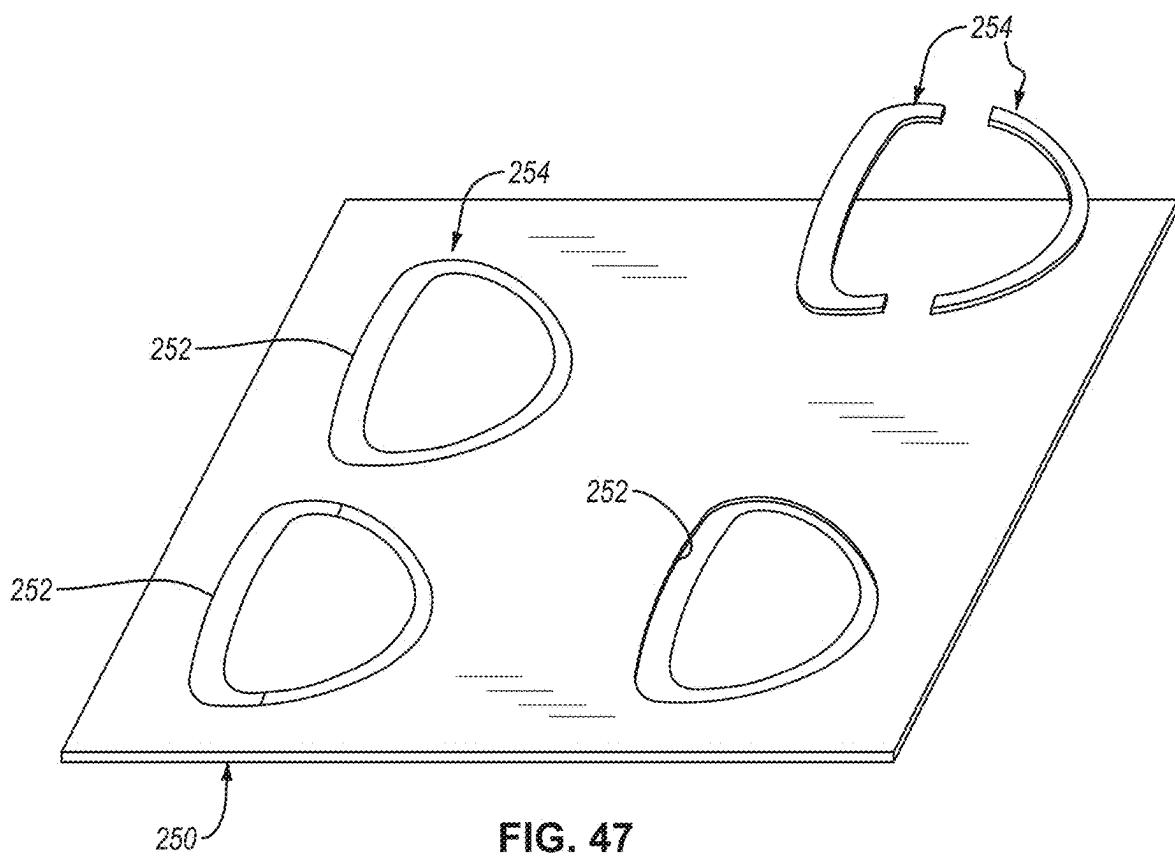


FIG. 46



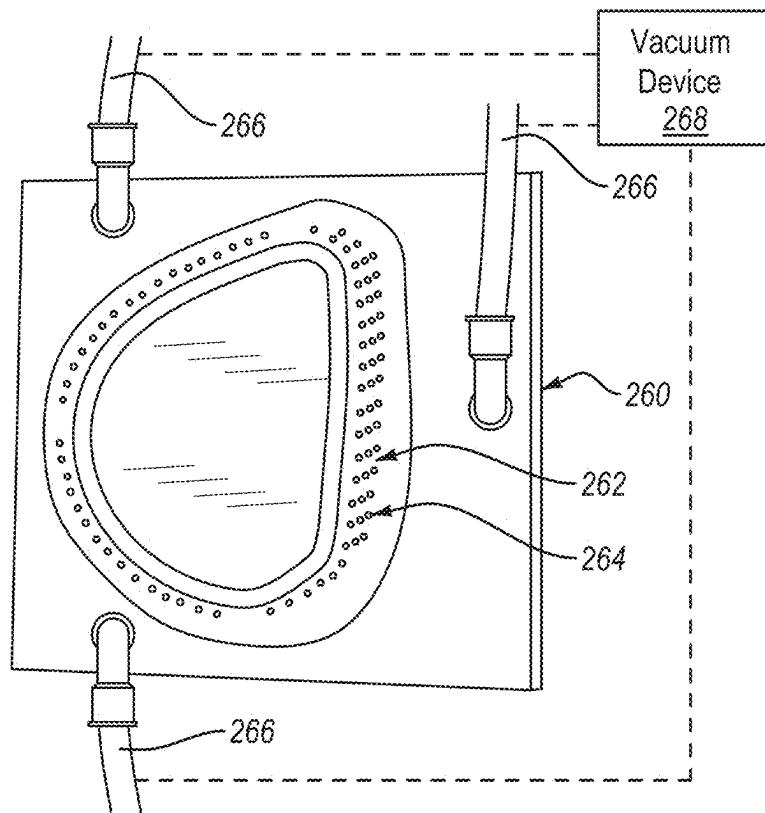


FIG. 49

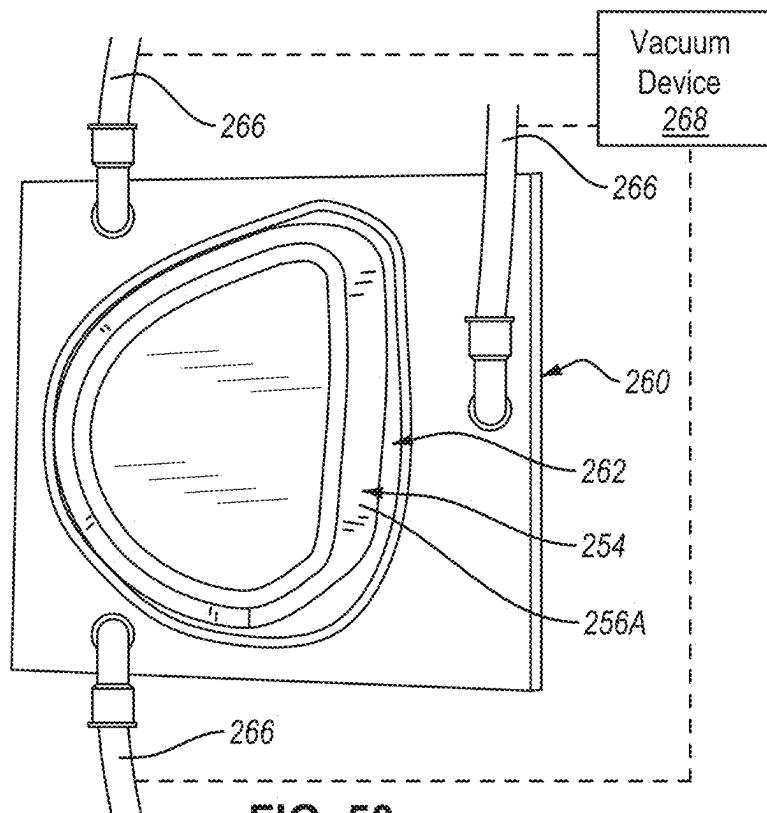


FIG. 50

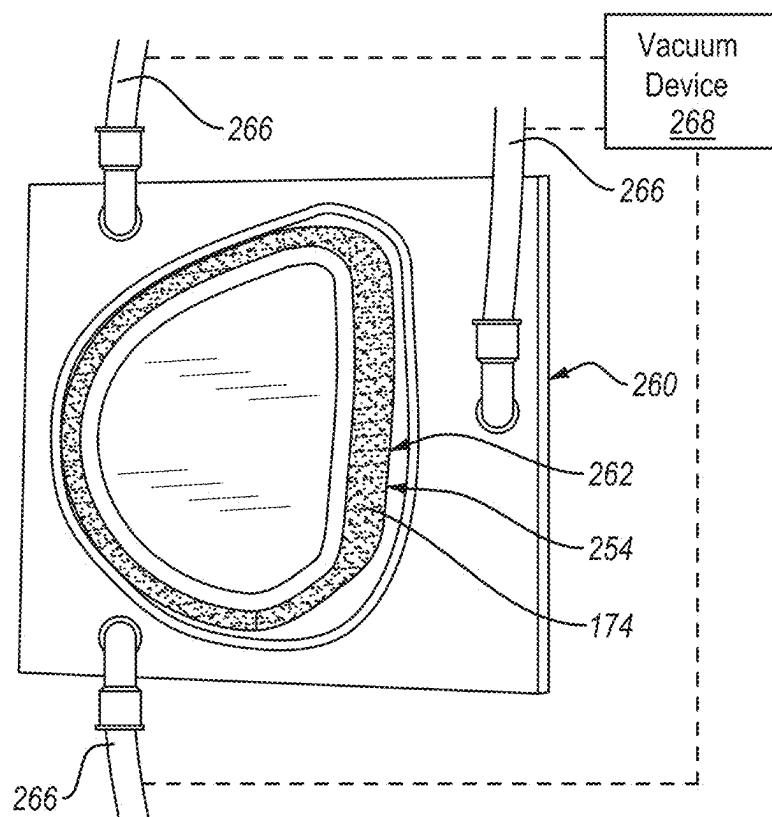


FIG. 51

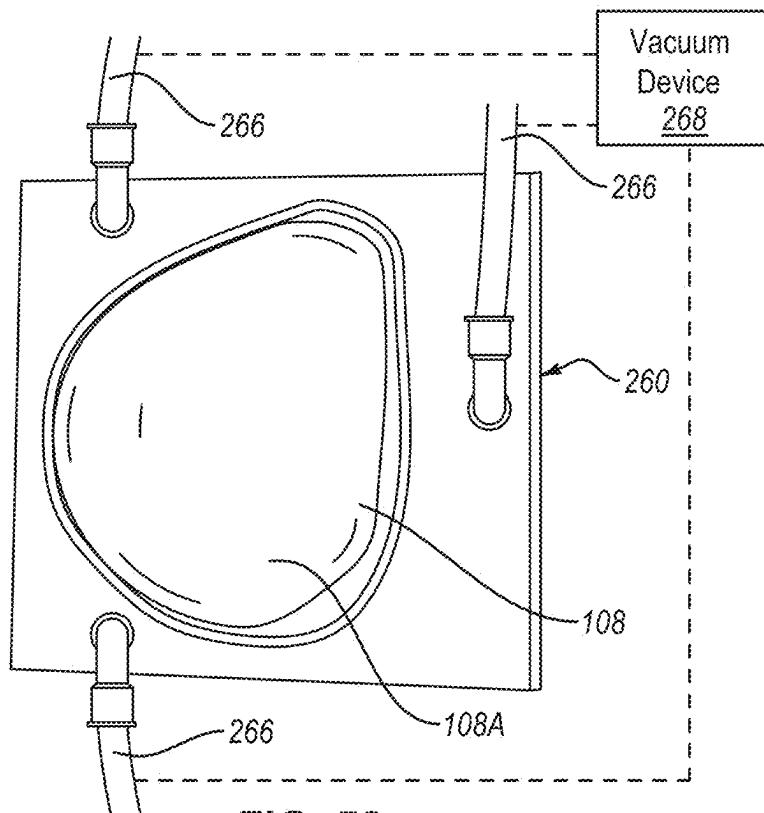


FIG. 52

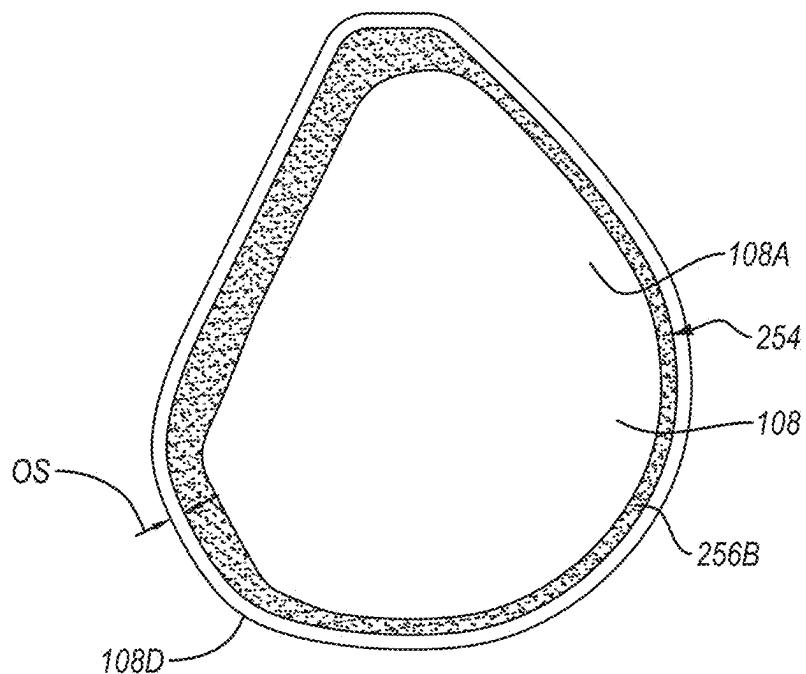


FIG. 53

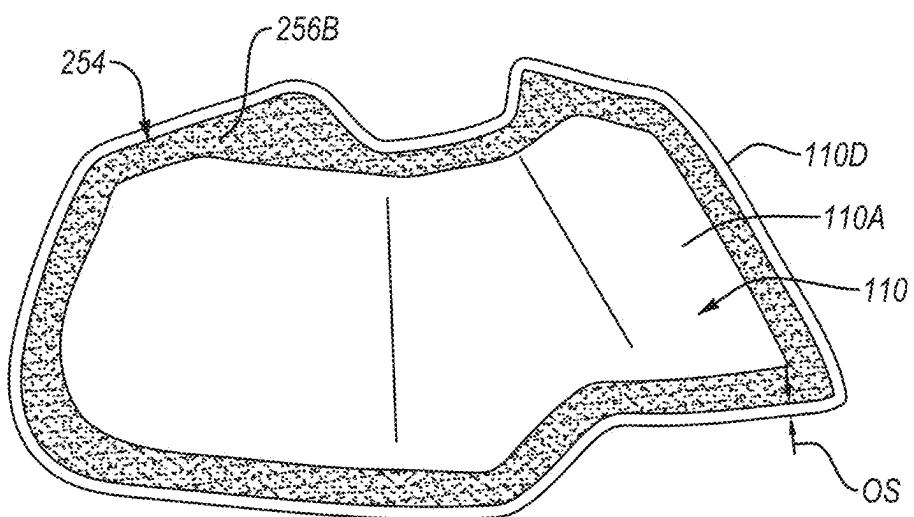


FIG. 54

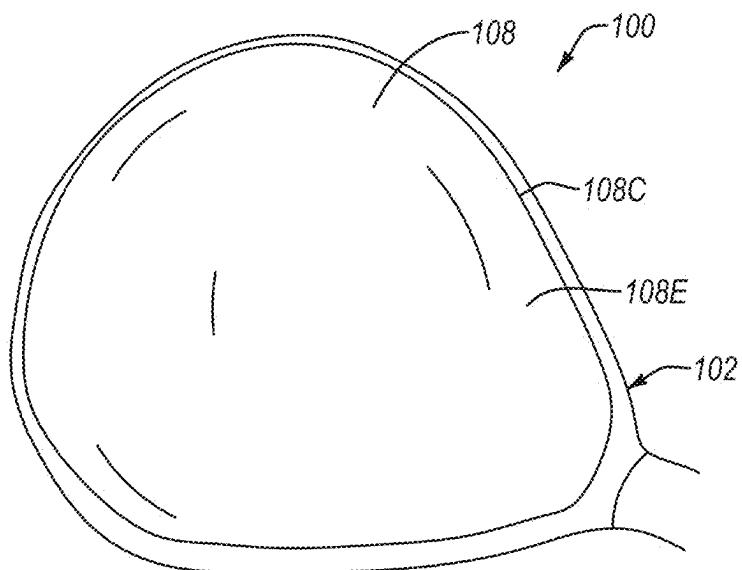


FIG. 55

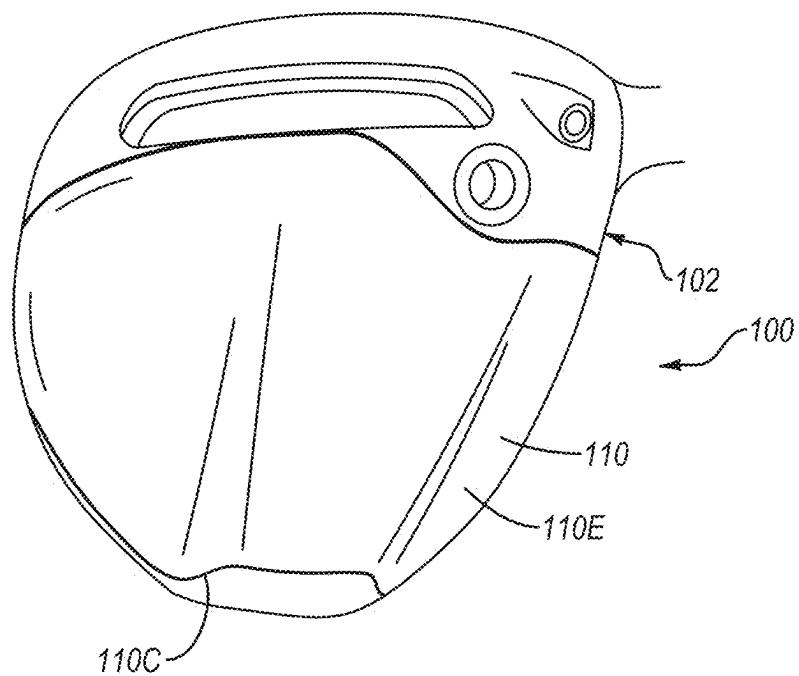


FIG. 56

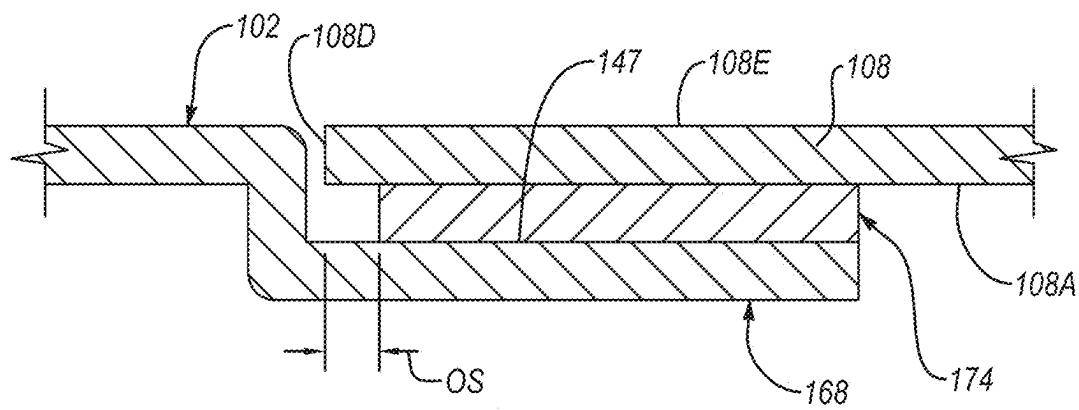


FIG. 57A

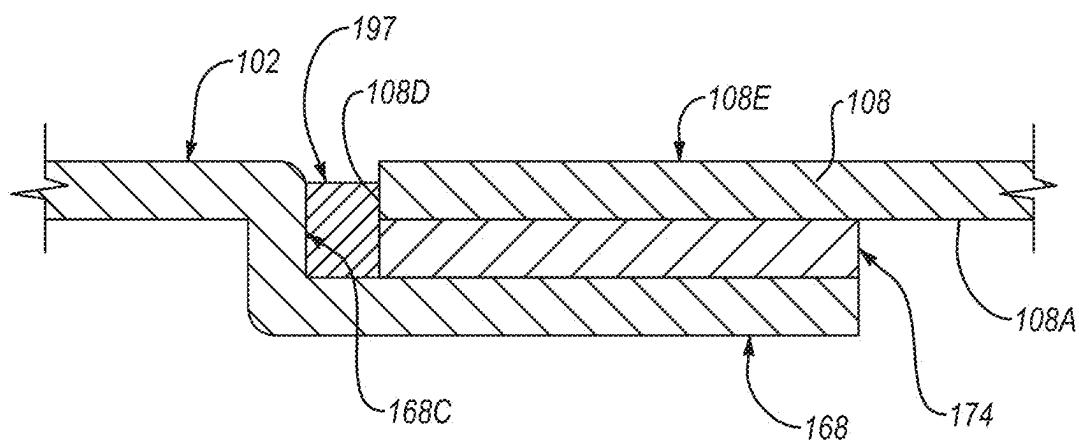
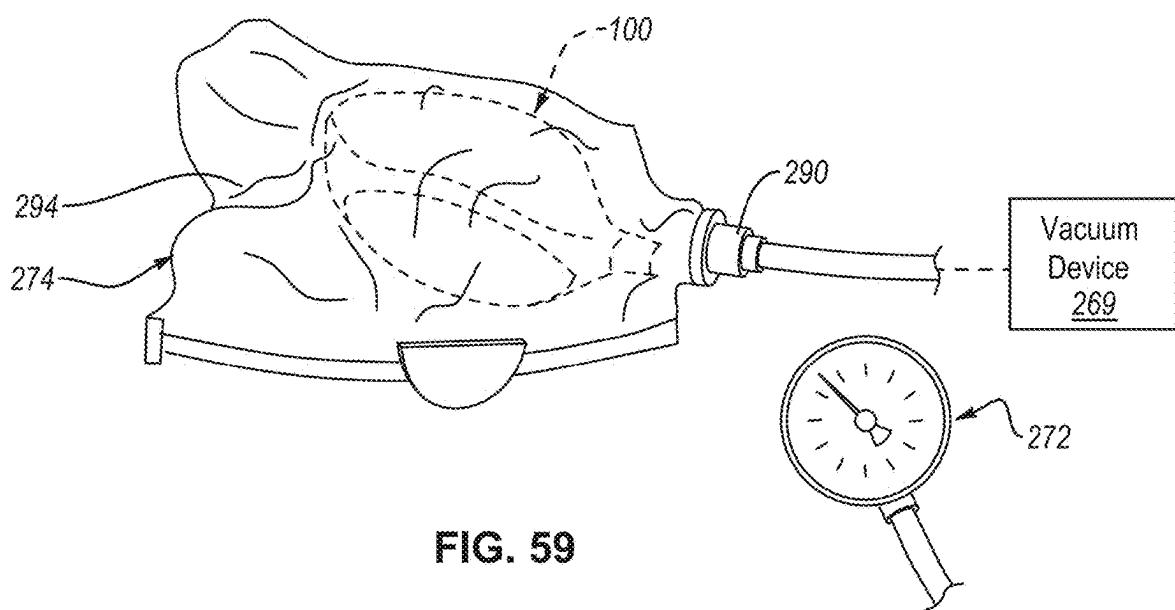
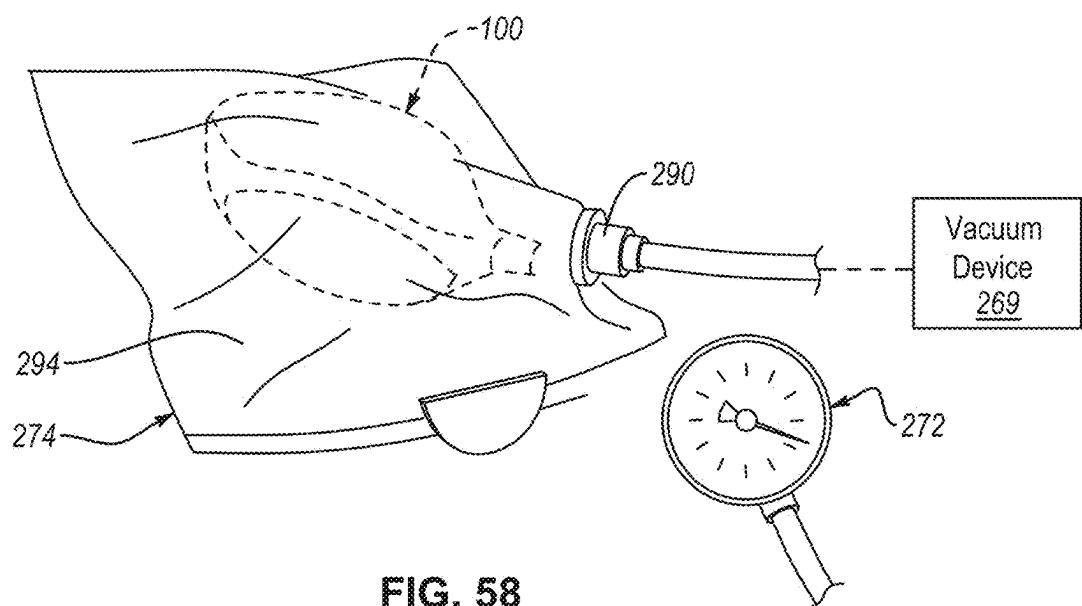
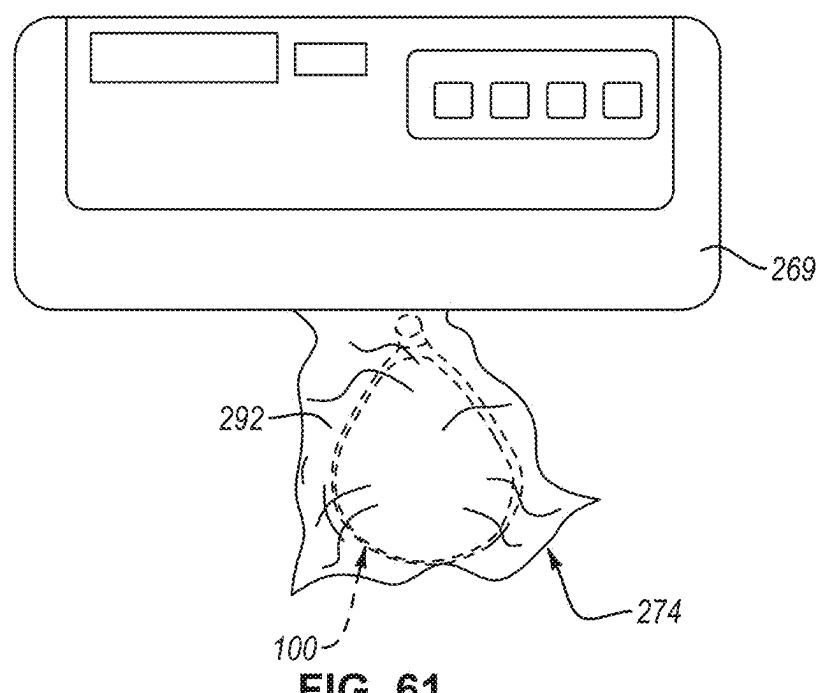
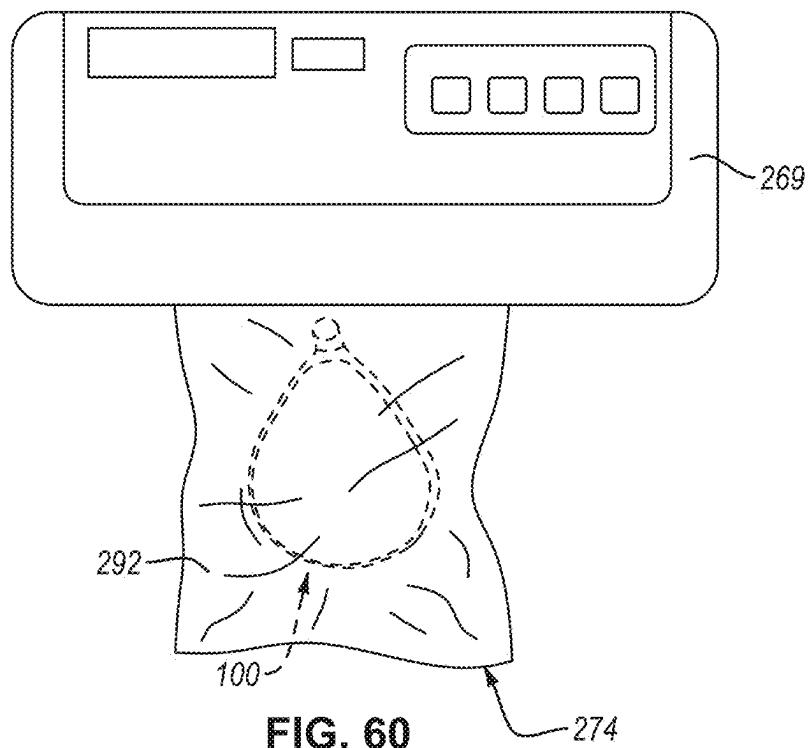


FIG. 57B





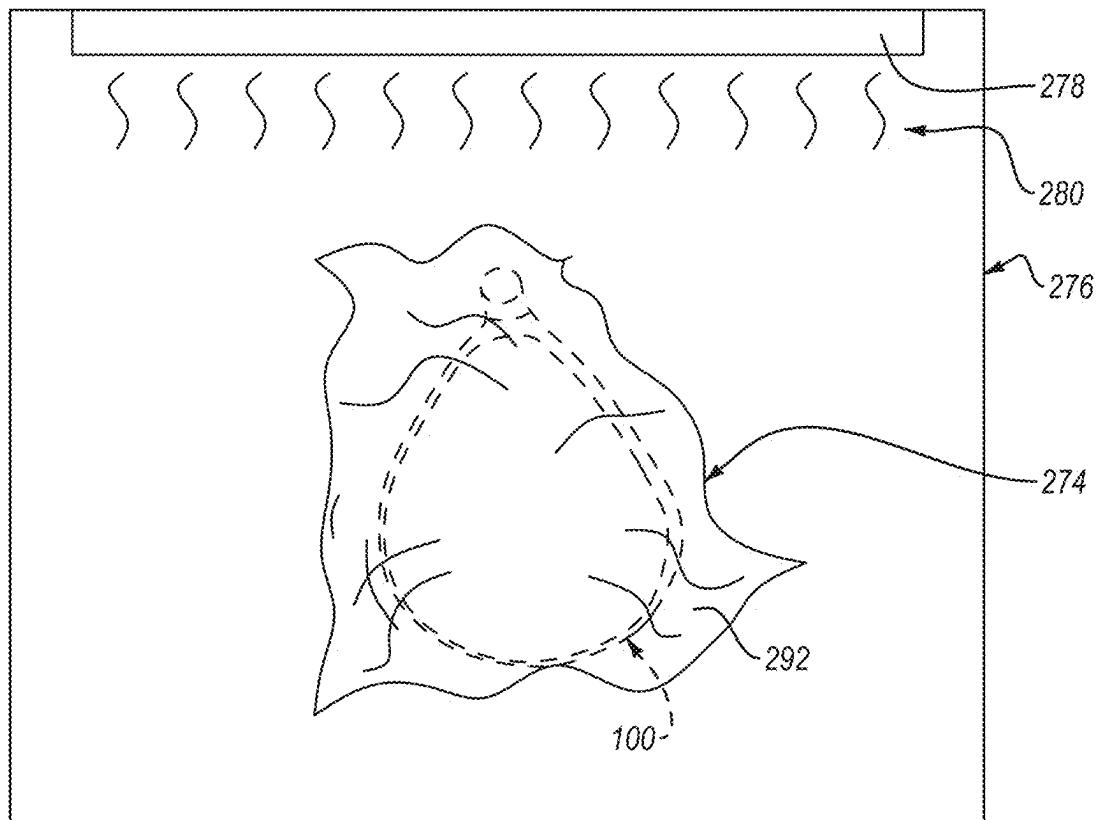


FIG. 62

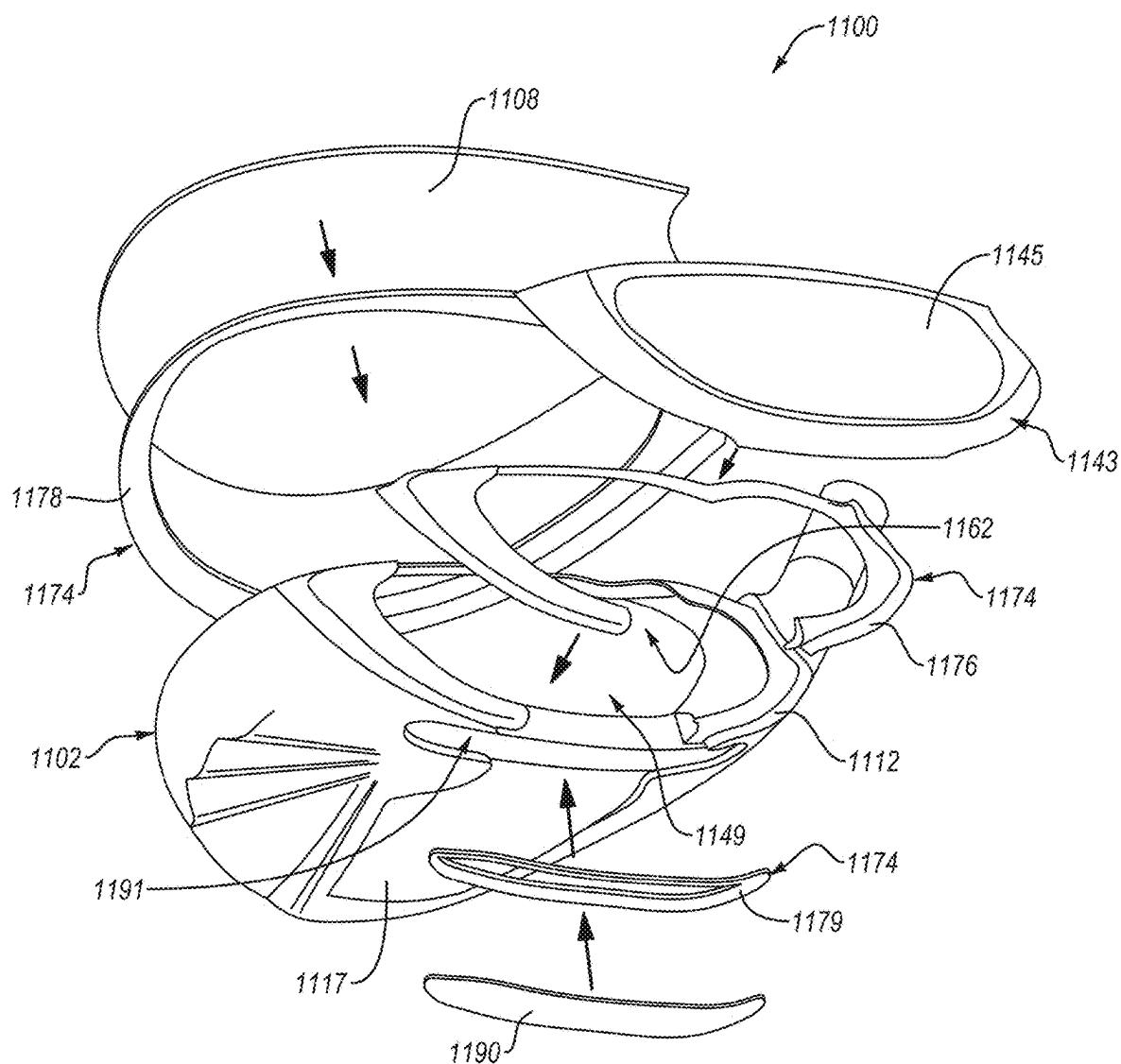


FIG. 63

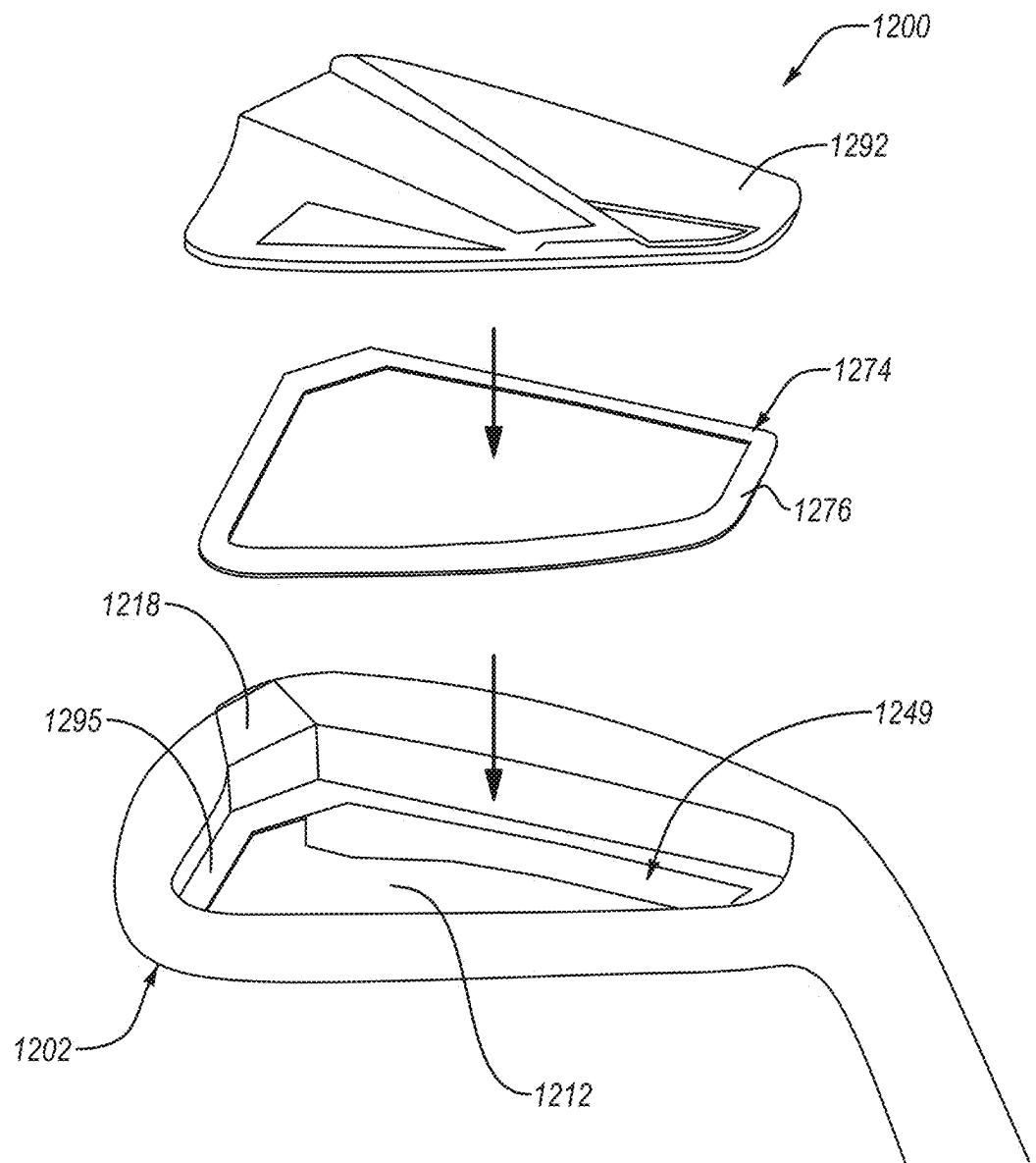


FIG. 64

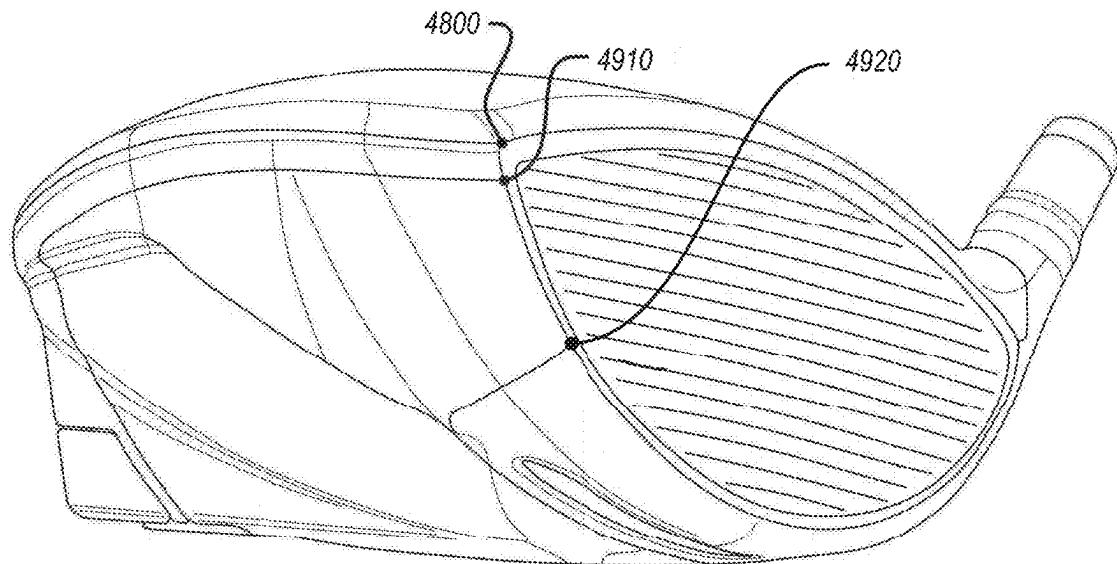


FIG. 65

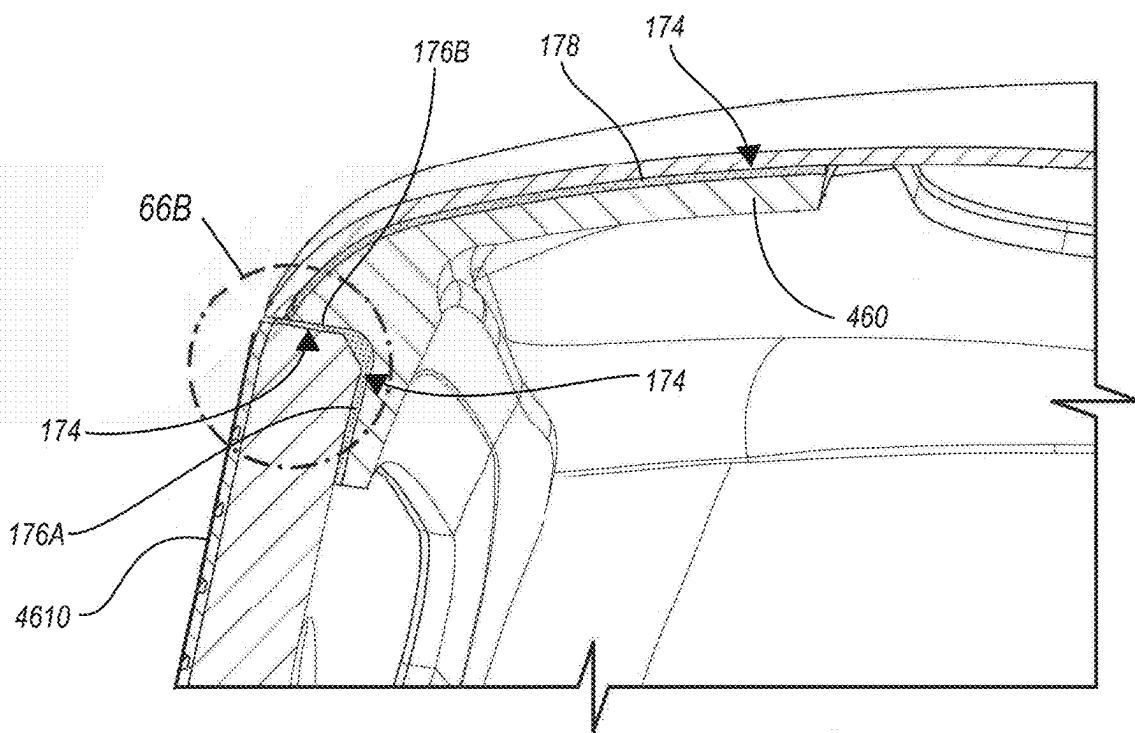


FIG. 66A

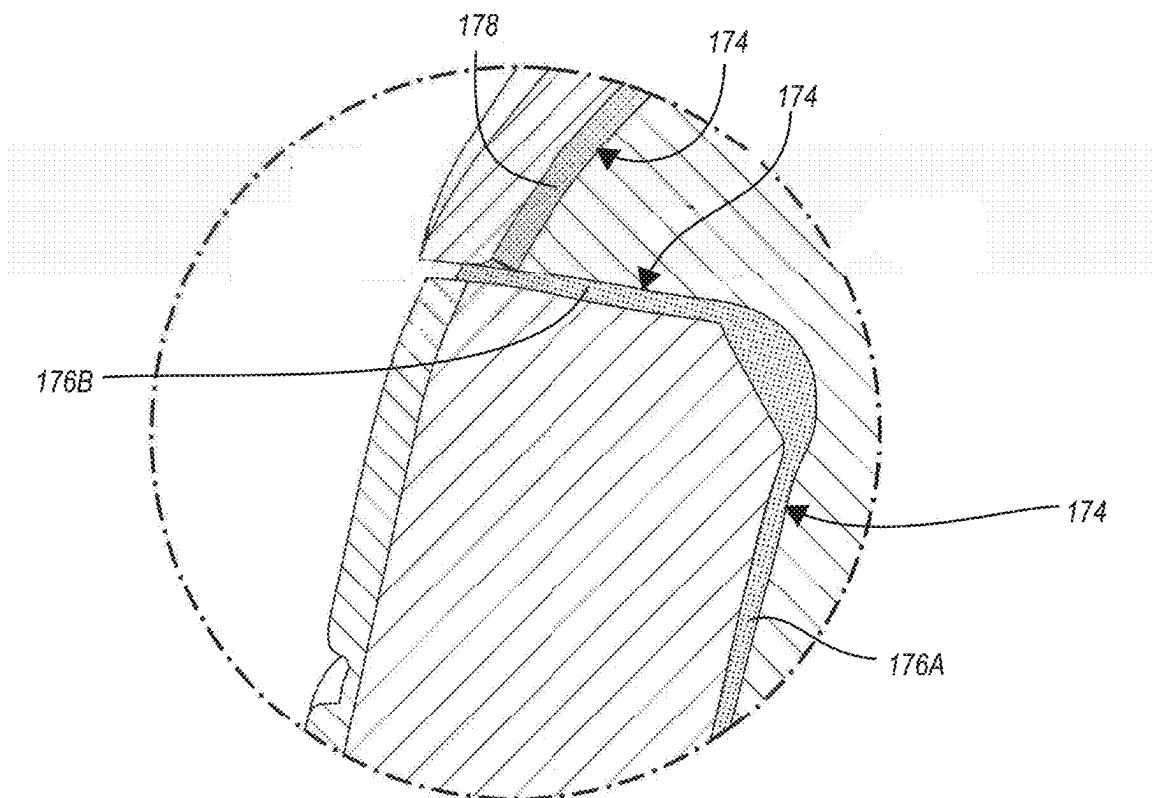


FIG. 66B

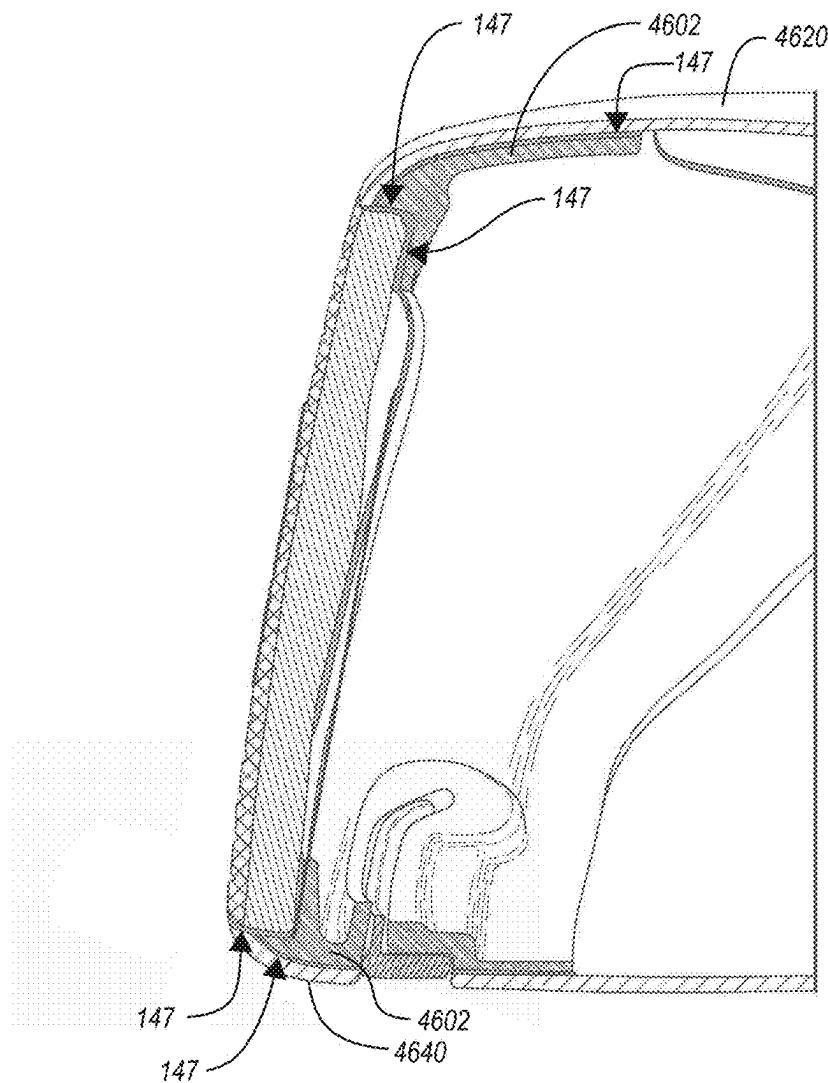


FIG. 67

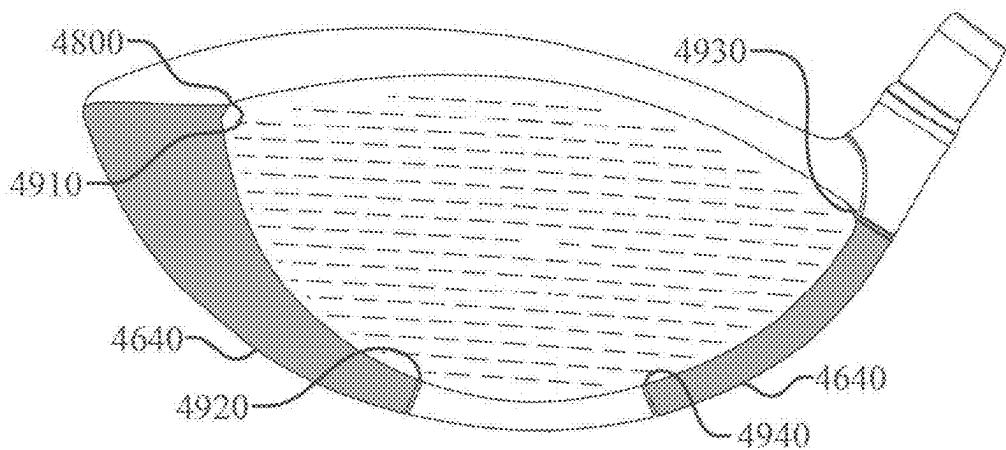


FIG. 68

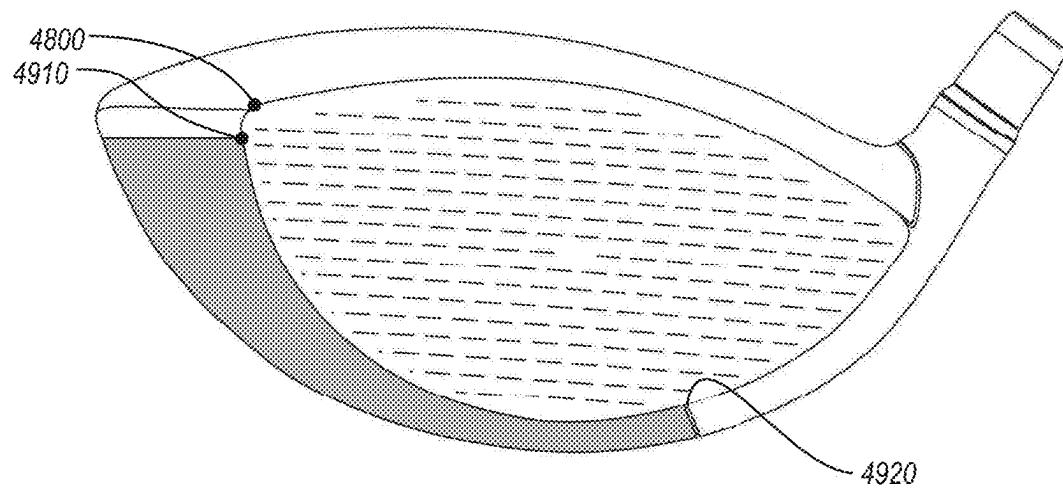


FIG. 69

MULTI-PIECE GOLF CLUB HEAD**CROSS-REFERENCE TO RELATED APPLICATION**

[0001] This application claims the benefit of U.S. patent application Ser. No. 18/323,935, filed on May 25, 2023, which claims the benefit of U.S. Provisional Patent Application No. 63/345,875, filed on May 25, 2022, which is herein incorporated by reference in its entirety.

FIELD

[0002] This disclosure relates generally to golf clubs, and more particularly to a golf club head constructed of multiple parts adhesively bonded together.

BACKGROUND

[0003] In the early history of golf, golf club heads were made primarily of a single material, such as wood. Subsequently, golf club heads progressed away from a construction made primarily from wood to one made primarily of metal. Initial golf club heads made of metal were made of steel alloys. Over time, golf club heads started to be made of titanium alloys. Some, but not all, golf club head manufacturers have transitioned away from use of a single material to a multi-material and multi-piece construction. The use of multiple pieces and the use of multiple materials can provide various manufacturing and performance advantages. The multiple pieces of a multi-piece golf club head can be bonded together in a variety of ways, such as adhesive bonding and welding.

[0004] Often, the strength of the bond between bonded pieces of a multi-piece golf club head affects the durability of the golf club head and thus the performance of the golf club head over time. A weak bond tends to accelerate degradation of the bond as the golf club head is used to impact golf balls. Degradation in a bond between bonded pieces can lead to a diminution of the performance of the golf club head, such as via a reduction in stiffness and lack of proper load transfer, at best, and complete failure of the golf club head, at worst. Typically, the strike face of a driver-type golf club head undergoes several thousand collisions with a golf ball through its life-cycle. Each collision imparts a force onto the strike face in the range of 10,000 g to 20,000 g, where g is equal to the force per unit mass due to gravity. Repeated impacts, at such high forces, tends to cause degradation of the bonds forming the golf club head. Accordingly, a strong initial and durable bond between bonded pieces of a golf club head is desired.

[0005] Because welding generally provides a stronger initial bond and can exhibit a higher durability compared to other bonding techniques, the pieces of many conventional multi-piece golf club heads utilize materials, such as compatible metals, that are conducive to welding. However, many metals used to construct multi-piece golf club heads have a higher mass than non-metallic materials. Therefore, the mass available to for distribution around such golf club heads (otherwise known as discretionary mass), which can be utilized for promote the performance of golf club heads, can be limited, difficult. For this reason, providing a multi-piece golf club head, which has strong and durable bonds between the pieces of the golf club head and promotes an increase in discretionary mass, can be difficult.

SUMMARY

[0006] The subject matter of the present application has been developed in response to the present state of the art, and in particular, in response to the shortcomings of golf club heads with a multi-piece construction, that have not yet been fully solved. Accordingly, the subject matter of the present application has been developed to provide a golf club head that overcomes at least some of the above-discussed shortcomings of conventional golf club heads.

[0007] Disclosed herein is a golf club head. The golf club head comprises a hollow interior cavity, a first piece, defining at least a first portion of the hollow interior cavity, and a second piece, defining at least a second portion of the hollow interior cavity. The first piece is adhesively bonded to the second piece, via bonding tape, along a bonded joint. The preceding subject matter of this paragraph characterizes example 1 of the present disclosure.

[0008] The bonding tape has a thickness between 90 µm and 550 µm. The preceding subject matter of this paragraph characterizes example 2 of the present disclosure, wherein example 2 also includes the subject matter according to example 1, above.

[0009] The thickness of the bonding tape is at least 100 µm. The preceding subject matter of this paragraph characterizes example 3 of the present disclosure, wherein example 3 also includes the subject matter according to example 2, above.

[0010] The thickness of the bonding tape is at least 150 µm. The preceding subject matter of this paragraph characterizes example 4 of the present disclosure, wherein example 4 also includes the subject matter according to example 3, above.

[0011] The thickness of the bonding tape is at least 250 µm. The preceding subject matter of this paragraph characterizes example 5 of the present disclosure, wherein example 5 also includes the subject matter according to example 4, above.

[0012] The thickness of the bonding tape is at least 300 µm. The preceding subject matter of this paragraph characterizes example 6 of the present disclosure, wherein example 6 also includes the subject matter according to example 5 above.

[0013] The bonding tape is a thermosetting adhesive material. The preceding subject matter of this paragraph characterizes example 7 of the present disclosure, wherein example 7 also includes the subject matter according to any of examples 1-6, above.

[0014] The bonding tape has a shear strength of at least 10 MPa. The preceding subject matter of this paragraph characterizes example 8 of the present disclosure, wherein example 8 also includes the subject matter according to example 7 above.

[0015] The bonding tape is a thermosetting adhesive material. The preceding subject matter of this paragraph characterizes example 9 of the present disclosure, wherein example 9 also includes the subject matter according to example 8 above.

[0016] The bonding tape comprises two or more, separate, bonding tape segments. The preceding subject matter of this paragraph characterizes example 10 of the present disclosure, wherein example 10 also includes the subject matter according to any of examples 1-9, above.

[0017] The bonding tape comprises three or more, separate, bonding tape segments. The preceding subject matter of

this paragraph characterizes example 11 of the present disclosure, wherein example 11 also includes the subject matter according to example 10 above.

[0018] The bonding tape comprises four or more, separate, bonding tape segments. The preceding subject matter of this paragraph characterizes example 12 of the present disclosure, wherein example 12 also includes the subject matter according to example 11 above.

[0019] The bonding tape has a width between, and inclusive of, 1 mm and 9 mm. The preceding subject matter of this paragraph characterizes example 13 of the present disclosure, wherein example 13 also includes the subject matter according to any of examples 1-12, above.

[0020] The width of the bonding tape is between, and inclusive of, 2 mm and 7 mm. The preceding subject matter of this paragraph characterizes example 14 of the present disclosure, wherein example 14 also includes the subject matter according to example 13 above.

[0021] The width of the bonding tape is between, and inclusive of, 2 mm and 5 mm. The preceding subject matter of this paragraph characterizes example 15 of the present disclosure, wherein example 15 also includes the subject matter according to example 14 above.

[0022] The width of the bonding tape is between, and inclusive of, 2.5 mm and 3.5 mm. The preceding subject matter of this paragraph characterizes example 16 of the present disclosure, wherein example 16 also includes the subject matter according to example 15 above.

[0023] The bonding tape has a variable width. The preceding subject matter of this paragraph characterizes example 17 of the present disclosure, wherein example 17 also includes the subject matter according to any of examples 1-16, above.

[0024] The bonding tape comprises two or more, separate, bonding tape segments. A first one of the two or more, separate, bonding tape segments has a size that is different than a size of a second one of the two or more bonding tape segments. The preceding subject matter of this paragraph characterizes example 18 of the present disclosure, wherein example 18 also includes the subject matter according to any of examples 1-17, above.

[0025] The bonding tape has a shear strength of at least 10 MPa. The preceding subject matter of this paragraph characterizes example 19 of the present disclosure, wherein example 19 also includes the subject matter according to any of examples 1-18, above.

[0026] The shear strength of the bonding tape is at least 11 MPa. The preceding subject matter of this paragraph characterizes example 20 of the present disclosure, wherein example 20 also includes the subject matter according to example 19, above.

[0027] The shear strength of the bonding tape is at least 12 MPa. The preceding subject matter of this paragraph characterizes example 21 of the present disclosure, wherein example 21 also includes the subject matter according to example 20, above.

[0028] The shear strength of the bonding tape is at least 13 MPa. The preceding subject matter of this paragraph characterizes example 22 of the present disclosure, wherein example 22 also includes the subject matter according to example 21, above.

[0029] The shear strength of the bonding tape is no more than 30 MPa. The preceding subject matter of this paragraph

characterizes example 23 of the present disclosure, wherein example 23 also includes the subject matter according to any of examples 19-22, above.

[0030] The bonding tape has a cure temperature of at least 100° C. The preceding subject matter of this paragraph characterizes example 24 of the present disclosure, wherein example 24 also includes the subject matter according to any of examples 1-23, above.

[0031] The cure temperature of the bonding tape is at least 120° C. The preceding subject matter of this paragraph characterizes example 25 of the present disclosure, wherein example 25 also includes the subject matter according to example 24, above.

[0032] The cure temperature of the bonding tape is between, and inclusive of, 120° C. and 230° C. The preceding subject matter of this paragraph characterizes example 26 of the present disclosure, wherein example 26 also includes the subject matter according to example 25, above.

[0033] The cure temperature of the bonding tape is between, and inclusive of, 140° C. and 190° C. The preceding subject matter of this paragraph characterizes example 27 of the present disclosure, wherein example 27 also includes the subject matter according to example 26, above.

[0034] The bonding tape has a reflow temperature of at least 160° C. The preceding subject matter of this paragraph characterizes example 28 of the present disclosure, wherein example 28 also includes the subject matter according to any of examples 1-27, above.

[0035] The reflow temperature of the bonding tape is at least 180° C. The preceding subject matter of this paragraph characterizes example 29 of the present disclosure, wherein example 29 also includes the subject matter according to example 28, above.

[0036] The reflow temperature of the bonding tape is at least 200° C. The preceding subject matter of this paragraph characterizes example 30 of the present disclosure, wherein example 30 also includes the subject matter according to example 29, above.

[0037] The reflow temperature of the bonding tape is at least 220° C. The preceding subject matter of this paragraph characterizes example 31 of the present disclosure, wherein example 31 also includes the subject matter according to example 30, above.

[0038] The golf club head further comprises a gap filler interposed between the first piece and the second piece, and interposed between the bonding tape and the second piece. The preceding subject matter of this paragraph characterizes example 32 of the present disclosure, wherein example 32 also includes the subject matter according to any of examples 30-31, above.

[0039] Further disclosed herein is a method of making a golf club head. The method comprises a step of interposing bonding tape between a first piece and a second piece of the golf club head such that the first piece is temporarily adhered to the second piece via a tackiness of the bonding tape. The method additionally comprises a step of positioning the first piece, the second piece, and the bonding tape, interposed between the first piece and the second piece, in a vacuum bag. The method also comprises a step of reducing a pressure within the vacuum bag, relative to a pressure external to the vacuum bag, such that the vacuum bag collapses onto the first piece and the second piece and compresses the bonding tape between the first piece and the second piece. The method further comprises a step of

heating the bonding tape, at least to a curing temperature of the bonding tape, when the pressure within the vacuum bag is reduced. The preceding subject matter of this paragraph characterizes example 33 of the present disclosure.

[0040] The step of interposing the bonding tape between the first piece and the second piece of the golf club head comprises temporarily coupling a bonding tape package, comprising the bonding tape, to a tape-retention fixture via a suction force. The preceding subject matter of this paragraph characterizes example 34 of the present disclosure, wherein example 34 also includes the subject matter according to 33, above.

[0041] The step of interposing the bonding tape between the first piece and the second piece of the golf club head further comprises removing a release layer, adhered to the bonding tape, from the bonding tape package when the bonding tape package is coupled to the tape-retention fixture via the suction force. The preceding subject matter of this paragraph characterizes example 35 of the present disclosure, wherein example 35 also includes the subject matter according to example 34, above.

[0042] The step of interposing the bonding tape between the first piece and the second piece of the golf club head further comprises temporarily adhering the bonding tape to the first piece when the bonding tape package is coupled to the tape-retention fixture via the suction force and after the release layer is removed. The preceding subject matter of this paragraph characterizes example 36 of the present disclosure, wherein example 36 also includes the subject matter according to example 35, above.

[0043] The step of interposing the bonding tape between the first piece and the second piece of the golf club head further comprises disabling the suction force and removing the first piece and the bonding tape package from the tape-retention fixture. The preceding subject matter of this paragraph characterizes example 37 of the present disclosure, wherein example 37 also includes the subject matter according to example 36, above.

[0044] The step of interposing the bonding tape between the first piece and the second piece of the golf club head further comprises removing a second release layer, adhered to the bonding tape, from the bonding tape package when the first piece and the bonding tape package from the tape-retention fixture are removed from the tape-retention fixture and applying the second piece onto the bonding tape when the second release layer is removed. The preceding subject matter of this paragraph characterizes example 38 of the present disclosure, wherein example 38 also includes the subject matter according to example 37 above.

[0045] Prior to reducing the pressure and heating the bonding tape, the bonding tape is a solid at 25° C. The preceding subject matter of this paragraph characterizes example 39 of the present disclosure, wherein example 39 also includes the subject matter according to any of examples 33-38, above.

[0046] Prior to reducing the pressure and heating the bonding tape, the bonding tape is a non-liquid at 25° C. The preceding subject matter of this paragraph characterizes example 40 of the present disclosure, wherein example 40 also includes the subject matter according to any of examples 33-39, above.

[0047] Prior to reducing the pressure and heating the bonding tape, the bonding tape is tacky at 25° C. The preceding subject matter of this paragraph characterizes

example 41 of the present disclosure, wherein example 41 also includes the subject matter according to any of examples 33-40, above.

[0048] The first piece is a non-metal insert. The second piece comprises at least one recessed ledge. The bonding tape comprises a first surface and a second surface, opposite the first surface. The step of interposing the bonding tape between the first piece and the second piece comprises attaching the first surface of the bonding tape to the non-metal insert and attaching the second surface of the bonding tape to the at least one recessed ledge. A total surface area of the second surface of the bonding tape, prior to attachment to the at least one recessed ledge, is less than 100% of a total surface area of the at least one recessed ledge. The preceding subject matter of this paragraph characterizes example 42 of the present disclosure, wherein example 42 also includes the subject matter according to any of examples 33-41, above.

[0049] The total surface area of the second surface of the bonding tape, prior to attachment to the at least one recessed ledge, is less than 99% of the total surface area of the at least one recessed ledge. The preceding subject matter of this paragraph characterizes example 43 of the present disclosure, wherein example 43 also includes the subject matter according to example 42 above.

[0050] The total surface area of the second surface of the bonding tape, prior to attachment to the at least one recessed ledge, is between, and inclusive of, 75% and 99% of the total surface area of the at least one recessed ledge. The preceding subject matter of this paragraph characterizes example 44 of the present disclosure, wherein example 44 also includes the subject matter according to any of examples 42-43, above.

[0051] The total surface area of the second surface of the bonding tape, prior to attachment to the at least one recessed ledge, is between, and inclusive of, 85% and 99% of the total surface area of the at least one recessed ledge. The preceding subject matter of this paragraph characterizes example 45 of the present disclosure, wherein example 45 also includes the subject matter according to any of examples 42-44, above.

[0052] The total surface area of the at least one recessed ledge is a total surface area of the at least one recessed ledge covered by the non-metal insert. The preceding subject matter of this paragraph characterizes example 46 of the present disclosure, wherein example 46 also includes the subject matter according to any of examples 42-45, above.

[0053] When the bonding tape is interposed between the first piece and the second piece, the bonding tape is offset from an outer perimeter of the at least one recessed ledge by at least 0.25 mm. The preceding subject matter of this paragraph characterizes example 47 of the present disclosure, wherein example 47 also includes the subject matter according to any of examples 42-46, above.

[0054] When the bonding tape is interposed between the first piece and the second piece, the bonding tape is offset from the outer perimeter of the at least one recessed ledge by at least 0.5 mm. The preceding subject matter of this paragraph characterizes example 48 of the present disclosure, wherein example 48 also includes the subject matter according to example 47 above.

[0055] When the bonding tape is interposed between the first piece and the second piece, the bonding tape is offset from the outer perimeter of the at least one recessed ledge by at least 1.0 mm. The preceding subject matter of this paragraph characterizes example 49 of the present disclosure.

sure, wherein example 49 also includes the subject matter according to example 48 above.

[0056] When the bonding tape is interposed between the first piece and the second piece, the bonding tape is offset from the outer perimeter of the at least one recessed ledge by no more than 2.5 mm. The preceding subject matter of this paragraph characterizes example 50 of the present disclosure, wherein example 50 also includes the subject matter according to example 49 above.

[0057] When the bonding tape is interposed between the first piece and the second piece, the bonding tape is offset from the outer perimeter of the at least one recessed ledge by no more than 3.0 mm. The preceding subject matter of this paragraph characterizes example 51 of the present disclosure, wherein example 51 also includes the subject matter according to any of examples 49-50, above.

[0058] When the bonding tape is interposed between the first piece and the second piece, the bonding tape is offset from the outer perimeter of the at least one recessed ledge by no more than 5.0 mm. The preceding subject matter of this paragraph characterizes example 52 of the present disclosure, wherein example 52 also includes the subject matter according to any of examples 49-51, above.

[0059] The golf club head comprises a body, comprising a plurality of openings. The first piece is a strike plate. The second piece is the body, such that, when the bonding tape is interposed between the first piece and the second piece, the strike plate covers one of the plurality of openings. When the pressure within the vacuum bag is reduced and the bonding tape is heated, at least one of the plurality of openings of the body is uncovered. The preceding subject matter of this paragraph characterizes example 53 of the present disclosure, wherein example 53 also includes the subject matter according to any of examples 33-52, above.

[0060] The first piece is a non-metal insert comprising an interior surface having a total surface area between, and inclusive of, 2,000 mm² and 13,000 mm². The method further comprises temporarily adhering the bonding tape to the interior surface of the non-metal insert, via a tackiness of the bonding tape, before the bonding tape is interposed between the first piece and the second piece. The preceding subject matter of this paragraph characterizes example 54 of the present disclosure, wherein example 54 also includes the subject matter according to any of examples 33-53, above.

[0061] The bonding tape comprises a thermoset adhesive. The preceding subject matter of this paragraph characterizes example 55 of the present disclosure, wherein example 55 also includes the subject matter according to example 54 above.

[0062] When temporarily adhered to the interior surface of the non-metal insert, the bonding tape is at least 0.25 mm from an outer periphery of the non-metal insert. The preceding subject matter of this paragraph characterizes example 56 of the present disclosure, wherein example 56 also includes the subject matter according to any of examples 54-55, above.

[0063] The method further comprises a step of cutting the bonding tape from a sheet of bonding tape. The preceding subject matter of this paragraph characterizes example 57 of the present disclosure, wherein example 57 also includes the subject matter according to any of examples 54-56, above.

[0064] The bonding tape comprises a plurality of separate bonding tape segments. The step of cutting the bonding tape comprises separately cutting the bonding tape segments

from the sheet of bonding tape. The preceding subject matter of this paragraph characterizes example 58 of the present disclosure, wherein example 58 also includes the subject matter according to example 57 above.

[0065] The bonding tape is cut from the sheet of bonding tape via a laser. The preceding subject matter of this paragraph characterizes example 59 of the present disclosure, wherein example 59 also includes the subject matter according to any of examples 57-58, above.

[0066] The method further comprises interposing second bonding tape between the second piece and a third piece of the golf club head such that the third piece is temporarily adhered to the second piece via the tackiness of the second bonding tape. The first piece is one of a crown insert, a sole insert, or a strike plate of the golf club head. The second piece is a body of the golf club head. The third piece is a second one of the crown insert, the sole insert, or the strike plate. The step of positioning the first piece, the second piece, and the bonding tape in the vacuum bag further comprises positioning the third piece, with the second bonding tape between the third piece and the second piece, in the vacuum bag. Reducing the pressure within the vacuum bag collapses the vacuum bag onto the third piece and the second piece such that the second bonding tape is compressed between the third piece and the second piece. Heating the bonding tape comprises heating the bonding tape at least to a curing temperature of the second bonding tape when the pressure within the vacuum bag is reduced. The preceding subject matter of this paragraph characterizes example 60 of the present disclosure, wherein example 60 also includes the subject matter according to any of examples 33-59, above.

[0067] The method further comprises placing the vacuum bag, with the first piece, the second piece, and the bonding tape sealed within the vacuum bag, in an autoclave. Reducing the pressure within the vacuum bag, relative to pressure external to the vacuum bag, comprises increasing a pressure within the autoclave. Heating the bonding tape comprises increasing a temperature within the autoclave. The preceding subject matter of this paragraph characterizes example 61 of the present disclosure, wherein example 61 also includes the subject matter according to any of examples 33-60, above.

[0068] The vacuum bag is a reusable vacuum bag. The preceding subject matter of this paragraph characterizes example 62 of the present disclosure, wherein example 62 also includes the subject matter according to any of examples 33-61, above.

[0069] The vacuum bag is one of a shrink-wrap material or a heat-shrink material. The preceding subject matter of this paragraph characterizes example 63 of the present disclosure, wherein example 63 also includes the subject matter according to any of examples 33-62, above.

[0070] The bonding tape is storable at 25° C., up to at least twenty-four hours, before reducing the pressure within the vacuum bag and heating the bonding tape. The preceding subject matter of this paragraph characterizes example 64 of the present disclosure, wherein example 64 also includes the subject matter according to any of examples 33-63, above.

[0071] The method further comprises, before positioning the first piece, the second piece, and the bonding tape in the vacuum bag, applying a gap filler into a gap, defined between the second piece and the first piece and defined between the second piece and the bonding tape, and curing the gap filler. The preceding subject matter of this paragraph

characterizes example 65 of the present disclosure, wherein example 65 also includes the subject matter according to any of examples 33-64, above.

[0072] The described features, structures, advantages, and/or characteristics of the subject matter of the present disclosure may be combined in any suitable manner in one or more embodiments and/or implementations. In the following description, numerous specific details are provided to impart a thorough understanding of embodiments of the subject matter of the present disclosure. One skilled in the relevant art will recognize that the subject matter of the present disclosure may be practiced without one or more of the specific features, details, components, materials, and/or methods of a particular embodiment or implementation. In other examples, additional features and advantages may be recognized in certain embodiments and/or implementations that may not be present in all embodiments or implementations. Further, in some examples, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the subject matter of the present disclosure. The features and advantages of the subject matter of the present disclosure will become more fully apparent from the following description and appended claims, or may be learned by the practice of the subject matter as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0073] In order that the advantages of the subject matter may be more readily understood, a more particular description of the subject matter briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the subject matter and are not therefore to be considered to be limiting of its scope, the subject matter will be described and explained with additional specificity and detail through the use of the drawings, in which:

[0074] FIG. 1 is a schematic, perspective view of a golf club head, according to one or more examples of the present disclosure;

[0075] FIG. 2 is a schematic, perspective view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0076] FIG. 3 is a schematic, side elevation view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0077] FIG. 4 is another schematic, side elevation view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0078] FIG. 5 is a schematic, front view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0079] FIG. 6 is a schematic, rear view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0080] FIG. 7 is a schematic, top plan view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0081] FIG. 8 is a schematic, bottom plan view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0082] FIG. 9A is a schematic, cross-sectional, side elevation view of the golf club head of FIG. 1, taken along the line 9-9 of FIG. 5, according to one or more examples of the present disclosure;

[0083] FIG. 9B is a schematic, cross-sectional, side elevation view of a detail of the golf club head of FIG. 9A, according to one or more examples of the present disclosure;

[0084] FIG. 10 is a schematic, exploded, perspective view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0085] FIG. 11 is another schematic, exploded, perspective view of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0086] FIG. 12 is a schematic, top plan view of a body of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0087] FIG. 13 is a schematic, bottom plan view of the body of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0088] FIG. 14 is a schematic, exploded, perspective view of the body of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0089] FIG. 15 is another schematic, exploded, perspective view of the body of the golf club head of FIG. 1, according to one or more examples of the present disclosure;

[0090] FIG. 16 is a schematic, perspective view of another golf club head, according to one or more examples of the present disclosure;

[0091] FIG. 17 is a schematic, cross-sectional, side elevation view of the golf club head of FIG. 16, taken along the line 16-16 of FIG. 16, according to one or more examples of the present disclosure;

[0092] FIG. 18 is a schematic, exploded, perspective view of another golf club head, according to one or more examples of the present disclosure;

[0093] FIG. 19 is a schematic, exploded, perspective view of yet another golf club head, according to one or more examples of the present disclosure;

[0094] FIG. 20 is a schematic, exploded, perspective view of the golf club head of FIG. 19, according to one or more examples of the present disclosure;

[0095] FIG. 21 is a schematic, front elevation view of a ring of the golf club head of FIG. 19, according to one or more examples of the present disclosure;

[0096] FIG. 22 is a schematic, rear view of a face portion of a golf club head, according to one or more examples of the present disclosure;

[0097] FIG. 23 is a schematic, rear view of a face portion of a golf club head, according to one or more examples of the present disclosure;

[0098] FIG. 24 is a schematic, perspective view of the face portion of FIG. 56, according to one or more examples of the present disclosure;

[0099] FIG. 25 is a schematic, rear view of a face portion of a golf club head, according to one or more examples of the present disclosure;

[0100] FIG. 26 is a schematic, front elevation view of a strike plate of a golf club head, according to one or more examples of the present disclosure;

[0101] FIG. 27 is a schematic, bottom view of a strike plate of a golf club head, according to one or more examples of the present disclosure;

- [0102] FIG. 28A is a schematic, bottom sectional view of a heel portion of a strike plate of a golf club head, according to one or more examples of the present disclosure;
- [0103] FIG. 28B a schematic, bottom sectional view of a toe portion of a strike plate of a golf club head, according to one or more examples of the present disclosure;
- [0104] FIG. 29 is a schematic, sectional view of a polymer layer of a strike plate of a golf club head, according to one or more examples of the present disclosure;
- [0105] FIG. 30 is a schematic, sectional, bottom plan view of a golf club head, taken along a line similar to the line 30-30 of FIG. 9B, according to one or more examples of the present disclosure;
- [0106] FIG. 31 is a schematic, sectional, side elevation view of a forward portion and a crown portion of the golf club head of FIG. 30, taken along the line 31-31 of FIG. 30, according to one or more examples of the present disclosure;
- [0107] FIG. 32 is a schematic, sectional, side elevation view of a forward portion and a crown portion of the golf club head of FIG. 30, taken along the line 32-32 of FIG. 30, according to one or more examples of the present disclosure;
- [0108] FIG. 33 is a schematic, side elevation view of a first part of a golf club head being laser ablated by a first laser, according to one or more examples of the present disclosure;
- [0109] FIG. 34 is a schematic, side elevation view of a second part of a golf club head being laser ablated by a second laser, according to one or more examples of the present disclosure;
- [0110] FIG. 35 is a schematic, side elevation view of a first part, of a golf club head, bonded to a second part, of the golf club head, according to one or more examples of the present disclosure;
- [0111] FIG. 36 is a schematic, perspective view of an ablation pattern, of peaks and valleys, of an ablated surface of a part of a golf club head, according to one or more examples of the present disclosure;
- [0112] FIG. 37 is a schematic, side elevation view of an ablation pattern, of peaks and valleys, of an ablated surface of a part of a golf club head, according to one or more examples of the present disclosure;
- [0113] FIG. 38 is a schematic, perspective view of a strike plate of a golf club head being laser ablated by a laser, according to one or more examples of the present disclosure;
- [0114] FIG. 39 is a schematic, perspective view of a body of a golf club head being laser ablated by a laser, according to one or more examples of the present disclosure;
- [0115] FIG. 40 is a schematic, perspective, exploded view of a strike plate and a body of a golf club head, according to one or more examples of the present disclosure;
- [0116] FIG. 41 is a schematic, perspective, exploded view of a strike plate and a body of a golf club head, according to one or more examples of the present disclosure;
- [0117] FIG. 42 is a schematic flow diagram of a method of making a golf club head, according to one or more examples of the present disclosure;
- [0118] FIG. 43 is a schematic flow diagram of a method of making a golf club head, according to one or more examples of the present disclosure;
- [0119] FIG. 44 is a schematic, side elevation view of a first part, of a golf club head, bonded to a second part, of the golf club head, according to one or more examples of the present disclosure;
- [0120] FIG. 45 is a schematic, top plan view of an ablation pattern on a part of a golf club head, according to one or more examples of the present disclosure;
- [0121] FIG. 46 is a schematic, top plan view of an ablation pattern on a part of a golf club head, according to one or more examples of the present disclosure;
- [0122] FIG. 47 is a schematic, perspective view of a sheet, including bonding tape, according to one or more examples of the present disclosure;
- [0123] FIG. 48 is a schematic, side elevation, sectional view of a bonding tape package, according to one or more examples of the present disclosure;
- [0124] FIG. 49 is a schematic, perspective view of a tape-retention fixture, according to one or more examples of the present disclosure;
- [0125] FIG. 50 is a schematic, perspective view of a tape-retention fixture, according to one or more examples of the present disclosure;
- [0126] FIG. 51 is a schematic, perspective view of a tape-retention fixture, according to one or more examples of the present disclosure;
- [0127] FIG. 52 is a schematic, perspective view of a tape-retention fixture, according to one or more examples of the present disclosure;
- [0128] FIG. 53 is a schematic, perspective view of a crown insert of a golf club head, according to one or more examples of the present disclosure;
- [0129] FIG. 54 is a schematic, perspective view of a sole insert of a golf club head, according to one or more examples of the present disclosure;
- [0130] FIG. 55 is a schematic, top plan view of a golf club head that includes a crown insert, according to one or more examples of the present disclosure;
- [0131] FIG. 56 is a schematic, bottom plan view of a golf club head that includes a sole insert, according to one or more examples of the present disclosure;
- [0132] FIG. 57A is a schematic, side elevation, sectional view of a crown insert temporarily bonded, via bonding tape, to a body of a golf club head, according to one or more examples of the present disclosure;
- [0133] FIG. 57B is a schematic, side elevation, sectional view of a crown insert temporarily bonded, via bonding tape, to a body of a golf club head, according to one or more examples of the present disclosure;
- [0134] FIG. 58 is a schematic, perspective view of a vacuum bag, in a non-collapsed state, enclosing a golf club head, according to one or more examples of the present disclosure;
- [0135] FIG. 59 is a schematic, perspective view of a vacuum bag, in a collapsed state, enclosing a golf club head, according to one or more examples of the present disclosure;
- [0136] FIG. 60 is a schematic, perspective view of a vacuum bag, in a non-collapsed state, enclosing a golf club head, according to one or more examples of the present disclosure;
- [0137] FIG. 61 is a schematic, perspective view of a vacuum bag, in a collapsed state, enclosing a golf club head, according to one or more examples of the present disclosure;
- [0138] FIG. 62 is a schematic, side elevation, sectional view of an oven, according to one or more examples of the present disclosure;
- [0139] FIG. 63 is a schematic, exploded, perspective view of a fairway-metal type golf club head, according to one or more examples of the present disclosure;

[0140] FIG. 64 is a schematic, exploded, perspective view of an iron-type golf club head, according to one or more examples of the present disclosure;

[0141] FIG. 65 is a schematic, perspective view of a golf club head, according to one or more examples of the present disclosure;

[0142] FIG. 66A is a schematic, sectional, side elevation view of a golf club head, according to one or more examples of the present disclosure;

[0143] FIG. 66B is a schematic, sectional, close-up, side elevation view of the golf club head of FIG. 66A, according to one or more examples of the present disclosure;

[0144] FIG. 67 is a schematic, sectional, side elevation view of a golf club head, according to one or more examples of the present disclosure;

[0145] FIG. 68 is a schematic, front elevation view of a golf club head, according to one or more examples of the present disclosure; and

[0146] FIG. 69 is a schematic, front elevation view of a golf club head, according to one or more examples of the present disclosure.

DETAILED DESCRIPTION

[0147] The following describes examples of golf club heads in the context of a driver-type golf club head having a multi-piece construction, but the principles, methods and designs described may be applicable, in whole or in part, to fairway wood golf club heads, utility golf club heads (also known as hybrid golf club heads), iron-type golf club heads, and the like, because such golf club heads can also be made to have a multi-piece construction.

[0148] In some examples disclosed herein, the golf club head has a strike face formed of a non-metallic material, such as a fiber-reinforced polymeric material. A breakdown of the adhesive joint formed between a body of the golf club head and a non-metallic strike plate can cause characteristic time (CT) creep. USGA regulations require the CT of a golf club head to remain within the regulated limit regardless of the number of impacts the golf club head has with a golf ball. The CT of conventional driver-type golf club heads tends to increase after multiple impacts with a golf ball. The increase of CT due to impacts with a golf ball is known as CT creep. In certain examples disclosed herein, the golf club heads are configured to strengthen the adhesive joint formed between the body of the golf club heads and the non-metallic strike plate, such as by optimizing the surface structure of the golf club head for stronger adhesive bonds.

[0149] U.S. Patent Application Publication No. 2014/0302946 A1 ('946 App), published Oct. 9, 2014, which is incorporated herein by reference in its entirety, describes a "reference position" similar to the address position used to measure the various parameters discussed throughout this application. The address or reference position is based on the procedures described in the United States Golf Association and R&A Rules Limited, "Procedure for Measuring the Club Head Size of Wood Clubs," Revision 1.0.0, (Nov. 21, 2003). Unless otherwise indicated, all parameters are specified with the club head in the reference position.

[0150] FIGS. 3, 4, 5, and 9A are examples that show a golf club head 100 in the address or reference position. The golf club head 100 is in the address or reference position when a hosel axis 191 of the golf club head 100 is at a lie angle θ of 60-degrees relative to a ground plane 181 (see, e.g., FIG. 5) and a strike face 145 of the golf club head 100 is

square relative to an imaginary target line 101 (see, e.g., FIG. 7). As shown in FIGS. 3, 4, 5, and 9A, positioning the golf club head 100 in the address or reference position lends itself to using a club head origin coordinate system 185, centered at a geometric center (e.g., center face 183) of the strike face 145, for making various measurements. With the golf club head in the address or reference position, using the USGA methodology, various parameters described throughout this application including head height, club head center of gravity (CG) location, and moments of inertia (MOI), can be measured relative to the club head origin coordinate system 185 or relative to another reference or references.

[0151] For further details or clarity, the reader is advised to refer to the measurement methods described in the '946 App and the USGA procedure. Notably, however, the origin and axes associated with the club head origin coordinate system 185 used in this application may not necessarily be aligned or oriented in the same manner as those described in the '946 App or the USGA procedure. Further details are provided below on locating the club head origin coordinate system 185.

[0152] In some examples, the golf club heads described herein include driver-type golf club heads, which can be identified, at least partially, as golf club heads with strike faces that have a total surface area of at least 3,500 mm², preferably at least 3,800 mm², and even more preferably at least 3,900 mm² (e.g., between 3,500 mm² and 5,000 mm² in one example, less than 5,000 mm² in various examples, and between 3,700 mm² and 4,300 mm² in another example). In some examples, such as when the strike face is defined by a non-metal material, the total surface area of the strike face is no more than 4,300 mm² and no less than 3,300 mm². The total surface area of the strike face is the outermost area of the striking face, which can be the outermost area of a face insert in some examples. In certain examples, the total surface area of the strike face is the surface area of the surface of the striking face that is bounded on its periphery by all points where the face transitions from a substantially uniform bulge radius (i.e., face heel-to-toe radius of curvature) and a substantially uniform roll radius (i.e., face crown-to-sole radius of curvature) to the body of the golf club head. In certain examples, the strike face of the golf club head disclosed herein is defined in the same manner as in one or more of U.S. Patent Application Publication No. 2020/0139208, filed Oct. 22, 2019, U.S. Pat. No. 8,801,541, issued Aug. 12, 2014, and U.S. Pat. No. 8,012,039, issued Sep. 6, 2011, all of which are incorporated herein by reference in their entirety. In yet some examples, the strike face has a uniform bulge radius and a uniform roll radius, except for portions that have a higher lofted toe and a lower lofted heel, such as described in U.S. patent application Ser. No. 17/006,561, filed Aug. 28, 2020, U.S. Pat. No. 9,814,944, issued Nov. 14, 2017, U.S. Pat. No. 10,265,586, issued Apr. 23, 2019, and U.S. Patent Application Publication No. 2019/0076705, filed Oct. 15, 2018, which are incorporated herein by reference in their entirety.

[0153] Additionally, in certain examples, driver-type golf club heads include a center-of-gravity (CG) projection, parallel to a horizontal (y-axis), which is, in one example, at most 3 mm above or below a center face of the strike face, and preferably at most 1 mm above or below the center face, as measured along a vertical axis (z-axis), or in another example, at most 5 mm below a center face of the strike face, and preferably at most 4 mm below the center face, as

measured along a vertical axis (z-axis). In some examples, the CG projection is toe-ward of the geometric center of the strike face. Moreover, in some examples, driver-type golf club heads have a relatively high moment of inertia about a vertical axis (e.g., a CG z-axis passing through the CG and parallel with the z-axis of the club head origin coordinate system 185) (e.g. $I_{zz} > 400 \text{ kg}\cdot\text{mm}^2$ and preferably $I_{zz} > 450 \text{ kg}\cdot\text{mm}^2$, and more preferably $I_{zz} > 500 \text{ kg}\cdot\text{mm}^2$, but less than $590 \text{ kg}\cdot\text{mm}^2$ in certain implementations), a relatively high moment of inertia about a horizontal axis (e.g., a CG x-axis passing through the CG and parallel with the x-axis of the club head origin coordinate system 185) (e.g. $I_{xx} > 250 \text{ kg}\cdot\text{mm}^2$ and preferably $I_{xx} > 300 \text{ kg}\cdot\text{mm}^2$ or $320 \text{ kg}\cdot\text{mm}^2$, and more preferably $I_{xx} > 350 \text{ kg}\cdot\text{mm}^2$, more preferably $I_{xx} > 375 \text{ kg}\cdot\text{mm}^2$, more preferably $I_{xx} > 385 \text{ kg}\cdot\text{mm}^2$, more preferably $I_{xx} > 400 \text{ kg}\cdot\text{mm}^2$, more preferably $I_{xx} > 415 \text{ kg}\cdot\text{mm}^2$, more preferably $I_{xx} > 430 \text{ kg}\cdot\text{mm}^2$, more preferably $I_{xx} > 450 \text{ kg}\cdot\text{mm}^2$, but no more than $590 \text{ kg}\cdot\text{mm}^2$ in some examples), and preferably a ratio of $I_{xx}/I_{zz} > 0.70$. More details about inertia I_{zz} and I_{xx} can be found in U.S. Patent Application Publication No. 2020/0139208, Published May 7, 2020, which is incorporated herein by reference in its entirety.

[0154] According to certain examples, a summation of I_{xx} and I_{zz} is greater than $780 \text{ kg}\cdot\text{mm}^2$, $800 \text{ kg}\cdot\text{mm}^2$, $820 \text{ kg}\cdot\text{mm}^2$, $825 \text{ kg}\cdot\text{mm}^2$, $850 \text{ kg}\cdot\text{mm}^2$, $860 \text{ kg}\cdot\text{mm}^2$, $875 \text{ kg}\cdot\text{mm}^2$, $900 \text{ kg}\cdot\text{mm}^2$, $925 \text{ kg}\cdot\text{mm}^2$, $950 \text{ kg}\cdot\text{mm}^2$, $975 \text{ kg}\cdot\text{mm}^2$, or $1000 \text{ kg}\cdot\text{mm}^2$, but less than $1,100 \text{ kg}\cdot\text{mm}^2$. For example, the summation of I_{xx} and I_{zz} can be between $740 \text{ kg}\cdot\text{mm}^2$ and $1,100 \text{ kg}\cdot\text{mm}^2$, such as around $869 \text{ kg}\cdot\text{mm}^2$. I_{xx} is at least 65% of I_{zz} in some examples, even more preferably I_{xx} is at least 68% of I_{zz} in some examples. In some example, a golf club head mass may range from 190 grams to 210 grams, preferably between 195 grams and 205 grams, even more preferably no more than 203 grams. The golf club head mass includes the mass of any FCT system and fastener to tighten the FCT system, but not the shaft of the golf club head or the grip of the golf club head. A maximum distance from a leading edge to a trailing edge of the club head as measured parallel to the y-axis is preferably is between 112 mm and 127 mm, preferably between 115 mm and 127 mm, even more preferably between 119 mm and 127 mm.

[0155] The larger inertia values and lower CG projection e.g. no more than 3 mm above center face can be achieved by including a forward weight and a rearward weight as discussed in more detail below. The forward weight can be a single forward weight or two or more forward weights. The forward weight can be located proximate to an imaginary vertical plane passing through the y-axis, or the forward weight can be offset to either a toe or a heel side of the imaginary vertical plane passing through the y-axis or both a toe and a heel side of the imaginary vertical plane passing through the y-axis of the golf club head. The forward weight can be separately formed and threadedly attached, welded, or bonded to the golf club head, or the forward weight can be a thickened region of the golf club head or in some cases the forwarded weight could be molded or over-molded into a forward portion of a golf club head. See below and U.S. Pat. No. 10,220,270, issued Mar. 5, 2019, which is incorporated herein by reference in its entirety, for further discussion on the various locations of forward and rearward weights. A forward weight is forward of a center of gravity

of the golf club head and a rearward weight is rearward of a center of gravity of the golf club head.

[0156] In some examples, the golf club heads described herein have a delta-1 value that is no more than 25 mm, preferably between 20 mm and 25 mm. The delta-1 of the driver-type golf club head is a distance, along the y-axis of the head center face origin coordinate system 185, between the CG of the golf club head and an XZ plane, passing through the x-axis and the z-axis of the head center face origin coordinate system 185 and passing through the hosel axis 191. In certain examples, the I_{xx} of the golf club head is at least $335 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is no more than 25 mm, the I_{xx} of the golf club head is at least $345 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is no more than 25 mm, the I_{xx} of the golf club head is at least $355 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is no more than 25 mm, the I_{xx} of the golf club head is at least $365 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is no more than 25 mm, or the I_{xx} of the golf club head is at least $375 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is no more than 25 mm.

[0157] In some examples, the golf club heads described herein have a delta-1 value that is between 20 mm and 35 mm. In certain examples, the I_{xx} of the golf club head is at least $335 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is between 22 mm and 32 mm, the I_{xx} of the golf club head is at least $345 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is between 22 mm and 32 mm, the I_{xx} of the golf club head is at least $355 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is between 22 mm and 32 mm, the I_{xx} of the golf club head is at least $365 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is between 22 mm and 32 mm, the I_{xx} of the golf club head is at least $375 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is between 23 mm and 32 mm, the I_{xx} of the golf club head is at least $385 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is between 24 mm and 32 mm, the I_{xx} of the golf club head is at least $395 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is between 25 mm and 32 mm, or the I_{xx} of the golf club head is at least $405 \text{ kg}\cdot\text{mm}^2$ and the delta 1 is between 27 mm and 32 mm.

[0158] Referring to FIGS. 1 and 2, according to some examples, the golf club head 100 of the present disclosure includes a toe portion 114 and a heel portion 116, opposite the toe portion 114. Additionally, the golf club head 100 includes a forward portion 112 (e.g., face portion) and a rearward portion 118, opposite the forward portion 112. The golf club head 100 additionally includes a sole portion 117, at a bottom region of the golf club head 100, and a crown portion 119, opposite the sole portion 117 and at a top region of the golf club head 100. Also, the golf club head 100 includes a skirt portion 121 that defines a transition region where the golf club head 100 transitions between the crown portion 119 and the sole portion 117. Accordingly, the skirt portion 121 is located between the crown portion 119 and the sole portion 117 and extends about a periphery of the golf club head 100. Referring to FIG. 9A, the golf club head 100 further includes an interior cavity 113 that is collectively defined and enclosed by the forward portion 112, the rearward portion 118, the crown portion 119, the sole portion 117, the heel portion 116, the toe portion 114, and the skirt portion 121.

[0159] The strike face 145 extends along the forward portion 112 from the sole portion 117 to the crown portion 119, and from the toe portion 114 to the heel portion 116. Moreover, the strike face 145, and at least a portion of an interior surface 166 of the forward portion 112, opposite the strike face 145, is planar in a top-to-bottom direction. As further defined, the strike face 145 faces in the generally forward direction. In some examples, the strike face 145 is

co-formed with the body 102. In such examples, a minimum thickness of the forward portion 112 at the strike face 145 is between 1.5 mm and 2.5 mm and a maximum thickness of the forward portion 112 at the strike face 145 is less than 3.7 mm. An interior surface 166 of the forward portion 112, opposite the strike face 145, is not chemically etched and has an alpha case thickness of no more than 0.30 mm, in some examples.

[0160] Referring to FIGS. 9A, 9B, and 38-41, in some examples, the golf club head 100 includes a strike plate 143 that is not co-formed with the body 102. The strike plate 143 is formed separately from the body 102 and bonded to the body 102. As shown, the strike plate 143 defines the strike face 145 of the golf club head 100. In these examples, the body 102 includes a plate opening 149 at the forward portion 112 of the golf club head 100 and a plate-opening recessed ledge 147 that extends continuously about the plate opening 149. The plate opening recessed ledge 147 is non-planar or curved in some examples. An inner periphery of the plate-opening recessed ledge 147 defines the plate opening 149. The plate-opening recessed ledge 147 is divided into at least a top plate-opening recessed ledge 147A, that extends adjacently along the crown portion 119 of the golf club head 100 in a heel-to-toe direction, and a bottom plate-opening recessed ledge 147B, that extends adjacently along the sole portion 117 of the golf club head 100 in a heel-to-toe direction. Although not shown, the plate-opening recessed ledge is further divided into toe and heel plate-opening recessed ledges. Some properties of a plate-opening recessed ledge can be found in U.S. Pat. No. 9,278,267, issued Mar. 8, 2016, which is incorporated herein by reference in its entirety.

[0161] As shown in FIG. 9B, the top plate-opening recessed ledge 147A has a width (TPLW) and a thickness (TPLT). The width TPLW is defined as the distance from the inner periphery of the ledge 147A defining the plate opening 149 to the furthest extent of the adhering surface of the ledge 147A away from the inner periphery. The thickness TPLT is defined as the thickness of the material defining the adhering surface of the ledge 147A. In some examples, a recess 190 (e.g., an internal recess) is formed in an internal surface of the body 102 and has depth that extends in a back-to-front direction such that in a sole-to-crown direction, the recess 190 is between the top plate-opening recessed ledge 147A and a top of the golf club head 100. In other words, the recess 190 overlaps the top plate-opening recessed ledge 147A in a crown-to-sole direction. Notably, rearward of the recess 190 the thickness of the crown may increase locally such that the thickness of the crown portion proximate to where the crown insert joins the club head is thicker than at the recess 190. This may be done to stiffen the overall structure of the crown joint and mitigate stress in the composite crown joint.

[0162] Referring to FIGS. 30-32, in some examples, the golf club head 100 further includes an interior mass pad 129 formed in the crown portion 119 at a location adjacent a top plate-opening recessed ledge 147A. The interior mass pad 129 is also located between and offset (e.g., spaced apart) from the heel portion 116 and the toe portion 114 of the golf club head 100. A portion of the recess 190 is formed in the interior mass pad 129 in some examples. The interior mass pad 129 extends along only a portion of a length of the top plate-opening recessed ledge 147A. The length of the top plate-opening recessed ledge 147A extends in a heel-to-toe

direction. Moreover, in some examples, the top plate-opening recessed ledge 147A is non-planar or curved. According to some examples, a thickness (WT) of the crown portion at the recess 190 is thicker at the interior mass pad 129 (see, e.g., FIG. 31) than away from the interior mass pad 129 (see, e.g., FIG. 32).

[0163] In certain examples, the width TPLW of the top plate-opening recessed ledge 147A is greater than 4.5 mm (e.g., greater than 5.0 mm in some examples and greater than 5.5 mm in other examples, but less than 8.0 mm, preferably less than 7.0 mm in some examples). In some examples, a ratio of the width TPLW to a maximum height of the strike plate 143 is between 0.08 and 0.15. In the same or different examples, a ratio of the width TPLW to a maximum height of the plate opening 149 is between 0.07 and 0.15, such as 0.1, where in some examples the maximum height of the plate opening 149 is between 50-60 mm, such as 53 mm.

[0164] According to some examples, the thickness TPLT of the top plate-opening recessed ledge 147A is between a minimum value of 0.8 mm and a maximum value of 1.7 mm (e.g., between 0.9 mm and 1.6 mm in some examples and between 0.95 mm and 1.5 mm in other examples). As shown, the thickness TPLT is greater away from the inner periphery of the ledge 147A than at the inner periphery of the ledge 147A. Accordingly, the thickness TPLT varies along the width TPLW of the ledge 147A in some examples. For example, as shown, the thickness TPLT tapers or decreases in a crown-to-sole direction (e.g., toward a center of the plate opening 149). In some examples, the top ledge thickness TPLT of the top plate-opening recessed ledge 147A varies such that a maximum value of the top ledge thickness TPLT is between 30% and 60% greater than a minimum value of the top ledge thickness TPLT. In certain examples, a ratio of the thickness TPLT to a thickness of the strike plate is between 0.2 and 1.2. According to certain examples, a ratio of the width TPLW to the thickness TPLT is between 2.6 and 10.

[0165] The bottom plate-opening recessed ledge 147B has a width (BPLW) and a thickness (BPLT). The width BPLW is defined as the distance from the inner periphery of the ledge 147B defining the plate opening 149 to the furthest extent of the adhering surface of the ledge 147B away from the inner periphery. The thickness BPLT is defined as the thickness of the material defining the adhering surface of the ledge 147B.

[0166] In certain examples, the width BPLW of the bottom plate-opening recessed ledge 147B is greater than 4.5 mm (e.g., greater than 5.0 mm in some examples and greater than 5.5 mm in other examples, but less than 8.0 mm, preferably less than 7.0 mm in some examples). In some examples, a ratio of the width BPLW to a maximum height of the strike plate 143 is between 0.08 and 0.15. In the same or different examples, a ratio of the width BPLW to a maximum height of the plate opening 149 is between 0.07 and 0.15, such as 0.1, where in some examples the maximum height of the plate opening 149 is between 50-60 mm, such as 53 mm.

[0167] According to some examples, the thickness BPLT of the bottom plate-opening recessed ledge 147B is between 0.8 mm and 1.7 mm (e.g., between 0.9 mm and 1.6 mm in some examples and between 0.95 mm and 1.5 mm in other examples). As shown, the thickness BPLT is greater away from the inner periphery of the ledge 147B than at the inner periphery of the ledge 147B. Accordingly, the thickness BPLT varies along the width BPLW of the ledge 147B in

some examples. For example, as shown, the thickness BPLT decreases in a sole-to-crown direction (e.g., toward a center of the plate opening 149). In some examples, the bottom ledge thickness BPLT of the bottom plate-opening recessed ledge 147B varies such that a maximum value of the bottom ledge thickness BPLT is between 30% and 60% greater than a minimum value of the bottom ledge thickness BPLT. In certain examples, a ratio of the thickness BPLT to a thickness of the strike plate is between 0.2 and 1.2. According to certain examples, a ratio of the width BPLW to the thickness BPLT is between 2.6 and 10.

[0168] As shown, the strike plate 143 is attached to the body 102 by fixing the strike plate 143 in seated engagement with at least the top plate-opening recessed ledge 147A and the bottom plate-opening recessed ledge 147B. When joined to the top plate-opening recessed ledge 147A and the bottom plate-opening recessed ledge 147B in this manner, the strike plate 143 covers or encloses the plate opening 149. Moreover, in some examples, the top plate-opening recessed ledge 147A and the strike plate 143 are sized, shaped, and positioned relative to the crown portion 119 of the golf club head 100 such that the strike plate 143 abuts the crown portion 119 when seatably engaged with the top plate-opening recessed ledge 147A. The strike plate 143, abutting the crown portion 119, defines a topline of the golf club head 100. Moreover, in some examples, the visible appearance of the strike plate 143 contrasts enough with that of the crown portion 119 of the golf club head 100 that the topline of the golf club head 100 is visibly enhanced. Because the strike plate 143 is formed separately from the body 102, the strike plate 143 can be made of a material that is different than that of the body 102. In one example, the strike plate 143 is made of a fiber-reinforced polymeric material, such as described hereafter.

[0169] Notably, the TPLW, TPLT, BPLW, and BPLT dimensions help to control the local stiffness of the club head and to ensure sufficient bonding area to bond the strike plate to the body 102. The modulus of the strike plate if formed from a fiber-reinforced polymeric material will be much different than the modulus of the body if formed from a metal material such that the stiffness or compliance of the two are different, and during impact the strike plate and the body will move at different rates due to the different moduli unless precautions are taken in the design to account for the stiffness differences. The recess 190, and the TPLW, TPLT, BPLW, and BPLT dimensions, all play a role in controlling the overall compliance and rate with which the face and body move during impact. Additionally, TPLW and BPLW contribute to ensuring sufficient bond area and face performance. Too little bond area and the bonded joint will fail, too much bond area and the face will not perform i.e. the coefficient of restitution will not be optimized, and in some examples too much bond area will result in the face peeling away from the club head due to the differences in stiffness. Thus, TPLW, TPLT, BPLW, and BPLT dimensions contribute to the overall performance of the club head and to the avoidance of bonded joint failure. In some examples, the bond area will range from 850 mm² to 1800 mm², preferably between 1,300 mm² to 1,500 mm². In some examples, a ratio of the bond area to the inner surface area of the strike plate (rear surface area of the strike plate) will range from 21% to 45%. In some examples, a total bond area of the strike plate will be less than a total bond area of the crown insert. In some examples, a ledge width TPLW and/or BPLW will be

less than a ledge width of the forward crown-opening recessed ledge 168A (front-back as measured along the y-axis).

[0170] The forward portion 112 includes a sidewall 146 that defines a depth of the plate-opening recessed ledge 147 and defines a radially outer periphery of the plate-opening recessed ledge 147 away from a center of the plate opening 149. The sidewall 146 is angled (e.g., acute, obtuse, or perpendicular) relative to the plate-opening recessed ledge 147. In some examples, the angle defined between the sidewall 146 and the plate-opening recessed ledge 147 is between 70° and 120°. In certain examples, the angle defined between the sidewall 146 and the plate-opening recessed ledge 147 is greater than 90°. The body 102 further includes a transition portion between the plate-opening recessed ledge 147 and the sidewall 146. In some examples, the transition portion defines a radiused surface, which couples together the surfaces of the plate-opening recessed ledge 147 and the sidewall 146.

[0171] Referring to FIGS. 9A, 9B, and 31, bonding tape 174 adhesively bonds the strike plate 143 to the body 102. In some examples, the bonding tape 174 is interposed between the plate-opening recessed ledge 147 and the strike plate 143 and interposed between the sidewall 146 and the strike plate 143. For example, a strike-plate ledge strip 176A of the bonding tape 174 is between the plate-opening recessed ledge 147 and the strike plate 143, and a strike-plate sidewall strip 176B of the bonding tape 174 is interposed between the sidewall 146 and the strike plate 143. However, in other examples, the strike-plate ledge strip 176A of the bonding tape 174 is interposed between the plate-opening recessed ledge 147 and the strike plate 143, but the strike-plate sidewall strip 176B of the bonding tape 174 is not interposed between the sidewall 146 and the strike plate 143. Referring to FIG. 31, a thickness (LT) of the strike-plate ledge strip 176A between the plate-opening recessed ledge 147 and the strike plate 143 is greater than a thickness (ST) of the strike-plate sidewall strip 176B between the sidewall 146 and the strike plate 143, in some examples. According to one particular example, the thickness (LT) of the strike-plate ledge strip 176A between the plate-opening recessed ledge 147 and the strike plate 143 is between 0.25 mm and 0.45 mm, and the thickness (ST) of the strike-plate sidewall strip 176B between the sidewall 146 and the strike plate 143 is between 0.15 mm and 0.25 mm. The thickness of the bonding tape 174 of a fully formed golf club head 100 (e.g., after the bonding tape 174 has been compressed and cured (i.e., thermally activated)) can be different than the thickness of the bonding tape 174 prior to fully forming the golf club head 100 (e.g., prior to the bonding tape 174 being compressed and cured). The above-presented values for the thickness of the bonding tape 174 is prior to compressing and curing the bonding tape 174.

[0172] In some examples, the strike plate may have a maximum face plate height of no more than 55 mm as measured along the z-axis through the club head origin, preferably no more than 55 mm and no less than 40 mm, even more preferably between 49 mm and 54 mm. In some instance, the strike plate formed of fiber-reinforced polymeric material may have a front surface area of no more than 4,180 mm², and preferably between 3,200 mm² and 4,180 mm², more preferably between 3,500 mm² and 4,180 mm². According to certain examples, the strike face 145 has a first bulge radius of at least 300 mm and a first roll radius of at

least 250 mm. Generally, a bulge radius greater than 300 mm has a better CT creep rate and club heads with a bulge no less than 300 mm bulge radius and a roll radius within 30-50 mm of the bulge radius performed well.

[0173] The golf club head 100 includes a body 102, a crown insert 108 (or crown panel) attached to the body 102 at a top of the golf club head 100, and a sole insert 110 (or sole panel) attached to the body 102 at a bottom of the golf club head 100 (see, e.g., FIGS. 10 and 11). Accordingly, the body 102 effectually provides a frame to which one or more inserts, panels, or plates are attached. The body 102 includes a cast cup 104 and a ring 106 (e.g., a rear ring). The ring 106 is joined to the cast cup 104 at a toe-side joint 112A and a heel-side joint 112B. The cast cup 104 defines at least part of the forward portion 112 of the golf club head 100. The ring 106 defines at least part of the rearward portion 118 of the golf club head 100. Additionally, the cast cup 104 defines part of the crown portion 119, the sole portion 117, the heel portion 116, the toe portion 114, and the skirt portion 121. Similarly, the ring 106 defines part of the heel portion 116, the toe portion 114, and the skirt portion 121.

[0174] The cast cup 104 (or just cup) is cup-shaped. More specifically, as shown in FIG. 14, the cast cup 104, including the strike face 145, is enclosed on one end by the strike face 145, enclosed on four sides (e.g., by the crown portion 119, the sole portion 117, the toe portion 114, and the heel portion 116), which extend substantially transversely from the strike face 145, and open on an end opposite the strike face 145. Accordingly, the cast cup 104, when coupled with the strike face 145, resembles a cup or a cup-like unit.

[0175] The ring 106 is not circumferentially closed or does not form a continuous annular or circular shape. Instead, the ring 106 is circumferentially open and defines a substantially semi-circular shape. Thus, as defined herein, the ring 106 is termed a ring because it has a ring-like, semi-circular shape, and, when joined to the cast cup 104, forms a circumferentially closed or annular shape with the cast cup 104.

[0176] The cast cup 104 is formed separately from the ring 106 and the ring 106 is subsequently joined to the cast cup 104. Accordingly, the body 102 has at least a two-piece construction where the cast cup 104 defines one piece of the body 102 and the ring 106 define another piece of the body 102. Accordingly, a seam is defined at each of the toe-side joint 112A and the heel-side joint 112B where the cast cup 104 and the ring 106 are adjoined. The cast cup 104 and the ring 106 are separately formed using any of various manufacturing techniques. In one example, the cast cup 104 and the ring 106 are formed using a casting process. Because the cast cup 104 and the ring 106 are formed separately, the cast cup 104 and the ring 106 can be made of different materials. For example, the cast cup 104 can be made of a first material and the ring 106 can be made of a second material where the second material is different than the first material.

[0177] Referring to FIGS. 14 and 15, the cast cup 104 includes a toe ring-engagement surface 150A and a heel ring-engagement surface 150B. Similarly, the ring 106 includes a toe cup-engagement surface 152A and a heel cup-engagement surface 152B. The toe-side joint 112A is formed by abutting and securing together the toe ring-engagement surface 150A of the cast cup 104 and the toe cup-engagement surface 152A of the ring 106 and abutting and securing together the heel ring-engagement surface 150B of the cast cup 104 and the heel cup-engagement surface 152B of the ring 106. The engagement surfaces are

secured together via any suitable securing techniques, such as welding, brazing, adhesives, mechanical fasteners, and the like. In the illustrated example, as shown in FIGS. 9A, 14, and 15, the engagement surfaces are bonded together via the bonding tape 174.

[0178] To help strengthen and stiffen the toe-side joint 112A and the heel-side joint 112B, complementary mating elements can be incorporated into or coupled to the engagement surfaces. In the illustrated example, the cast cup 104 includes a toe projection 154A protruding from the toe ring-engagement surface 150A and a heel projection 154B protruding from the heel ring-engagement surface 150B. In contrast, in the illustrated example, the ring 106 includes a toe receptacle 156A formed in the toe cup-engagement surface 152A and a heel receptacle 156B formed in the heel cup-engagement surface 152B. The toe projection 154A mates with (e.g., is received within) the toe receptacle 156A and the heel projection 154B mates with (e.g., is received within) the heel receptacle 156B as the engagement surfaces abut each other to form the joints. Although in the illustrated example, the toe projection 154A and the heel projection 154B form part of the cast cup 104 and the toe receptacle and the heel receptacle 156B form part of the ring 106, in other examples, the mating elements can be reversed such that the toe projection 154A and the heel projection 154B form part of the ring 106 and the toe receptacle and the heel receptacle 156B form part of the cast cup 104. Additionally, different types of complementary mating elements, such as tabs and notches, can be used in addition to or in place of the projections and receptacles.

[0179] In some examples, the toe-side joint 112A and the heel-side joint 112B are located a sufficient distance from the strike face 145 to avoid potential failures due to severe impacts undergone by the golf club head 100 when striking a golf ball. For example, each one of the toe-side joint 112A and the heel-side joint 112B can be spaced at least 20 mm, at least 30 mm, at least 40 mm, at least 50 mm, at least 60 mm, and/or from 20 mm to 70 mm rearward of the center face 183 of the strike face 145, as measured along a y-axis (front-to-back direction) of the club head origin coordinate system 185. Referring to FIG. 14, according to certain examples, a first distance D1, from the strike face 145 to the heel ring-engagement surface 150B, is less than a second distance D2, from the strike face 145 to the toe ring-engagement surface 150A. In other words, in some examples, the cast cup 104 extends rearwardly from the strike face 145 a shorter distance at the heel portion 116 than at the toe portion 114.

[0180] Referring to FIGS. 10-13, the body 102 comprises a crown opening 162 and a sole opening 164. The crown opening 162 is located at the crown portion 119 of the golf club head 100 and when open provides access into the interior cavity 113 of the golf club head 100 from a top of the golf club head 100. In contrast, the sole opening 164 is located at the sole portion 117 of the golf club head 100 and when open provides access into the interior cavity 113 of the golf club head 100 from a bottom of the golf club head 100. Corresponding sections of the crown opening 162 and the sole opening 164 are defined by the cast cup 104 and the ring 106. More specifically, referring to FIGS. 10-15, a forward section 162A of the crown opening 162 and a forward section 164A of the sole opening 164 are defined by the cast cup 104, and a rearward section 162B of the crown opening 162 and a rearward section 164B of the sole opening 164 are

defined by the ring 106. Accordingly, when the cast cup 104 and the ring 106 are joined together, the forward section 162A and the rearward section 162B collectively define the crown opening 162, and the forward section 164A and the rearward section 164B collectively define the sole opening 164.

[0181] The cast cup 104 additionally includes a forward crown-opening recessed ledge 168A and a forward sole-opening recessed ledge 170A. The ring 106 includes a rearward crown-opening recessed ledge 168B and a rearward sole-opening recessed ledge 170B. The forward sole-opening recessed ledge 170A and the rearward sole-opening recessed ledge 170B form a sole-opening recessed ledge 170 of the golf club head 100. Moreover, in some examples, the sole-opening recessed ledge 170 is non-planar or curved. The ledges are offset inwardly, toward the interior cavity 113, from the exterior surfaces of the body 102 surrounding the ledges by distances corresponding with the thicknesses of the crown insert 108 and the sole insert 110. In some examples, the offset of the ledges from the exterior surfaces of the body 102 is approximately equal to the corresponding thicknesses of the crown insert 108 and the sole insert 110, such that the inserts are flush with the corresponding surrounding exterior surfaces of the body 102 when attached to the ledges. However, in some examples, the crown insert 108 and the sole insert 110 need not be flush with (e.g., can be raised or recessed relative to) the surrounding exterior surface of the body 102 when seatably engaged with the corresponding ledges. In some examples, a thickness of the sole insert 110 is greater than a thickness of the crown insert 108. Moreover, the sole insert 110 is made up of a first quantity of stacked plies, each made of a fiber-reinforced polymeric material, and the crown insert 108 is made up of a second quantity of stacked plies, each made of a fiber-reinforced polymeric material. In some examples, the first quantity of stacked plies is greater than the second quantity of stacked plies.

[0182] When the cast cup 104 and the ring 106 are joined, the forward crown-opening recessed ledge 168A and the rearward crown-opening recessed ledge 168B collectively define a crown-opening recessed ledge 168 of the body 102, and the forward sole-opening recessed ledge 170A and the rearward sole-opening recessed ledge 170B collectively define a sole-opening recessed ledge 170 of the body 102. The inner periphery of the forward crown-opening recessed ledge 168A defines the forward section 162A of the crown opening 162 and the inner periphery of the rearward crown-opening recessed ledge 168B defines the rearward section 162B of the crown opening 162. Likewise, the inner periphery of the forward sole-opening recessed ledge 170A defines the periphery of the forward section 164A of the sole opening 164 and the inner periphery of the rearward sole-opening recessed ledge 170B defines the periphery of the rearward section 164B of the sole opening 164. Accordingly, the inner periphery of the crown-opening recessed ledge 168 defines the periphery of the crown opening 162 and the inner periphery of the sole-opening recessed ledge 170 defines the periphery of the sole opening 164.

[0183] Referring to FIG. 31, a thickness of the body 102 at the crown portion 119 decreases in a rearward-to-forward direction from a forward extent 132 of the crown-opening recessed ledge 168, and decreases in a forward-to-rearward direction from the forward extent 132 of the crown-opening recessed ledge 168. This results in a localized increase in

thickness at the forward extent 132, which helps to strengthen and stiffen the joint between the body 102 and the crown insert 108.

[0184] The crown insert 108 and the sole insert 110 are formed separately from each other and separately from the body 102. Accordingly, the crown insert 108 and the sole insert 110 are attached to the body 102 as shown in FIGS. 10 and 11. In the illustrated examples, the crown insert 108 is seated on and bonded to, such as with the bonding tape 174, the crown-opening recessed ledge 168. For example, a crown-insert strip 178 of the bonding tape 174 is between the crown-opening recessed ledge 168 and the crown insert 108. Furthermore, in the illustrated examples, the sole insert 110 is seated on and bonded to, such as with the bonding tape 174, the sole-opening recessed ledge 170. For example, a sole-insert strip 180 of the bonding tape 174 is between the sole-opening recessed ledge 170 and the sole insert 110. In this manner, the crown insert 108 encloses or covers the crown opening 162 and defines, at least in part, the crown portion 119 of the golf club head 100, and the sole insert 110 encloses or covers the sole opening 164 and defines, at least in part, the sole portion 117 of the golf club head 100.

[0185] The crown insert 108 and the sole insert 110 can have any of various shapes. Referring to FIG. 4, in one example, the crown insert 108 is shaped such that a location (PCH), corresponding with the peak crown height of the golf club head 100, is rearward of a hosel 120 of the golf club head 100 and rearward of the hosel axis 191 of the hosel 120 of the golf club head 100. The peak crown height is the maximum crown height of a golf club head where the crown height at a given location along the golf club head is the distance from the ground plane 181, when the golf club head is in the address position on the ground plane, to an uppermost point on the crown portion at the given location. In some examples, the crown height of the golf club head 100 increases and then decreases in a front-to-rear direction away from the strike face 145. In certain examples, the portion or exterior surface of the crown portion that defines the peak crown height is made of at least one first material. According to some examples, a first crown height is defined at a face-to-crown transition region in the forward crown area where the club face connects to the crown portion of the club head, a second crown height is defined at a crown-to-skirt transition region where the crown portion connects to a skirt of the golf club head near a rear end of the golf club head, and a maximum crown height is defined rearward of the first crown height and forward of the second crown height, where the maximum crown height is greater than both the first and second crown heights. In some examples, the maximum crown height occurs toward of a geometric center of the strike face. According to certain examples, the maximum crown height is formed by a non-metal composite crown insert.

[0186] Referring to FIG. 3, a peak skirt height (shown associated with a location (PSH)) is the maximum skirt height of a golf club head, where the skirt height at a given location along the golf club head is the distance from the ground plane, when the golf club head is in the address position on the ground plane, to an uppermost point on the skirt portion at the rearwardmost point of the skirt portion on the golf club head.

[0187] According to some examples, a ratio of a peak crown height of the crown portion 119 to a peak skirt height of the skirt portion 121 ranges between about 0.45 to 0.59,

preferably 0.49-0.55, and in one example the skirt height is about 34 mm and the peak crown height is about 65 mm, which results in a ratio of peak skirt height to peak crown height of about 0.52. A peak skirt height typically ranges between 28 mm and 38 mm, preferably between 31 mm and 36 mm. A peak crown height typically ranges between 60 mm and 70 mm, preferably between 62 mm and 67 mm. It is desirable to limit a difference between the peak crown height and the peak skirt height to no more than 40 mm, preferably between 27 mm and 35 mm. It is desirable for the peak skirt height to be the same as or greater than a Z-up value for the golf club head i.e. the vertical distance along a z-axis from the ground plane 181 to the center of gravity. It is desirable for the peak crown height to be two times (2 \times) larger than a Z-up value for the golf club head. A greater peak skirt height may help with better aerodynamics and better air flow attachment especially for faster swing speeds. Likewise, if the difference between the peak crown height and peak skirt height is too great there will be a greater likelihood of the flow separating early from the golf club head i.e. increased likelihood of turbulent flow.

[0188] The construction and material diversity of the golf club head 100 enables the golf club head 100 to have a desirable center-of-gravity (CG) location and peak crown height location. In one example, a y-axis coordinate, on the y-axis of the club head origin coordinate system 185, of the location (PCH) of the peak crown height is between about 26 mm and about 42 mm. In the same or a different example, a distance parallel to the z-axis of the club head origin coordinate system 185, from the ground plane 181, when the golf club head 100 is in the address position, of the location (PCH) of the peak crown height ranges between 60 mm and 70 mm, preferably between 62 mm and 67 mm as described above. According to some examples, a y-axis coordinate, on the y-axis of the head origin coordinate system 185, of the center-of-gravity (CG) of the golf club head 100 ranges between 25 mm and 50 mm, preferably between 32 mm and 38 mm, more preferably between 36.5 mm and 42 mm, an x-axis coordinate, on the x-axis of the head origin coordinate system 185, of the center-of-gravity (CG) of the golf club head 100 ranges between -10 mm and 10 mm, preferably between -6 mm and 6 mm, and more preferably between -7 mm and 7 mm, and a z-axis coordinate, on the z-axis of the head origin coordinate system 185, of the center-of-gravity (CG) of the golf club head 100 is less than 2 mm, such as ranges between -10 mm and 2 mm, preferably between -7 mm and -2 mm.

[0189] Additionally, the construction and material diversity of the golf club head 100 enables the golf club head 100 to have desirable mass distribution properties. Referring to FIGS. 3, 5, and 6, the golf club head 100 includes a rearward mass and a forward mass. The rearward mass of the golf club head 100 is defined as the mass of the golf club head 100 within an imaginary rearward box 133 having a height (HRB), parallel to a crown-to-sole direction (parallel to z-axis of golf club head origin coordinate system 185), of 35 mm, a depth (DRB), in a front-to-rear direction (parallel to y-axis of golf club head origin coordinate system 185), of 35 mm, and a width (WRB), in a toe-to-heel direction (parallel to x-axis of golf club head origin coordinate system 185), greater than a maximum width of the golf club head 100. As shown, a rear side of the imaginary rearward box 133 is coextensive with a rearmost end of the golf club head 100 and a bottom side of the imaginary rearward box 133 is

coextensive with the ground plane 181 when the golf club head 100 is in the address position on the ground plane 181. The forward mass of the golf club head 100 is defined as the mass of the golf club head 100 within an imaginary forward box 135 having a height (HFB), parallel to the crown-to-sole direction, of 20 mm, a depth (DFB), in the front-to-rear direction, of 35 mm, and a width (WFB), in the toe-to-heel direction, greater than a maximum width of the golf club head 100. As shown, a forward side of the imaginary forward box 135 is coextensive with a forwardmost end of the golf club head 100 and a bottom side of the imaginary forward box 135 is coextensive with the ground plane 181 when the golf club head 100 is in the address position on the ground plane 181.

[0190] According to some examples, a first vector distance (V1) from a center-of-gravity of the rearward mass (RMCG) to a CG of the driver-type golf club head is between 49 mm and 64 mm (e.g., 55.7 mm), a second vector distance (V2) from a center-of-gravity of the forward mass (FMCG) to the CG of the driver-type golf club head is between 22 mm and 34 mm (e.g., 29.0 mm), and a third vector distance (V3) from the CG of the rearward mass (RMCG) to the CG of the forward mass (FMCG) is between 75 mm and 82 mm (e.g., 79.75 mm). In certain examples, V1 is no more than 56.3 mm. In some examples, V2 is no less than 23.7 mm, preferably no less than 25 mm, or even more preferably no less than 27 mm. Some additional values of V1 and V2 relative to Zup and CGy values for various examples of the golf club head 100 are provided in Table 1 below. As defined herein, Zup measures the center-of-gravity of the golf club head 100 relative to the ground plane 181 along a vertical axis (e.g., parallel to the z-axis of the club head origin coordinate system 185) when the golf club head 100 is in the proper address position on the ground plane 181. CGy is the coordinate of the center-of-gravity of the golf club head 100 on the y-axis of the club head origin coordinate system 185.

TABLE 1

Example	Zup	CGy	V1	V2
1	26 mm	37 mm	55.7 mm	29.0 mm
2	30 mm	37 mm	56.3 mm	31.8 mm
3	22 mm	37 mm	55.2 mm	27.3 mm
4	25 mm	32 mm	61.0 mm	23.7 mm
5	25 mm	40 mm	52.7 mm	30.76 mm

[0191] The crown insert 108 has a crown-insert outer surface that defines an outward-facing surface or exterior surface of the crown portion 119. Similarly, the sole insert 110 has a sole-insert outer surface that defines an outward-facing surface or exterior surface of the sole portion 117. As defined herein, the crown-insert outer surface and the sole-insert outer surface includes the combined outer surfaces of multiple crown inserts and multiple sole inserts, respectively, if multiple crown inserts or multiple sole inserts are used. In one example, a total surface area of the sole-insert outer surface is smaller than a total surface area of the crown-insert outer surface. According to one example, the total surface area of the crown-insert outer surface is at least 9,482 mm². In one example, the total surface area of the sole-insert outer surface is at least 8,750 mm² and the sole insert has a maximum width, parallel to a heel-to-toe direction, of at least between 80 mm and 120 mm. The total surface area of the crown-insert outer surface can range

between 5,300 mm² to 11,000 mm², preferably between 9,200 mm² and 10,300 mm², preferably between 5,300 mm² and 7,000 mm². The total surface area of the sole-insert outer surface can range between 4,300 mm² to 10,200 mm², preferably between 7,700 mm² and 9,900 mm², preferably between 4,300 mm² and 6,600 mm².

[0192] Preferably the total surface area of the sole-insert outer surface is greater than the total surface area of the sole-insert outer surface in the instance when at least a portion of the sole is formed of a composite material. A ratio of total surface area of the crown-insert outer surface formed of composite material to the total surface area of the sole-insert outer surface formed of composite material may be at least 2:1 in some examples, in other instance the ratio may be between 0.95 and 1.5, more preferably between 1.03 and 1.4, even more preferably between 1.05 and 1.3. In this instance a composite material will generally have a density between about 1 g/cc and about 2 g/cc, and preferably between about 1.3 g/cc and about 1.7 g/cc.

[0193] In some embodiments, the total exposed composite surface area in square centimeters multiplied by the CGy in centimeters and the resultant divided by the volume in cubic centimeters may range from 1.22 to 2.1, preferably between 1.24 and 1.65, even more preferably between 1.49 and 2.1, and even more preferably 1.7 and 2.1.

[0194] Moreover, the total mass of the crown insert 108 is less than a total mass of the sole insert 110 in some examples. According to some examples, where the crown insert 108 and the sole insert 110 are made of a fiber-reinforced polymeric material and the body 102 is made of a metallic material, a ratio of a total exposed surface area of the body 102 to a total exposed surface area (e.g., the surface area of the outward-facing surfaces) of the crown insert 108 and the sole insert 110 is between 0.95 and 1.25 (e.g., 1.08). The crown insert 108, whether a single piece or split into multiple pieces, has a mass of 9 grams and the sole insert 110, whether a single piece or split into multiple pieces, has a mass of 13 grams, in some examples. Moreover, in certain examples, the crown insert 108 is about 0.65 mm thick and the sole insert 110 is about 1.0 mm thick. However, in certain examples, the minimum thickness of the crown portion 119 is less than 0.6 mm. According to some examples, an areal weight of the crown portion 119 of the golf club head 100 is less than 0.35 g/cm² over more than 50% of an entire surface area of the crown portion 119 and/or at least part of the crown portion 119 is formed of a non-metal material with a density between about 1 g/cm³ to about 2 g/cm³. These and other properties of the crown insert 108 and the sole insert 110 can be found in U.S. Patent Application Publication No. 2020/0121994, published Apr. 23, 2020, which is incorporated herein by reference in its entirety. In certain examples, an areal weight of the sole portion 117 is less than about 0.35 g/cm² over more than about 50% of an entire surface area of the sole portion 117. In certain examples, an areal weight of the crown insert 108 is less than an areal weight of the sole insert 110. At least 50% of the crown portion 119 has a variable thickness that changes at least 25% along at least 50% of the crown portion 119, in certain examples.

[0195] The cast cup 104 of the body 102 also includes the hosel 120, which defines the hosel axis 191 extending coaxially through a bore 193 of the hosel 120 (see, e.g., FIG. 14). The hosel 120 is configured to be attached to a shaft of a golf club. In some examples, the hosel 120 facilitates the

inclusion of a flight control technology (FCT) system 123 between the hosel 120 and the shaft to control the positioning of the golf club head 100 relative to the shaft.

[0196] The FCT system 123 may include a fastener 125 that is accessible through a lower opening 195 formed in a sole region of the cast cup 104. An additional example of the FCT system 123 is shown in association with the golf club head 400 of FIGS. 19 and 20, which has a hosel 420 and a lower opening 495 to facilitate attachment of the FCT system 123 to the body 102. The FCT system 123 includes multiple movable parts that fit within the and extend from the hosel 120. The fastener 125 facilitates adjustability of the FCT system 123 system by loosening the fastener 125 and maintaining an adjustable position of the golf club head relative to the shaft by tightening the fastener 125. The lower opening 195 is open to the bore 193 of the hosel 120. To promote an increase in discretionary mass, an internal portion 127 of the hosel 120 (i.e., a portion of the hosel 120 that is within the interior cavity 113) includes a lateral opening 189 that is open to the interior cavity 113. Because of the lateral opening 189, the internal portion 127 of the hosel 120 only partially surrounds FCT components extending through the bore 193 of the hosel 120. In some examples a height of the lateral opening 189, in a direction parallel to the hosel axis 191, is between 10 mm and 15 mm, a width of the lateral opening 189, in a direction perpendicular to the hosel axis 191, is at least 1 radian, and/or a projected area of the lateral opening 189 is at least 75 mm².

[0197] Referring to FIG. 15, in some examples, the cast cup 104 includes the strike face 145. In other words, in some examples, the strike face 145 is co-formed (e.g., co-cast) with all other portions of the cast cup 104. Accordingly, in these examples, the strike face 145 is made of the same material as the rest of the cast cup 104. However, in other examples, similar to those associated with the golf club heads of FIGS. 9A, 9B, 17 and 18, the strike face 145 is defined by a strike plate that is formed separate from the cast cup 104 and separately attached to the cast cup 104. According to certain examples, the portion of the golf club head 100 defining the strike face 145 or the strike plate defining the strike face 145 includes variable thickness features similar to those described in more detail in U.S. patent application Ser. No. 12/006,060; and U.S. Pat. Nos. 6,997,820; 6,800,038; and 6,824,475, which are incorporated herein by reference in their entirety.

[0198] FIG. 21 illustrates an exemplary rear surface of a face portion 600 of one or more of the golf club heads disclosed herein. In FIG. 21, the rear surface is viewed from the rear with the hosel/heel to the left and the toe to the right. FIGS. 22 and 23 illustrate another exemplary face portion 700 having a variable thickness profile, and FIG. 24 illustrates yet another exemplary face portion 800 having a variable thickness profile. The variable thickness profile of the face portion 700 is formed by a cone-shaped projection, which can have a geometric center that is toward of a geometric center of the strike face in some examples. The face portions disclosed herein can be formed as a result of a casting process and optional post-casting modifications to the face portions. Accordingly, the face portion can have a great variety of novel thickness profiles. For example, in one examples, a thickness of the forward portion, at the strike face, changes at least 25% along the strike face. By casting the face into a desired geometry, rather than forming the face plate from a flat rolled sheet of metal in a traditional process,

the face can be created with greater variety of geometries and can have different material properties, such as different grain direction and chemical impurity content, which can provide advantages for a golf performance and manufacturing.

[0199] In a traditional process, the face plate is formed from a flat sheet of metal having a uniform thickness. Such a sheet of metal is typically rolled along one axis to reduce the thickness to a certain uniform thickness across the sheet. This rolling process can impart a grain direction in the sheet that creates a different material properties in the rolling axis direction compared to the direction perpendicular to the rolling direction. This variation in material properties can be undesirable and can be avoided by using the disclosed casting methods instead to create face portion.

[0200] Furthermore, because a conventional face plate starts off as a flat sheet of uniform thickness, the thickness of the whole sheet has to be at least as great as the maximum thickness of the desired end product face plate, meaning much of the starting sheet material has to be removed and wasted, increasing material cost. By contrast, in the disclosed casting methods, the face portion is initially formed much closer to the final shape and mass, and much less material has to be removed and wasted. This saves time and cost.

[0201] Still further, in a conventional process, the initial flat sheet of metal has to be bent in a special process to impart a desired bulge and roll curvature to the face plate. Such a bending process is not needed when using the disclosed casting methods.

[0202] The unique thickness profiles illustrated in FIGS. 22-25 are made possible using casting methods, such as those disclosed in U.S. Pat. No. 10,874,915 issued Dec. 29, 2020, which is incorporated by reference in its entirety, and were previously not possible to achieve using conventional processes, such as starting from a sheet of metal having a uniform thickness, mounting the sheet in a lathe or similar machine and turning the sheet to produce a variable thickness profile across the rear of the face plate. In such a turning process, the imparted thickness profile must be symmetrical about the central turning axis, which limits the thickness profile to a composition of concentric circular ring shapes each having a uniform thickness at any given radius from the center point. In contrast, no such limitations are imposed using the disclosed casting methods, and more complex face geometries can be created.

[0203] By using casting methods, large numbers of the disclosed club heads can be manufacture faster and more efficiently. For example, 50 or more heads can be cast at the same time on a single casting tree, whereas it would take much longer and require more resources to create the novel face thickness profiles on face plates using a conventional milling methods using a lathe, one at a time.

[0204] In FIG. 22, the rear face surface or interior surface of the face portion 600 includes a non-symmetrical variable thickness profile, illustrating just one example of the wide variety of variable thickness profiles made possible using the disclosed casting methods. The center 602 of the face can have a center thickness, and the face thickness can gradually increase moving radially outwardly from the center across an inner blend zone 603 to a maximum thickness ring 604, which can be circular. The face thickness can gradually decrease moving radially outwardly from the maximum thickness ring 604 across an variable blend zone 606 to a

second ring 608, which can be non-circular, such as elliptical. The face thickness can gradually decrease moving radially outwardly from the second ring 608 across an outer blend zone 609 to heel and toe zones 610 of constant thicknesses (e.g., minimum thickness of the face portion) and/or to a radial perimeter zone 612 defining the extent of the face portion 600 where the face transitions to the rest of the golf club head 100.

[0205] The second ring 608 can itself have a variable thickness profile, such that the thickness of the second ring 608 varies as a function of the circumferential position around the center 602. Similarly, the variable blend zone 606 can have a thickness profile that varies as a function of the circumferential position around the center 602 and provides a transition in thickness from the maximum thickness ring 604 to the variable and less thicknesses of the second ring 608. For example, the variable blend zone 606 to a second ring 608 can be divided into eight sectors that are labeled A-H in FIG. 22, including top zone A, top-toe zone B, toe zone C, bottom-toe zone D, bottom zone E, bottom-heel zone F, heel zone G, and top-heel zone H. These eight zones can have differing angular widths as shown, or can each have the same angular width (e.g., one eighth of 360 degrees). Each of the eight zones can have its own thickness variance, each ranging from a common maximum thickness adjacent the ring 604 to a different minimum thickness at the second ring 608. For example, the second ring can be thicker in zones A and E, and thinner in zones C and G, with intermediate thicknesses in zones B, D, F, and H. In this example, the zones B, D, F, and H can vary in thickness both along a radial direction (thinning moving radially outwardly) and along a circumferential direction (thinning moving from zones A and E toward zones C and G).

[0206] One example of the face portion 600 can have the following thicknesses: 3.1 mm at center 602, 3.3 mm at ring 604, the second ring 608 can vary from 2.8 mm in zone A to 2.2 mm in zone C to 2.4 mm in zone E to 2.0 mm in zone G, and 1.8 mm in the heel and toe zones 610.

[0207] According to one example, the ring 604 can be about 8 mm away from the center 602 and the ring 608 can be about 19 mm away from the center 602. The thickness of the face portion 600 at the center 602 can be between 2.8 mm and 3.0 mm. The thickness of the face portion 600 along the ring 604 can be between 2.9 mm and 3.1 mm. The thickness of the face portion 600 along the ring 608 proximate zone A can be between 2.35 mm and 2.55 mm, proximate zone C can be between 2.3 mm and 2.5 mm, proximate zone E can be between 2.1 mm and 2.3 mm, and proximate zone G can be between 2.6 mm and 2.8 mm. The thickness of the face portion 600 at approximately 35 mm away from the center 602 can be between 1.7 mm and 1.9 mm.

[0208] According to yet another example, the thickness of the face portion 600 at the center 602 is between 2.95 mm and 3.35 mm, at about 9 mm away from the center 602 is between 3.3 mm and 3.65 mm, at about 16 mm away from the center 602 is between 2.95 mm and 3.36 mm, and at about 28 mm away from the center 602 is between 2.03 mm and 2.27 mm. The thickness of the face portion 600 greater than 28 mm away from the center 602 can be between 1.8 mm and 1.95 mm on a toe side of the face portion 600 and between 1.83 mm and 1.98 mm on a heel side of the face portion 600.

[0209] FIGS. 23 and 24 show the rear face surface of another exemplary face portion 700 that includes a non-symmetrical variable thickness profile. The center 702 of the face can have a center thickness, and the face thickness can gradually increase moving radially outwardly from the center across an inner blend zone 703 to a maximum thickness ring 704, which can be circular. The face thickness can gradually decrease moving radially outwardly from the maximum thickness ring 704 across a variable blend zone 705 to an outer zone 706 comprised of a plurality of wedge shaped sectors A-H having varying thicknesses. As best shown in FIG. 24, sectors A, C, E, and G can be relatively thicker, while sectors B, D, F, and H can be relatively thinner. An outer blend zone 708 surrounding the outer zone 706 transitions in thickness from the variable sectors down to a perimeter ring 710 having a relatively small yet constant thickness. The outer zone 706 can also include blend zones between each of the sectors A-H that gradually transition in thickness from one sector to an adjacent sector.

[0210] One example of the face portion 700 can have the following thicknesses: 3.9 mm at center 702, 4.05 mm at ring 704, 3.6 mm in zone A, 3.2 mm in zone B, 3.25 mm in zone C, 2.05 mm in zone D, 3.35 mm in zone E, 2.05 mm in zone F, 3.00 mm in zone G, 2.65 mm in zone H, and 1.9 mm at perimeter ring 710.

[0211] FIG. 25 shows the rear face of another exemplary face portion 800 that includes a non-symmetrical variable thickness profile having a targeted thickness offset toward the heel side (left side). The center 802 of the face has a center thickness, and to the toe/top/bottom the thickness gradually increases across an inner blend zone 803 to inner ring 804 having a greater thickness than at the center 802. The thickness then decreases moving radially outwardly across a second blend zone 805 to a second ring 806 having a thickness less than that of the inner ring 804. The thickness then decreases moving radially outwardly across a third blend zone 807 to a third ring 808 having a thickness less than that of the second ring 806. The thickness then decreases moving radially outwardly across a fourth blend zone 810 to a fourth ring 811 having a thickness less than that of the third ring 808. A toe end zone 812 blends across an outer blend zone 813 to an outer perimeter 814 having a relatively small thickness.

[0212] To the heel side, the thicknesses are offset by set amount (e.g., 0.15 mm) to be slightly thicker relative to their counterpart areas on the toe side. A thickening zone 820 (dashed lines) provides a transition where all thicknesses gradually step up toward the thicker offset zone 822 (dashed lines) at the heel side. In the offset zone 822, the ring 823 is thicker than the ring 806 on the heel side by a set amount (e.g., 0.15 mm), and the ring 825 is thicker than the ring 808 by the same set amount. Blend zones 824 and 826 gradually decrease in thickness moving radially outwardly, and are each thicker than their counterpart blend zones 807 and 810 on the toe side. In the thickening zone 820, the inner ring 804 gradually increases in thickness moving toward the heel.

[0213] One example of the face portion 800 can have the following thicknesses: 3.8 mm at the center 802, 4.0 mm at the inner ring 804 and thickening to 4.15 mm across the thickening zone 820, 3.5 mm at the second ring 806 and 3.65 mm at the ring 823, 2.4 mm at the third ring 808 and 2.55 mm at the ring 825, 2.0 mm at the fourth ring 811, and 1.8 mm at the perimeter ring 814.

[0214] The targeted offset thickness profile shown in FIG. 25 can help provide a desirable CT profile across the face. Thickening the heel side can help avoid having a CT spike at the heel side of the face, for example, which can help avoid having a non-conforming CT profile across the face. Such an offset thickness profile can similarly be applied to the toe side of the face, or to both the toe side and the heel side of the face to avoid CT spikes at both the heel and toe sides of the face. In other embodiments, an offset thickness profile can be applied to the upper side of the face and/or toward the bottom side of the face.

[0215] As shown in FIGS. 2, 4, 8, 9A, and 13, in some examples, the cast cup 104 further includes a slot 171 located in the sole portion 117 of the golf club head 100. The slot 171 is open to an exterior of the golf club head 100 and extends lengthwise from the heel portion 116 to the toe portion 114. More specifically, the slot 171 is elongate in a lengthwise direction substantially parallel to, but offset from, the strike face 145. Generally, the slot 171 is a groove or channel formed in the cast cup 104 at the sole portion 117 of the golf club head 100. In some implementations, the slot 171 is a through-slot, or a slot that is open to the interior cavity 113 from outside of the golf club head 100. However, in other implementations, the slot 171 is not a through-slot, but rather is closed on an interior cavity side or interior side of the slot 171. For example, the slot 171 can be defined by a portion of the side wall of the sole portion 117 of the body 102 that protrudes into the interior cavity 113 and has a concave exterior surface having any of various cross-sectional shapes, such as a substantially U-shape, V-shape, and the like.

[0216] In some examples, the slot 171 is offset from the strike face 145 by an offset distance, which is the minimum distance between a first vertical plane passing through a center of the strike face 145 and the slot at the same x-axis coordinate as the center of the strike face 145, between about 5 mm and about 50 mm, such as between about 5 mm and about 35 mm, such as between about 5 mm and about 30 mm, such as between about 5 mm and about 20 mm, or such as between about 5 mm and about 15 mm.

[0217] Although not shown, the cast cup 104 and/or the ring 106 may include a rearward slot, with a configuration similar to the slot 171, but oriented in a forward-to-rearward direction, as opposed to a heel-to-toe direction. The cast cup 104 includes a rearward slot, but no slot 171 in some examples, and both a rearward slot and the slot 171 in other examples. In one example, the rearward slot is positioned rearwardly of the slot 171. The rearward slot can act as a weight track in some implementations. Moreover, the rearward track can be offset from the strike face 145 by an offset distance, which is the minimum distance between a first vertical plane passing through the center of the strike face 145 and the rearward track at the same x-axis coordinate as the center of the strike face 145, between about 5 mm and about 50 mm, such as between about 5 mm and about 40 mm, such as between about 5 mm and about 30 mm, or such as between about 10 mm and about 30 mm.

[0218] In certain embodiments, the slot 171, as well as the rearward slot if present, has a certain slot width, which is measured as a horizontal distance between a first slot wall and a second slot wall. For the slot 171, as well as the rearward slot, the slot width may be between about 5 mm and about 20 mm, such as between about 10 mm and about 18 mm, or such as between about 12 mm and about 16 mm.

According to some embodiments, a depth of the slot 171 (i.e., the vertical distance between a bottom slot wall and an imaginary plane containing the regions of the sole portion 117 adjacent opposing slot walls of the slot 171) may be between about 6 mm and about 20 mm, such as between about 8 mm and about 18 mm, or such as between about 10 mm and about 16 mm.

[0219] Additionally, the slot 171, as well as the rearward slot if present, has a certain slot length, which can be measured as the horizontal distance between a slot end wall and another slot end wall. For both the slot 171 and rearward slot, their lengths may be between about 30 mm and about 120 mm, such as between about 50 mm and about 100 mm, or such as between about 60 mm and about 90 mm. Additionally, or alternatively, the length of the slot 171 may be represented as a percentage of a total length of the strike face 145. For example, the slot 171 may be between about 30% and about 100% of the length of the strike face 145, such as between about 50% and about 90%, or such as between about 60% and about 80% mm of the length of the strike face 145.

[0220] In some examples, the slot 171 is a feature to improve and/or increase the coefficient of restitution (COR) across the strike face 145. With regards to a COR feature, the slot 171 may take on various forms such as a channel or through slot. The COR of the golf club head 100 is a measurement of the energy loss or retention between the golf club head 100 and a golf ball when the golf ball is struck by the golf club head 100. Desirably, the COR of the golf club head 100 is high to promote the efficient transfer of energy from the golf club head 100 to the ball during impact with the ball. Accordingly, the COR feature of the golf club head 100 promotes an increase in the COR of the golf club head 100. Generally, the slot 171 increases the COR of the golf club head 100 by increasing or enhancing the flexibility of the strike face 145. In some examples of the golf club heads disclosed herein, the COR is at least 0.8 for at least 25% of the strike face within the central region, as defined below.

[0221] Further details concerning the slot 171 as a COR feature of the golf club head 100 can be found in U.S. patent application Ser. Nos. 13/338,197, 13/469,031, 13/828,675, filed Dec. 27, 2011, May 10, 2012, and Mar. 14, 2013, respectively, U.S. patent application Ser. No. 13/839,727, filed Mar. 15, 2013, U.S. Pat. No. 8,235,844, filed Jun. 1, 2010, U.S. Pat. No. 8,241,143, filed Dec. 13, 2011, U.S. Pat. No. 8,241,144, filed Dec. 14, 2011, all of which are incorporated herein by reference.

[0222] The slot 171 can be any of various flexible boundary structures (FBS) as described in U.S. Pat. No. 9,044,653, filed Mar. 14, 2013, which is incorporated by reference herein in its entirety. Additionally, or alternatively, the golf club head 100 can include one or more other FBS at any of various other locations on the golf club head 100. The slot 171 may be made up of curved sections, or several segments that may be a combination of curved and straight segments. Furthermore, the slot 171 may be machined or cast into the golf club head 100. Although shown in the sole portion 117 of the golf club head 100, the slot 171 may, alternatively or additionally, be incorporated into the crown portion 119 of the golf club head 100.

[0223] In some examples, the slot 171 is filled with a filler material. However, in other examples, the slot 171 is not filled with a filler material, but rather maintains an open, vacant, space within the slot 171. The filler material can be

made from a non-metal, such as a thermoplastic material, thermoset material, and the like, in some implementations. The slot 171 may be filled with a material to prevent dirt and other debris from entering the slot and possibly the interior cavity 113 of the golf club head 100 when the slot 171 is a through-slot. The filler material may be any relatively low modulus materials including polyurethane, elastomeric rubber, polymer, various rubbers, foams, and fillers. The filler material should not substantially prevent deformation of the golf club head 100 when in use as this would counteract the flexibility of the golf club head 100.

[0224] According to one embodiment, the filler material is initially a viscous material that is injected or otherwise inserted into the slot 171. Examples of materials that may be suitable for use as a filler to be placed into a slot, channel, or other flexible boundary structure include, without limitation: viscoelastic elastomers; vinyl copolymers with or without inorganic fillers; polyvinyl acetate with or without mineral fillers such as barium sulfate; acrylics; polyesters; polyurethanes; polyethers; polyamides; polybutadienes; polystyrenes; polyisoprenes; polyethylenes; polyolefins; styrene/isoprene block copolymers; hydrogenated styrenic thermoplastic elastomers; metallized polyesters; metallized acrylics; epoxies; epoxy and graphite composites; natural and synthetic rubbers; piezoelectric ceramics; thermoset and thermoplastic rubbers; foamed polymers; ionomers; low-density fiber glass; bitumen; silicone; and mixtures thereof. The metallized polyesters and acrylics can comprise aluminum as the metal. Commercially available materials include resilient polymeric materials such as Scotchweld™ (e.g., DP-105™) and Scotchdamp™ from 3M, Sorbothane™ from Sorbothane, Inc., DYAD™ and GPTM from Soundcoat Company Inc., Dynamat™ from Dynamat Control of North America, Inc., NoViFlex™ Sylomer™ from Pole Star Maritime Group, LLC, Isoplast™ from The Dow Chemical Company, Legetolex™ from Piqua Technologies, Inc., and Hybrar™ from the Kuraray Co., Ltd. In some embodiments, a solid filler material may be press-fit or adhesively bonded into a slot, channel, or other flexible boundary structure. In other embodiments, a filler material may be poured, injected, or otherwise inserted into a slot or channel and allowed to cure in place, forming a sufficiently hardened or resilient outer surface. In still other embodiments, a filler material may be placed into a slot or channel and sealed in place with a resilient cap or other structure formed of a metal, metal alloy, metallic, composite, hard plastic, resilient elastomeric, or other suitable material.

[0225] Referring to FIGS. 4, 8, 9A, and 14, in some examples, the golf club head 100 further includes a weight 173 attached to the cast cup 104. The cast cup 104 includes a threaded port 175 that receives and retains the weight 173. The threaded port 175 is open to an exterior and the interior cavity 113 of the golf club head 100 and includes internal threads in certain examples. In other examples, the threaded port 175 is closed to the interior cavity 113. The weight 173 includes external threads that threadably engage with the internal threads of the threaded port 175 to retain the weight 173 within the threaded port 175. When the threaded port 175 is open to the interior cavity 113, the weight 173 effectually closes the threaded port 175 to prevent access to the interior cavity 113 when threadably attached to the cast cup 104 within the threaded port 175. As shown, when the threaded port 175 is open to the interior cavity 113, a portion of the weight 173 is located external to the interior cavity

113 and another portion is located within the interior cavity 113. In contrast, in other examples, such as when the threaded port 175 is closed to the interior cavity 113, an entirety of the weight 173 is located external to the interior cavity 113. Although not shown, in one example, the threaded port 175 can be open to the interior cavity 113 and closed to an exterior of the golf club head 100 (e.g., the threaded port 175 faces inwardly as opposed to outwardly). In such an example, the entirety of the weight 173 would be located internally within the interior cavity 113. As defined herein, when any portion of the weight 173 is internal relative to or within the interior cavity 113, the weight 173 is considered internal to the interior cavity 113 and when any portion of the weight 173 is external relative to the interior cavity 113, the weight 173 is alternatively, or also, considered external to the interior cavity 113.

[0226] In some examples, as shown, the threaded port 175, and thus the weight 173, is located in the sole portion 117 of the golf club head 100. Moreover, according to certain examples, the threaded port 175 and the weight 173 are located closer to the heel portion 116 than the toe portion 114. In one example, the threaded port 175 and the weight are located closer to the heel portion 116 than the slot 171. The weight 173 has a mass between about 3 g and about 23 g (e.g., 6 g) in some examples.

[0227] Referring to FIGS. 9A, 11, and 14, the cast cup 104 further comprises a mass pad 186 attached to or co-formed with the rest of the cast cup 104. The mass pad 186 has a thickness greater than any other portion of the cast cup 104. In the illustrated example, the mass pad 186 is located proximate the sole portion 117 of the golf club head 100, and thus a sole region of the cast cup 104. Additionally, in certain examples, a portion of the mass pad 186 is located proximate the heel portion 116 of the golf club head 100, and thus a heel region of the cast cup 104. As defined herein, when located at the sole portion 117 of the golf club head 100, the mass pad 186 is considered a sole mass pad, and when located at the heel portion 116 of the golf club head 100, the mass pad 186 is considered a heel mass pad. It is recognized that when the mass pad 186 is located at both the sole portion 117 and the heel portion 116, the mass pad 186 is considered to be a sole mass pad and a heel mass pad.

[0228] Referring to FIGS. 11 and 14, in some examples, the cast cup 104 further includes internal ribs 187 co-formed with other portions of the cast cup 104. The internal ribs 187 can be in any of various locations within the cast cup 104. In the illustrated example, the internal ribs 187 are located (e.g., formed in) a sole region of the cast cup 104 closer to a toe region of the cast cup 104 than a heel region of the cast cup 104. The internal ribs 187 help to stiffen and promote desirable acoustic properties of the golf club head 100.

[0229] Referring to FIGS. 11, 14, and 15, the ring 106 includes a cantilevered portion 161, and a toe arm portion 163A and a heel arm portion 163B extending from the cantilevered portion 161. The toe arm portion 163A and the heel arm portion 163B are on opposite sides of the golf club head 100, initiate at the cantilevered portion 161, and terminate at a corresponding one of the toe cup-engagement surface 152A and the heel cup-engagement surface 152B. The cantilevered portion 161 defines at least part of the rearward portion 118 of the golf club head 100 and further defines a rearmost end of the golf club head 100. Moreover, in the illustrated examples, the cantilevered portion 161 extends from the crown portion 119 to the sole portion 117.

Accordingly, the cantilevered portion 161 defines part of the sole portion 117 of the golf club head 100 in some examples, such as defining an outwardly-facing surface of the sole portion 117 of the golf club head 100.

[0230] In some examples, the cantilevered portion 161 is close to the ground plane 181 when the golf club head 100 is in the address position. According to certain examples, a ratio of the peak crown height to a vertical distance from the peak crown height to a lowest surface of the cantilevered portion 161 of the ring 106 is at least 6.0, at least 5.0, at least 4.0, or more preferably at least 3.0. Alternatively, or additionally, in some examples, a vertical distance from the peak skirt height of the skirt portion to a lowermost surface of the cantilevered portion 161 of the ring 106, when the golf club head 100 is in the address position, is no less than between 20 mm and 30 mm.

[0231] The toe arm portion 163A and the heel arm portion 163B define a toe side of the skirt portion 121 and a heel side of the skirt portion 121, respectively, as well as part of the toe portion 114 and heel portion 116, respectively, of the golf club head 100. The cantilevered portion 161 extends downwardly away from the toe arm portion 163A and the heel arm portion 163B, while the toe arm portion 163A and the heel arm portion 163B extend forwardly away from the cantilevered portion 161. Accordingly, the cantilevered portion 161 is closer to the ground plane 181 than the toe arm portion 163A and the heel arm portion 163B when the golf club head 100 is in the address position. In other words, referring to FIGS. 3, 4, and 9A, a height (HR) of the lowest surface of the ring 106 above the ground plane 181, in a vertical direction when the golf club head 100 is in the address position, at any location along the cantilevered portion 161 is less than at any location along the toe arm portion 163A and the heel arm portion 163B.

[0232] In some examples, the height HR of the lowest surface of the toe arm portion 163A at the toe portion 114 of the golf club head 100 is different than the height HR of the lowest surface of the heel arm portion 163B at the heel portion 116 of the golf club head 100. More specifically, in one example, the height HR of the lowest surface of the toe arm portion 163A at the toe portion 114 of the golf club head 100 is greater than the height HR of the lowest surface of the heel arm portion 163B at the heel portion 116 of the golf club head 100.

[0233] According to certain examples, as shown in FIGS. 3, 4, and 9A, a width (WR) of the ring 106, as measured in a vertical direction when the golf club head 100 is in the address position, varies in a forward-to-rearward direction (e.g., along a length of the ring 106). In one example, the width WR increases from a minimum width to a maximum width in the forward-to-rearward direction. In other words, the width WR of the ring 106 varies in the forward-to-rearward direction in certain examples. In some examples, the maximum width WR of the ring 106 is at the rearmost end of the golf club head 100. In one example, the maximum width WR of the ring 106 is at least 20 mm. According to certain examples, as shown in FIG. 14, the width WR of the ring 106 at the toe portion 114 is less than the width WR of the ring 106 at the heel portion 116. According to some additional examples, a thickness of the ring 106 can vary along the ring 106 in a forward-to-rearward direction.

[0234] Referring to FIGS. 2-4, 6, 8, 9A, and 11-15, in some examples, the golf club head 100 further includes a

mass element 159 attached to the cantilevered portion 161 of the ring 106, such as at a rearmost end of the golf club head 100. The mass element 159 can be selectively removable from (e.g., interchangeable with differently weighted mass elements) or permanently attached to the cantilevered portion 161. According to one example, the mass element 159 and the weight 173 are interchangeably coupleable to the cast cup 104 and the cantilevered portion 161 of the ring 106. Accordingly, in some examples, the flight control technology component of the golf club head 100, the mass element 159, and the weight 173 are adjustable relative to the golf club head 100. In certain examples, the flight control technology component of the golf club head 100, the mass element 159, and the weight 173 are configured to be adjustable via a single or the same tool.

[0235] In one example, the mass element 159 includes external threads. The golf club head 100 can additionally include a mass receptacle 157 attached to the cantilevered portion 161 of the ring 106. The mass receptacle 157 can include a threaded aperture, with internal threads, that threadably engages the mass element 159 to secure the mass element 159 to the cantilevered portion 161. The mass receptacle 157 is welded to the cantilevered portion 161 in some examples and adhered to the cantilevered portion 161 in other examples. In certain examples, the mass receptacle 157 is co-formed with the cantilevered portion 161. The cantilevered portion 161 also includes a mass pad 155 (see, e.g., FIGS. 9A, 12, and 15) or a portion of the cantilevered portion 161 with a localized increase in thickness and thus mass. The mass receptacle 157 can be formed in the mass pad 155 of the cantilevered portion 161. The mass element 159 has a mass between about 15 g and about 35 g (e.g., 24 g) in some examples.

[0236] The outer peripheral shape of one or both of the mass element 159 and the weight 173 in the illustrated examples is circular. Accordingly, an orientation of one or both of the mass element 159 and the weight 173 is rotatable about a central axis of the mass element 159 and the weight 173, respectively, in any of various orientations between 0-degrees and 360-degrees. However, in other examples, the outer peripheral shape of at least one or both of the mass element 159 and the weight 173 is non-circular, such as ovular, triangular, trapezoidal, square, and the like. For example, as shown in FIG. 16, the weight 273 has an outer peripheral shape that is trapezoidal or rectangular. In certain examples, the mass element 159 and/or the weight 173, having a non-circular outer peripheral shape, is rotatable about the central axis of the mass element 159 and the weight 173, respectively, in any of various orientations between 0-degrees and at least 90-degrees in certain implementations and 0-degrees and at least 180-degrees in other implementations.

[0237] The construction and material diversity of the golf club head 100 enables flexibility of the position of the weight 173 (e.g., first weight or forward weight) relative to the position of the mass element 159 (e.g., second weight or rearward weight). In some examples, the relative positions of the weight 173 and the mass element 159 can be similar to those disclosed in U.S. patent application Ser. No. 16/752, 397, filed Jan. 24, 2020. Referring to FIG. 9A, according to one example, a z-axis coordinate of the CG of the first weight (FWCG), on the z-axis of the head origin coordinate system 185, is between -30 mm and -10 mm (e.g., -21 mm), a y-axis coordinate of the CG of the first weight

(FWCG), on the y-axis of the head origin coordinate system 185 is between 10 mm and 30 mm (e.g., 23 mm), and an x-axis coordinate of the CG of the first weight (FWCG), on the x-axis of the head origin coordinate system 185 is between 15 mm and 35 mm (e.g., 22 mm). According to the same, or a different, example, a z-axis coordinate of the CG of the second weight (SWCG), on the z-axis of the head origin coordinate system 185, is between -30 mm and 10 mm (e.g., -11 mm), a y-axis coordinate of the CG of the second weight (SWCG), on the y-axis of the head origin coordinate system 185 is between 90 mm and 120 mm (e.g., 110 mm), and an x-axis coordinate of the CG of the second weight (SWCG), on the x-axis of the head origin coordinate system 185 is between -20 mm and 10 mm (e.g., -7 mm).

[0238] In certain examples, the sole portion 117 of the golf club head 100 includes an inertia generating feature 177 that is elongated in a lengthwise direction. The lengthwise direction is perpendicular or oblique to the strike face 145. According to some examples, the inertia generating feature 177 includes the same features and provides the same advantages as the inertia generator disclosed in U.S. patent application Ser. No. 16/660,561, filed Oct. 22, 2019, which is incorporated herein by reference in its entirety. In the illustrated examples, the sole insert 110 forms at least a portion of the inertia generating feature 177. More specifically, in some examples, the sole insert 110 forms all or a majority of the inertia generating feature 177. The cantilevered portion 161 of the ring 106 also forms part, such as a rearmost part, of the inertia generating feature 177 in certain examples. The inertia generating feature 177 helps to increase the inertia of the golf club head 100 and lower the center-of-gravity (CG) of the golf club head 100.

[0239] The inertia generating feature 177 includes a raised or elevate platform that extends from a location rearwardly of the hosel 120 to a location proximate the rearward portion 118 of the golf club head 100. The inertia generating feature 177 includes a substantially flat or planar surface that is raised above (or protrudes from, depending on the orientation of the golf club head 100) the surrounding external surface of the sole portion 117. In certain examples, at least a portion of the inertia generating feature 177 is raised above the surrounding external surface of the sole portion 117 by at least 1.5 mm, at least 1.8 mm, at least 2.1 mm, or at least 3.0 mm. The inertia generating feature 177 also has a width that is less than an entire width (e.g., less than half the entire width) of the sole portion 117. In view of the foregoing, the inertia generating feature 177 has a complex curved geometry with multiple inflection points. Accordingly, the sole insert 110, which defines the inertia generating feature 177, has a complex curved surface that has multiple inflection points.

[0240] Referring to FIGS. 1-3 and 5, in some examples, the golf club head 100 includes a through-aperture 172 in the body 102 at the toe portion 114. The through-aperture 172 extends entirely through the wall of the body 102 such that the interior cavity 113 is accessible through the aperture 172. The aperture 172 can be used to insert a stiffener into the interior cavity 113 against an interior surface of the forward portion 112 to help set the CT of the strike face 145. Further details of the stiffener, the insertion process, and the effect of the stiffener on the CT of the strike face 145 can be found in U.S. Patent Application Publication No. 2019/0201754, published Jul. 4, 2019, which is incorporated herein by reference in its entirety. As shown, the through-aperture 172

is not located in the forward portion 112 (e.g., the strike face 145). Accordingly, in some examples, the strike face 145 is void of through-apertures open to the interior cavity 113 or the hollow interior region of the golf club head 100. Moreover, in some examples, no material having a shore D value greater than 10, greater than 5, or greater than 1 contacts an interior surface 166 of the forward portion 112, opposite the strike face 145 and open to the hollow interior region, at a location toward and/or heelward of the geometric center of the strike face 145. In yet other examples, no material, regardless of hardness, contacts an interior surface 166 of the forward portion 112, opposite the strike face 145 and open to the hollow interior region.

[0241] The CT properties of the golf club heads disclosed herein can be defined as CT values within a central region of the strike face 145. The central region, is forty millimeter by twenty millimeter rectangular area centered on a center of the strike face and elongated in a heel-to-toe direction. The center of the strike face 145 can be a geometric center of the strike face 145 in some examples. Within the central region, the strike face 145 has a characteristic time (CT) of no more than 257 microseconds. In some examples, the CT of at least 60% of the strike face, within the central region, is at least 235 microseconds. According to some examples, the CT of at least 35% of the strike face, within the central region, is at least 240 microseconds.

[0242] The CT of the strike face 145, at the geometric center of the strike face, has an initial CT value. The initial CT value is the CT value of the strike face 145 before any impacts with a standard golf ball. As defined herein, an impact with the standard golf ball is an impact of the standard golf ball when the golf ball is traveling at a velocity of 52 meters per second. According to some examples, the initial CT value is at least 244 microseconds. In certain examples, the driver-type golf club heads disclosed herein, including the golf club head 100, are configured such that after 500 impacts of a standard golf ball at the geometric center of the strike face 145, the CT of the strike face at any point within the central region is less than 256 microseconds and the CT at the geometric center of the strike face is no more than five microseconds different than (e.g., greater than) the initial CT value.

[0243] In certain examples, the driver-type golf club heads disclosed herein, including the golf club head 100, are configured such that after 1,000, 1,500, 2,000, 2,500, or 3,000 impacts of the standard golf ball at the geometric center of the strike face, the CT of the strike face at any point within the central region is less than 256 microseconds. According to some examples, after 2,000 impacts of the standard golf ball at the geometric center of the strike face, the CT of the strike face 145 at any point within the central region is no more than seven microseconds or nine microseconds different than the initial CT value. Moreover, in certain examples, after 2,000 impacts of the standard golf ball at the geometric center of the strike face, the CT of the strike face 145 at the geometric center of the strike face is no less than 249 microseconds and no more than ten microseconds different than the initial CT value. According to some examples, after 3,000 impacts of the standard golf ball at the geometric center of the strike face, the CT of the strike face 145 at any point within the central region is no more than nine microseconds or thirteen microseconds different than the initial CT value. In certain examples, such as those where the strike face 145 is made of a metallic

material, an inward face progression of the strike face 145 is less than 0.01 inches after 500 impacts of the standard golf ball at the geometric center of the strike face.

[0244] Referring to FIGS. 16 and 17, and according to another example of a golf club head disclosed herein, a golf club head 200 is shown. The golf club head 200 includes features similar to the features of the golf club head 100, with like numbers (e.g., same numbers but in 200-series) referring to like features. For example, like the golf club head 100, the golf club head 200 includes a toe portion 214 and a heel portion 216, opposite the toe portion 214. Additionally, the golf club head 200 includes a forward portion 212 and a rearward portion 218, opposite the forward portion 212. The golf club head 200 additionally includes a sole portion 217, at a bottom region of the golf club head 200, and a crown portion 219, opposite the sole portion 217 and at a top region of the golf club head 200. Also, the golf club head 200 includes a skirt portion 221 that defines a transition region where the golf club head 200 transitions between the crown portion 219 and the sole portion 217. The golf club head 200 further includes an interior cavity 213 that is collectively defined and enclosed by the forward portion 212, the rearward portion 218, the crown portion 219, the sole portion 217, the heel portion 216, the toe portion 214, and the skirt portion 221. Additionally, the forward portion 212 includes a strike face 245 that extends along the forward portion 212 from the sole portion 217 to the crown portion 219, and from the toe portion 214 to the heel portion 216. Additionally, the golf club head 200 further includes a body 202, a crown insert 208 attached to the body 202 at a top of the golf club head 200, and a sole insert 210 attached to the body 202 at a bottom of the golf club head 200. The body 202 includes a cast cup 204 and a ring 206. The ring 206 is joined to the cast cup 204 at a toe-side joint 212A and a heel-side joint 212B. The cast cup 204 of the body 202 also includes a slot 271 in the sole portion 217 of the golf club head 200. Further, the golf club head 200 additionally includes a mass element 259 and a mass receptacle 257 attached to the ring 206 of the body 202, as well as a weight 273 attached to the cast cup 204. Accordingly, in view of the foregoing, the golf club head 200 shares some similarities with the golf club head 100.

[0245] Unlike the golf club head 100, however, the strike face 245 of the golf club head 200 in FIGS. 16 and 17 is not co-formed with the cast cup 204. Rather, the strike face 245 forms part of a strike plate 243 that is formed separately from the cast cup 204 and bonded to the cast cup 204 by the bonding tape 174. Accordingly, the strike plate 243 defines the strike face 245. The cast cup 204 includes a plate opening 249 at the forward portion 212 of the golf club head 200 and a plate-opening recessed ledge 247 that extends continuously about the plate opening 249. An inner periphery of the plate-opening recessed ledge 247 defines the plate opening 249. The strike plate 243 is attached to the cast cup 204 by fixing the strike plate 243 in seated engagement with the plate-opening recessed ledge 247. When joined to the plate-opening recessed ledge 247 in this manner, the strike plate 243 covers or encloses the plate opening 249. Moreover, the plate-opening recessed ledge 247 and the strike plate 243 are sized, shaped, and positioned relative to the crown portion 219 of the golf club head 200 such that the strike plate 243 abuts the crown portion 219 when seatably engaged with the plate-opening recessed ledge 247. The

strike plate 243, abutting the crown portion 219, defines a topline of the golf club head 200. Moreover, in some examples, the visible appearance of the strike plate 243 contrasts enough with that of the crown portion 219 of the golf club head 200, which is partially defined by the cast cup 204, that the topline of the golf club head 200 is visibly enhanced. Because the strike plate 243 is formed separately from the cast cup 204, the strike plate 243 can be made of a material that is different than that of the cast cup 204. In one example, the strike plate 243 is made of a fiber-reinforced polymeric material. In yet another example, the strike plate 243 is made of a metallic material, such as a titanium alloy (e.g., Ti 6-4, Ti 9-1-1, and ZA 1300).

[0246] Additionally, unlike the golf club head 100, the cast cup 204 includes a weight track 279 in the sole portion 217 of the golf club head 200. The weight track 279 extends lengthwise in a heel-to-toe direction along the sole portion 217. In examples where the cast cup 204 also includes the slot 271, such as shown, the weight track 279 is substantially parallel to the slot 271 and offset from the slot 271 in a front-to-rear direction. The weight track 279 includes at least one ledge that extends lengthwise along the length of the weight track 279. In the illustrated example, the weight track 279 includes a forward ledge 297A and a rearward ledge 297B, which are spaced apart from each other in the front-to-rear direction. The weight 273, which positioned within the weight track 279, is selectively clampable to the ledge or ledges of the weight track 279 to releasably fix the weight 273 to the weight track 279. In the illustrated example, the weight 273 is selectively clampable to both the forward ledge 297A and the rearward ledge 297B. When unclamped to the one or more ledges of the weight track 279, the weight 273 is slid able along the one or more ledges, as shown by directional arrows in FIG. 16, to change a position of the weight 273 relative to the weight track 279 and, when re-clamped to the one or more ledges, adjust the mass distribution, center-of-gravity (CG), and other performance characteristics of the golf club head 200.

[0247] According to one example, the weight 273 includes a washer 273A, a nut 273B, and a fastening bolt 273C that interconnects with the washer 273A and the nut 273B to clamp down on the ledges 297A, 297B of the weight track 279. The washer 273A has a non-threaded aperture and the nut 273B has a threaded aperture. The fastening bolt 273C is threaded and passes through the non-threaded aperture of the washer 273A to threadably engage the threaded aperture of the nut 273B. Threadable engagement between the fastening bolt 273C and the nut 273B allows a gap between the washer 273A and the nut 273B to be narrowed, which facilitates the clamping of the ledge or ledges between the washer 273A and the nut 273B, or widened, which facilitates the un-clamping of the ledge or ledges from between the washer 273A and the nut 273B. The fastening bolt 273C can be rotatable relative to both the washer 273A and the nut 273B or form a one-piece monolithic construction and be co-rotatable with one of the washer 273A and the nut 273B.

[0248] To reduce the weight of the golf club head 200 and the depth of the weight track 279, the fastening bolt 273C is short. For example, the length of the fastening bolt 273C, when the weight 273 is clamped on the ledges 297A, 297B, extends no more than 3 mm past the nut 273B (or the washer 273A if the position of the nut 273B and the washer 273A are reversed). In some examples, the entire length of the fastening bolt 273C is no more than 15% greater than the

combined thicknesses of the washer 273A, the nut 273B, and one of the ledges 297A, 297B.

[0249] As shown, an outer peripheral shape of the washer 273A is non-circular, such as trapezoidal or rectangular. Similarly, the outer peripheral shape of the nut 273B can be non-circular, such as trapezoidal or rectangular. Alternatively, as shown, the outer peripheral shape of the nut 273B is circular and the outer peripheral shape of the washer 273A is non-circular.

[0250] Referring to FIG. 18, and according to another example of a golf club head disclosed herein, a golf club head 300 is shown. The golf club head 300 includes features similar to the features of the golf club head 100 and the golf club head 200, with like numbers (e.g., same numbers but in 300-series) referring to like features. For example, like the golf club head 100 and the golf club head 200 includes a body 302, a crown insert 308 attached to the body 302 at a top of the golf club head 300, and a sole insert 310 attached to the body 302 at a bottom of the golf club head 300. The body 302 includes a cast cup 304 and a ring 306. The ring 306 is joined to the cast cup 304 at a toe-side joint and a heel-side joint. The cast cup 304 of the body 302 also includes a slot 371 in the sole portion of the golf club head 300. Further, the golf club head 300 additionally includes a mass element 359 and a mass receptacle 357 attached to the ring 306 of the body 302, as well as a weight 373 attached to the cast cup 304 via a fastener 379.

[0251] Additionally, like the golf club head 200, the golf club head 300 includes a strike plate 343, defining a strike face 145, that is formed separate from and attached to the cast cup 304. The strike plate 343 is made of a fiber-reinforced polymer in some examples and includes a base portion 347 and a cover 349 applied onto the base portion 347. The base portion 347 is thicker compared to the cover 349, the base portion 347 is made of a fiber-reinforced polymer, and the cover 349 is made of a fiber-less polymer in some examples. The cover 349 is made of polyurethane in certain examples. Also, the cover 349 includes grooves 351 or scorelines formed in the fiber-less polymer. The surface roughness of the portion of the cover 349 that defines the strike face 345 is greater than the surface roughness of the body 302. Accordingly, in view of the foregoing, the golf club head 300 shares some similarities with the golf club head 100 and the golf club head 200.

[0252] Unlike the illustrated examples of the cast cup 104 of the golf club head 100 and the cast cup 204 of the golf club head 200, however, the cast cup 304 has a multi-piece construction. More specifically, the cast cup 304 includes an upper cup piece 304A and a lower cup piece 304B. The upper cup piece 304A is formed separately from the lower cup piece 304B. Accordingly, the upper cup piece 304A and the lower cup piece 304B are joined or attached together to form the cast cup 304. Because the upper cup piece 304A and the lower cup piece 304B are formed separately, the upper cup piece 304A can be made of a material that is different than that of the lower cup piece 304B. The cast cup 304 includes a hosel 320 where a portion of the hosel 320 is formed into the upper cup piece 304A and another portion of the hosel 320 is formed into the lower cup piece 304B.

[0253] According to some examples, the upper cup piece 304A is made of a material that is different than that of the lower cup piece 304B. For example, the upper cup piece 304A can be made of a material with a density that is lower than the material of the lower cup piece 304B. In one

example, the upper cup piece 304A is made of a titanium alloy and the lower cup piece 304B is made of a steel alloy. According to another example, the upper cup piece 304A is made of an aluminum alloy and the lower cup piece 304B is made of a steel alloy or a tungsten alloy, such as 10-17 density tungsten. Such configurations help to increase the mass of the cast cup 304 and lower the center-of-gravity (CG) of the cast cup 304 and the golf club head 300 compared to the single-piece cast cup 104 of the golf club head 100. In alternative configurations, according to some examples, the upper cup piece 304A is made of an aluminum alloy and the lower cup piece 304B is made of a titanium alloy. These later configurations help to lower the overall mass of the cast cup 304. According to some examples, the upper cup piece 304A and the lower cup piece 304B are made using different manufacturing techniques. For example, the upper cup piece 304A can be made by stamping, forging, and/or metal-injection-molding (MIM) and the lower cup piece 304B can be made by another one or a different combination of stamping, forging, and/or metal-injection-molding (MIM). Various examples of combinations of materials and mass properties for the upper cup piece 304A and the lower cup piece 304B are shown in Table 2 below.

like features. For example, like the golf club head 100, the golf club head 200, and the golf club head 300, the golf club head 400 includes a body 402, a crown insert 408 attached to the body 402 at a top of the golf club head 400, and a sole insert 410 attached to the body 402 at a bottom of the golf club head 400. The body 402 includes a cast cup 404 and a ring 406. The ring 406 is joined to the cast cup 404 at a toe-side joint 412A and a heel-side joint 412B. Additionally, like the golf club head 200 and the golf club head 300, the golf club head 400 includes a strike plate 443, defining a strike face 445, that is formed separate from and attached to the cast cup 404. Accordingly, in view of the foregoing, the golf club head 400 shares some similarities with the golf club head 100, the golf club head 200, and the golf club head 300.

[0257] Furthermore, the golf club head 400 additionally includes a weight 473 attached to the cast cup 404 via a fastener 479. As shown, the cast cup 404 includes a port 475 that receives and retains the weight 473. The port 475 is configured to retain the weight 473 in a fixed location on the sole portion of the golf club head 400. However, in other examples, the port 475 can be replaced with a weight track, similar to the weight track 279 of the golf club head 200, such that the weight 473 can be selectively adjustable and moved into any of various positions along the weight track. In this manner, a weight track, and a corresponding ledge or ledges of the weight track, can form part of one piece of a multi-piece cast cup.

TABLE 2

Example	Material		Density (g/cc)		Mass (g)		CG (z-axis) (mm)		Mass (g)	Delta-CG	Delta-CG
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower			
1	Ti-64	Ti-64	4.4	4.4	37.5	37.5	15	-15	75	0	0
2	Ti-64	Steel	4.4	7.8	37.5	66.5	15	-15	104.0	-4.2	-2.2
3	Al-7075	Steel	2.8	7.8	23.9	66.5	15	-15	90.3	-7.1	-3.2
4	Al-7075	W-10	2.8	10	23.9	85.2	15	-15	109.1	-8.4	-4.6
5	Al-7075	Ti-64	2.8	4.4	23.9	37.5	15	-15	61.4	-3.3	-1.0
6	Al-7075	Al-7075	2.8	2.8	23.9	23.9	15	-15	47.7	0.0	0.0

[0254] As shown, the cast cup 304 includes a port 375 that receives and retains the weight 373. The port 375 is configured to retain the weight 373 in a fixed location on the sole portion of the golf club head 300. However, in other examples, the port 375 can be replaced with a weight track, similar to the weight track 279 of the golf club head 200, such that the weight 373 can be selectively adjustable and moved into any of various positions along the weight track. In this manner, a weight track, and a corresponding ledge or ledges of the weight track, can form part of one piece of a multi-piece cast cup.

[0255] Although the cast cup 304 is shown to have a two-piece construction, in other examples, the cast cup 304 has a three-piece construction or constructed with more than three pieces. According to one instance, the cast cup 304 has a crown-toe piece, a crown-heel piece, and a sole piece. The crown-toe piece and the crown-heel piece are made of titanium alloys and the sole piece is made of a steel alloy in certain implementations. The titanium alloy of the crown-toe piece can be the same as or different than the titanium alloy of the crown-heel piece.

[0256] Referring to FIGS. 19 and 20, and according to another example of a golf club head disclosed herein, a golf club head 400 is shown. The golf club head 400 includes features similar to the features of the golf club head 100, the golf club head 200, and the golf club head 300, with like numbers (e.g., same numbers but in 400-series) referring to

moved into any of various positions along the weight track. In this manner, a weight track, and a corresponding ledge or ledges of the weight track, can form part of the cast cup 404.

[0258] Also, like the golf club head 100, the golf club head 200, and the golf club head 300, the golf club head 400 additionally includes a mass element 459 and a mass receptacle 457. However, unlike some examples, of the receptacles of the previously discussed golf club heads, the mass receptacle 457 of the golf club head 400 forms a one-piece monolithic construction with a cantilevered portion 461 of the ring 406. Accordingly, in certain examples, the mass receptacle 457 is co-cast with the ring 406. The mass receptacle 457 includes an opening or recess that is configured to nestably receive the mass element 459. The mass element 459 can be made of a material, such as tungsten, that is different (e.g., denser) than the material of the ring 406. The mass element 459 is bonded, such as via an adhesive, to the ring 406 to secure the mass element 459 within the mass receptacle 457. In some examples, the mass element 459 includes prongs 463 that engage corresponding apertures in the mass receptacle 457 when bonded to the ring 406. Engagement between the prongs 463 and the corresponding apertures of the mass receptacle 457 help to strengthen and stiffen the coupling between the mass element 459 and the ring 406.

[0259] Referring to FIG. 21, the ring 406 includes a toe arm portion 463A that defines a toe side of a skirt portion

421 of the golf club head **400** and a heel arm portion **463B** that defines a heel side of the skirt portion **421**. Moreover, the toe arm portion **463A** and the heel arm portion **463B** define part of a toe portion **414** and a heel portion **416**, respectively, of the golf club head **400** (see, e.g., FIGS. 19 and 20). The cantilevered portion **461** extends downwardly away from the toe arm portion **463A** and the heel arm portion **463B**, while the toe arm portion **463A** and the heel arm portion **463B** extend forwardly away from the cantilevered portion **461**. Accordingly, the cantilevered portion **461** is closer to the ground plane **181** than the toe arm portion **463A** and the heel arm portion **463B** when the golf club head **400** is in the address position. In FIG. 21, the ring **406** is shown in a position corresponding with the position of the ring **406** when the golf club head **400** is in the address position relative to the ground plane **181**.

[0260] In some examples, the height HR of the lowest surface (and in some examples, an entirety) of the toe arm portion **463A** at the toe portion **414** of the golf club head **400** is different than the height HR of the lowest surface (and in some examples, an entirety) of the heel arm portion **463B** at the heel portion **416** of the golf club head **400**. More specifically, in one example, the height HR of the lowest surface of the toe arm portion **463A** at the toe portion **414** of the golf club head **400** is greater than the height HR of the lowest surface of the heel arm portion **463B** at the heel portion **416** of the golf club head **100**.

[0261] According to certain examples, the width WR of the toe arm portion **463A** of the ring **406** at the toe portion **414** is less than the width WR of the heel arm portion **463B** of the ring **406** at the heel portion **416**. According to some additional examples, a thickness (TR) of the ring **406** can vary along the ring **406** in a forward-to-rearward direction. For example, in some examples, the thickness TR of the ring **406** varies from a minimum thickness to a maximum thickness in a forward-to-rearward direction. In certain examples, as shown, the thickness TR of the toe arm portion **463A** of the ring **406** at the toe portion **414** is less than the thickness TR of the heel arm portion **463B** of the ring **406** at the heel portion **416**.

[0262] The golf club heads disclosed herein, including the golf club head **100**, the golf club head **200**, and the golf club head **300**, each has a volume, equal to the volumetric displacement of the golf club head, that is between 390 cubic centimeters (cm^3 or cc) and about 600 cm^3 . In more particular examples, the volume of each one of the golf club heads disclosed herein is between about 350 cm^3 and about 500 cm^3 or between about 420 cm^3 and about 500 cm^3 . The total mass of each one of the golf club heads disclosed herein is between about 145 g and about 245 g, in some examples, and between 185 g and 210 g in other examples.

[0263] The golf club heads disclosed herein have a multi-piece construction. For example, with regards to the golf club head **100**, the cast cup **104**, the ring **106**, the crown insert **108**, and the sole insert **110** each comprises one piece of the multi-piece construction. Because each piece of the multi-piece construction is separately formed and attached together, each piece can be made of a material different than at least one other of the pieces. Such a multi-material construction allows for flexibility of the material composition, and thus the mass composition and distribution, of the golf club heads.

[0264] The following properties of the golf club heads disclosed herein proceeds with reference to the golf club

head **100**. However, unless otherwise noted, the properties described with reference to the golf club head **100** also apply to the golf club head **200**, the golf club head **300**, and the golf club head **400**. The golf club head **100** is made from at least one first material, having a density between 0.9 g/cc and 3.5 g/cc, at least one second material, having a density between 3.6 g/cc and 5.5 g/cc, and at least one third material, having a density between 5.6 g/cc and 20.0 g/cc. In a first example, the cast cup **104** is made of the third material, the ring **106** is made of the second material, and the crown insert **108** and the sole insert **110** are made of the first material. In this first example, according to one instance, the cast cup **104** is made of a steel alloy, the ring **106** is made of a titanium alloy, and the crown insert **108** and the sole insert **110** are made of a fiber-reinforced polymeric material. In a second example, the cast cup **104** is made of the second and third material, the ring **106** is made of the first or the second material, and the crown insert **108** and the sole insert **110** are made of the first material. In this second example, according to one instance, the cast cup **104** is made of a steel alloy and a titanium alloy, the ring **106** is made of a titanium alloy, aluminum alloy, or plastic, and the crown insert **108** and the sole insert **110** are made of a fiber-reinforced polymeric material.

[0265] According to some examples, the at least one first material has a first mass no more than 55% of the total mass of the golf club head **100** and no less than 25% of the total mass of the golf club head **100** (e.g., between 50 g and 110 g). In certain examples, the first mass of the at least one first material is no more than 45% of the total mass of the golf club head **100** and no less than 30% of the total mass of the golf club head **100**. The first mass of the at least one first material can be greater than the second mass of the at least one second material. Alternatively, or additionally, the first mass of the at least one first material can be within 10 g of the second mass of the at least one second material.

[0266] In some examples, the at least one second material has a second mass no more than 65% of the total mass of the golf club head **100** and no less than 20% of the total mass of the golf club head **100** (e.g., between 40 g and 130 g). According to certain examples, the second mass of the at least one second material is no more than 50% of the total mass of the golf club head **100**. The second mass of the at least one second material is less than two times the first mass of the at least one first material in certain examples. The second mass of the at least one second material is between 0.9 times and 1.8 times the first mass of the at least one first material in some examples. In one example, the second mass of the at least one second material is less than 0.9 times, or less than 1.8 times, the first mass of the at least one first material.

[0267] The at least one third material has a third mass equal to the total mass of the golf club head **100** less the first mass of the at least one first material and the second mass of the at least one second material. In one example, the third mass of the at least one third material is no less than 5% of the total mass of the golf club head **100** and no more than 50% of the total mass of the golf club head **100** (e.g., between 10 g and 100 g). According to another example, the third mass of the at least one third material is no less than 10% of the total mass of the golf club head **100** and no more than 20% of the total mass of the golf club head **100**.

[0268] According to one example, the cast cup **104** of the body **102** of the golf club head **100** is made from the at least

one first material and the at least one first material is a first metal material that has a density between 4.0 g/cc and 8.0 g/cc. In this example, the ring **106** of the body **102** of the golf club head **100** is made of a material that has a density between 0.5 g/cc and 4.0 g/cc. According to certain implementations, the first metal material of the cast cup **104** is a titanium alloy and/or a steel alloy and the material of the ring **106** is an aluminum alloy and/or a magnesium alloy. In some implementations, the first metal material of the cast cup **104** is a titanium alloy and/or a steel alloy and the material of the ring **106** is a non-metal material, such as a plastic or polymeric material. Accordingly, in some examples, the ring **106** is made of any of various materials, such as titanium alloys, aluminum alloys, and fiber-reinforced polymeric materials.

[0269] The ring **106**, in some examples, is made of one of 6000-series, 7000-series, or 8000-series aluminum, which can be anodized to have a particular color the same as or different than the cast cup **104**. According to some examples, the ring **106** can be anodized to have any one of an array of colors, including blue, red, orange, green, purple, etc. Contrasting colors between the ring **105** and the cast cup **104** may help with alignment or suit a user's preferences. In one example, the ring **106** is made of 7075 aluminum. According to some examples, the ring **106** is made of a fiber-reinforced polycarbonate material. The ring **106** can be made from a plastic with a non-conductive vacuum metallizing coating, which may also have any of various colors. Accordingly, in certain examples, the ring **106** is made of a titanium alloy, a steel alloy, a boron-infused steel alloy, a copper alloy, a beryllium alloy, composite material, hard plastic, resilient elastomeric material, carbon-fiber reinforced thermoplastic with short or long fibers. The ring **106** can be made via an injection molded, cast molded, physical vapor deposition, or CNC milled technique.

[0270] As described herein, the ring (e.g., the ring **106**) of any of the club heads disclosed herein can comprise various different materials and features, and be made of different materials and have different properties than the cast cup (e.g., the cast cup **104**), which is formed separately and later coupled to the ring. In addition to or alternative to other materials described herein, the ring can comprise metallic materials, polymeric materials, and/or composite materials, and can include various external coatings.

[0271] In some embodiments, the ring comprises anodized aluminum, such as 6000, 7000, and 8000 series aluminum. In one specific example, the ring comprises 7075 grade aluminum. The anodized aluminum can be colored, such as red, green, blue, gray, white, orange, purple, pink, fuchsia, black, clear, yellow, gold, silver, or metallic colors. In some embodiments, the ring can have a color that contrasts from a majority color located on other parts of the club head (e.g., the crown insert, the sole insert, the cup, the rear weight, etc.).

[0272] In some embodiments, the ring can comprise any combination of metals, metal alloys (e.g., Ti alloys, steel, boron infused steel, aluminum, copper, beryllium), composite materials (e.g., carbon fiber reinforced polymer, with short or long fibers), hard plastics, resilient elastomers, other polymeric materials, and/or other suitable materials. Any material selection for the ring can also be combined with any of various formation methods, such as any combination of the following: casting, injection molding, sintering, machining, milling, forging, extruding, stamping, and rolling.

[0273] A plastic ring (fiber reinforced polycarbonate ring) may offer both mass savings e.g. about 5 grams compared to an aluminum ring, cost savings as well, give greater design flexibility due to processes used to form the ring e.g. injection molded thermoplastic, and perform similarly to an aluminum ring in abuse testing e.g. slamming the club head into a concrete cart path (extreme abuse) or shaking it in a bag where other metal clubs can repeatedly impact it (normal abuse).

[0274] In some embodiments, the ring can comprise a polymeric material (e.g., plastic) with a non-conductive vacuum metallizing (NCVM) coating. For example, in some embodiments, the ring may include a primer layer having an average thickness of about 5-11 micrometers (μm) or about 8.5 μm , and under coating layer on top of the primer layer having an average thickness of about 5-11 μm or about 8.5 μm , a NCVM layer on top of under coating layer having an average thickness of about 1.1-3.5 μm or about 2.5 μm , a color coating layer on top of the NCVM layer having an average thickness of about 25-35 μm or about 29 μm , and a top coating (UV protection coat) outer layer on top of the color coating layer having an average thickness of about 20-35 μm or about 26 μm . In general, for a NCVM coated part or ring the NCVM layer will be the thinnest and the color coating layer and the top coating layers will be the thickest and generally about 8-15 times thicker than NCVM layer. Generally, all the layers will combine to have a total average thickness of about 60-90 μm or about 75 μm . The described layers and NCVM coating could be applied to other parts other than the ring, such as the crown, sole, forward cup, and removable weights, and it can be applied prior to assembly.

[0275] In some embodiments, the ring can comprise a physical vapor deposition (PVD) coating or film layer. In some embodiments, the ring can include a paint layer, or other outer coloring layer. Conventionally, painting a golf club heads is all done by hand and requires masking various components to prevent unwanted spray on unwanted surfaces. Hand painting, however, can lead to great inconsistency from club to club. Separately forming the ring not only allows for greater access to the rearward portion of the face for milling operations to remove unwanted alpha case and allows for machining in various face patterns, but it also eliminates the need for masking off various components. The ring can be painted in isolation prior to assembly. Or in the case of anodized aluminum, no painting may be necessary, eliminating a step in the process such that the ring can simply be bonded or attached to a cup that may also be fully finished. Similarly if the ring is coated using PVD or NCVM, this coating can be applied to the ring prior to assembly, again eliminating several steps. This also allows for attachment of various color rings that may be selectable by an end user to provide an alignment or aesthetic benefit to the user. Whether the ring is a NCVM coated ring or a PVD coated ring, as mentioned above, it can be colored an array of colors, such as red, green, blue, gray, white, orange, purple, pink, fuchsia, black, clear, yellow, gold, silver, or metallic colors.

[0276] The following properties of the golf club heads disclosed herein proceeds with reference to the golf club head **100**. However, unless otherwise noted, the properties described with reference to the golf club head **100** also apply to the golf club head **200**, the golf club head **300**, and the golf club head **400**. The golf club head **100** is made from two

of at least one first material, having a density between 0.9 g/cc and 3.5 g/cc, at least one second material, having a density between 3.6 g/cc and 5.5 g/cc, and at least one third material, having a density between 5.6 g/cc and 20.0 g/cc. In a first example, the cast cup 104 is made of the second material and the ring 106, the crown insert 108, and the sole insert 110 are made of the first material. In this first example, according to one instance, the cast cup 104 is made of a titanium alloy, the ring 106 is made of an aluminum alloy, and the crown insert 108 and the sole insert 110 are made of a fiber-reinforced polymeric material. In this first example, according to another instance, the cast cup 104 is made of a titanium alloy, the ring 106 is made of plastic, and the crown insert 108 and the sole insert 110 are made of a fiber-reinforced polymeric material. In a second example, the cast cup 104 is made of the second material, the ring 106 is made of the second material, and the crown insert 108 and the sole insert 110 are made of the first material. In this second example, according to one instance, the cast cup 104 and the ring 106 are made of a titanium alloy and the crown insert 108 and the sole insert 110 are made of a fiber-reinforced polymeric material.

[0277] In some examples, the at least one first material is a fiber-reinforced polymeric material that includes continuous fibers embedded in a polymeric matrix (e.g., epoxy or resin), which is a thermoset polymer in certain examples. The continuous fibers are considered continuous because each one of the fibers is continuous across a length, width, or diagonal of the part formed by the fiber-reinforced polymeric material. The continuous fibers can be long fibers having a length of at least 3 millimeters, 10 millimeters, or even 50 millimeters. In other embodiments, shorter fibers can be used having a length of between 0.5 and 2.0 millimeters. Incorporation of the fiber reinforcement increases the tensile strength, however it may also reduce elongation to break therefore a careful balance can be struck to maintain sufficient elongation. Therefore, one embodiment includes 35-55% long fiber reinforcement, while in an even further embodiment has 40-50% long fiber reinforcement. The continuous fibers, as well as the fiber-reinforced polymeric material in general, can be the same or similar to that described in Paragraph 295 of U.S. Patent Application Publication No. 2016/0184662, published Jun. 30, 2016, now U.S. Pat. No. 9,468,816, issued Oct. 18, 2016, which is incorporated herein by reference in its entirety. In several examples, the crown insert 108 and the sole insert 110 are made of the fiber-reinforced polymeric material. Accordingly, in some examples, each one of the continuous fibers of the fiber-reinforced polymeric material does not extend from the crown portion 119 to the sole portion 117 of the golf club head 100. Alternatively, or additionally, in certain examples, each one of the continuous fibers of the fiber-reinforced polymeric material does not extend from the crown portion 119 to the forward portion 112 of the golf club head 100. The crown insert 108 is made of a material that has a density between 0.5 g/cc and 4.0 g/cc in one example. The sole insert 110 is made of a material that has a density between 0.5 g/cc and 4.0 g/cc in one example.

[0278] In certain examples, the first material is a fiber-reinforced polymeric material as described in U.S. patent application Ser. No. 17/006,561, filed Aug. 28, 2020. Composite materials that are useful for making club-head components comprise a fiber portion and a resin portion. In general the resin portion serves as a "matrix" in which the

fibers are embedded in a defined manner. In a composite for club-heads, the fiber portion is configured as multiple fibrous layers or plies that are impregnated with the resin component. The fibers in each layer have a respective orientation, which is typically different from one layer to the next and precisely controlled. The usual number of layers for a striking face is substantial, e.g., forty or more. However for a sole or crown, the number of layers can be substantially decreased to, e.g., three or more, four or more, five or more, six or more, examples of which will be provided below. During fabrication of the composite material, the layers (each comprising respectively oriented fibers impregnated in uncured or partially cured resin; each such layer being called a "prepreg" layer) are placed superimposed on each other in a "lay-up" manner. After forming the prepreg lay-up, the resin is cured to a rigid condition. If interested, a specific strength may be calculated by dividing the tensile strength by the density of the material. This is also known as the strength-to-weight ratio or strength/weight ratio.

[0279] In tests involving certain club-head configurations, composite portions formed of prepreg plies having a relatively low fiber areal weight (FAW) have been found to provide superior attributes in several areas, such as impact resistance, durability, and overall club performance. FAW is the weight of the fiber portion of a given quantity of prepreg, in units of g/m². FAW values below 100 g/m², and more desirably below 70 g/m², can be particularly effective. A particularly suitable fibrous material for use in making prepreg plies is carbon fiber, as noted. More than one fibrous material can be used. In other embodiments, however, prepreg plies having FAW values below 70 g/m² and above 100 g/m² may be used. Generally, cost is the primary prohibitive factor in prepreg plies having FAW values below 70 g/m².

[0280] In particular embodiments, multiple low-FAW prepreg plies can be stacked and still have a relatively uniform distribution of fiber across the thickness of the stacked plies. In contrast, at comparable resin-content (R/C, in units of percent) levels, stacked plies of prepreg materials having a higher FAW tend to have more significant resin-rich regions, particularly at the interfaces of adjacent plies, than stacked plies of low-FAW materials. Resin-rich regions tend to reduce the efficacy of the fiber reinforcement, particularly since the force resulting from golf-ball impact is generally transverse to the orientation of the fibers of the fiber reinforcement. The prepreg plies used to form the panels desirably comprise carbon fibers impregnated with a suitable resin, such as epoxy.

[0281] FIG. 26 is a front elevation view of a strike plate 943, which can replace any one of the strike plates disclosed herein. The strike plate 943 is made of composite materials, and can be termed a composite strike plate in some examples. The non-metal or composite material of the strike plate 943 comprises a fiber-reinforced polymer comprising fibers embedded in a resin. A percent composition of the resin in the fiber-reinforced polymer is between 38% and 44%. Further details concerning the construction and manufacturing processes for the composite strike plate 943 are described in U.S. Pat. No. 7,871,340 and U.S. Published Patent Application Nos. 2011/0275451, 2012/0083361, and 2012/0199282, which are incorporated herein by reference. The composite strike plate 943 is attached to an insert support structure located at the opening at the front portion of a golf club head, such as one disclosed herein.

[0282] In some examples, the strike plate 943 can be machined from a composite plaque. In an example, the composite plaque can be substantially rectangular with a length between about 90 mm and about 130 mm or between about 100 mm and about 120 mm, preferably about 110 mm \pm 1.0 mm, and a width between about 50 mm and about 90 mm or between about 6 mm and about 80 mm, preferably about 70 mm \pm 1.0 mm plaque size and dimensions. The strike plate 943 is then machined from the plaque to create a desired face profile. For example, the face profile length 912 can be between about 80 mm and about 120 mm or between about 90 mm and about 110 mm, preferably about 102 mm. The face profile width 911 can be between about 40 mm and about 65 mm or between about 45 mm and about 60 mm, preferably about 53 mm. The height 913 of a preferred impact zone 953 on the strike face, defined by the strike plate 943 and centered on a geometric center of the strike face, can be between about 25 mm and about 50 mm, between about 30 mm and about 40 mm, or between about 17 mm and about 45 mm, such as preferably about 34 mm. The length 914 of the preferred impact zone 953 can be between about 40 mm and about 70 mm, between about 28 mm and about 65 mm, or between about 45 mm and about 65 mm, preferably about 55.5 mm or 56 mm. In certain examples, the preferred impact zone 953 of the strike face defined by the strike plate 943 has an area between 500 mm² and 1,800 mm². Alternatively, the strike plate 943 can be molded to provide the desired face dimensions and profile.

[0283] Additional features can be machined or molded into face the strike plate 943 to create the desired face profile. For example, as shown in FIG. 27, a notch 920 can be machined or molded into the backside of a heel portion of the strike plate 943. The notch 920 in the back of the strike plate 943 allows for the golf club head to utilize flight control technology (FCT) in the hosel, in some examples. The notch 920 can be configured to accept at least a portion of the hosel within the strike plate 943. Alternatively or additionally, the notch 920 can be configured to accept at least a portion of the club head body within the strike plate 943. The notch may allow for the reduction of center-face y-axis location (CFY) by accommodating at least a portion of the hosel and/or at least a portion of the club body within the strike plate 943, allowing the preferred impact zone 953 of the strike plate 943 to be closer to a plane passing through a center point location of the hosel. The strike plate 943 can be configured to provide a CFY no more than about 18 mm and no less than about 9 mm, preferably between about 11.0 mm and about 16.0 mm, and more preferably no more than about 15.5 mm and no less than about 11.5 mm. The strike plate 943 can be configured to provide face progression no more than about 21 mm and no less than about 12 mm, preferably no more than about 19.5 mm and no less than about 13 mm and more preferably no more than about 18 mm and no less than about 14.5 mm. In some embodiments, a difference between CFY and face progression is at least 3 mm and no more than 12 mm.

[0284] In another example, backside bumps 4230A, 4230B, 4230C, 4230D may be machined or molded into the backside of the strike plate 943. The backside bumps 4230A, 4230B, 4230C, 4230D can be configured to provide for a bond gap. A bond gap is an empty space between the club head body and the strike plate 943 that is filled with adhesive during manufacturing. The backside bumps 4230A, 4230B, 4230C, 4230D protrude to separate the face from the club

head body when bonding the strike plate 943 to the club head body during manufacturing. In some examples, too large or too small of a bond gap may lead to durability issues of the club head, the strike plate 943, or both. Further, too large of a bond gap can allow too much adhesive to be used during manufacturing, adding unwanted additional mass to the club head. The backside bumps 4230A, 4230B, 4230C, 4230D can protrude between about 0.1 mm and 0.5 mm, preferably about 0.25 mm. In some embodiments, the backside bumps are configured to provide for a minimum bond gap, such as a minimum bond gap of about 0.25 mm and a maximum bond gap of about 0.45 mm.

[0285] Further, one or more of the edges of the strike plate 943 can be machined or molded with a chamfer. In an example, the strike plate 943 includes a chamfer substantially around the inside perimeter edge of the strike plate 943, such as a chamfer between about 0.5 mm and about 1.1 mm, preferably 0.8 mm.

[0286] FIG. 27 is a bottom perspective view of the strike plate 943. The strike plate 943 has a heel portion 941 and a toe portion 942. The notch 920 is machined or molded into the heel portion 941. In this example, the strike plate 943 has a variable thickness, such as with a peak thickness 947 within the preferred impact zone 953. The peak thickness 947 can be between about 2 mm and about 7.5 mm, between about 4.3 mm and 5.15 mm, between about 4.0 mm and about 5.15 or 5.5 mm, or between about 3.8 mm and about 4.8 mm, preferably 4.1 mm \pm 0.1 mm, 4.25 mm \pm 0.1 mm, or 4.5 mm \pm 0.1 mm. The peak thickness 947 can be located at the geometric center of the strike face defines by the strike plate 943. A minimum thickness of the strike plate 943 is between 3.0 mm and 4.0 mm in some examples.

[0287] Additionally, in certain examples, the preferred impact zone 953 is off-center or offset relative to the geometric center of the strike face, and can be thicker toward the geometric center of the strike face. In some examples, the thickness of the strike plate 943 within the preferred impact zone 953 is variable (e.g., between about 3.5 mm and about 5.0 mm) and the thickness of the strike plate 943 outside of the preferred impact zone 953 is constant (e.g., between 3.5 mm and 4.2 mm) and less than within preferred impact zone 953. In some examples, the strike plate 943 have a thickness between 3.5 mm and 6.0 mm.

[0288] The strike plate 943 has a toe edge region and a heel edge region outside of the preferred impact zone 953 such that the preferred impact zone is between the toe edge region and the heel edge region. The toe edge region is closer to the toe portion than the heel edge region. The heel edge region is closer to the heel portion than the toe edge region. The toe edge region thickness is less than the maximum thickness. A thickness of the strike plate 943 transitions from the maximum thickness, within the preferred impact zone 953, to a toe edge region thickness, within the toe edge region, between 3.85 mm and 4.5 mm.

[0289] In some embodiments, the strike plate 943 is manufactured from multiple layers of composite materials. Exemplary composite materials and methods for making the same are described in U.S. patent application Ser. No. 13/452,370 (published as U.S. Pat. App. Pub. No. 2012/0199282), which is incorporated by reference. In some embodiments, an inner and outer surface of the composite face can include a scrim layer, such as to reinforce the strike plate 943 with glass fibers making up a scrim weave. Multiple quasi-isotropic

panels (Q's) can also be included, with each Q panel using multiple plies of unidirectional composite panels offset from each other. In an exemplary four-ply Q panel, the unidirectional composite panels are oriented at 90°, -45°, 0°, and 45°, which provide for structural stability in each direction. Clusters of unidirectional strips (C's) can also be included, with each C using multiple unidirectional composite strips. In an exemplary four-strip C, four 27 mm strips are oriented at 0°, 125°, 90°, and 55°. C's can be provided to increase thickness of the strike plate 943 in a localized area, such as in the center face at the preferred impact zone. Some Q's and C's can have additional or fewer plies (e.g., three-ply rather than four-ply), such as to fine tune the thickness, mass, localized thickness, and provide for other properties of the strike plate 943, such as to increase or decrease COR of the strike plate 943.

[0290] In some embodiments, the strike face, such as the strike plate 243, of some examples of the golf club head disclosed herein is manufactured from multiple layers of composite materials. Exemplary composite materials and methods for making the same are described in U.S. patent application Ser. No. 13/452,370 (published as U.S. Pat. App. Pub. No. 2012/0199282), which is incorporated by reference. In some embodiments, an inner and outer surface of the composite face can include a scrim layer, such as to reinforce the strike face with glass fibers making up a scrim weave. Multiple quasi-isotropic panels (Q's) can also be included, with each Q panel using multiple plies of unidirectional composite panels offset from each other. In an exemplary four-ply Q panel, the unidirectional composite panels are oriented at 90°, -45°, 0°, and 45°, which provide for structural stability in each direction. Clusters of unidirectional strips (C's) can also be included, with each C using multiple unidirectional composite strips. In an exemplary four-strip C, four 27 mm strips are oriented at 0°, 125°, 90°, and 55°. C's can be provided to increase thickness of the strike face, or other composite features, in a localized area, such as in the center face at the preferred impact zone. Some Q's and C's can have additional or fewer plies (e.g., three-ply rather than four-ply), such as to fine tune the thickness, mass, localized thickness, and provide for other properties of the strike face, such as to increase or decrease COR of the strike face.

[0291] Additional composite materials and methods for making the same are described in U.S. Pat. Nos. 8,163,119 and 10,046,212, which is incorporated by reference. For example, the usual number of layers for a strike plate is substantial, e.g., fifty or more. However, improvements have been made in the art such that the layers may be decreased to between 30 and 50 layers. According to one example, the strike plate, according to any of the various examples disclosed herein, when made of a fiber-reinforced polymeric material, can be made in a manner the same as, or similar to, that described in U.S. patent application Ser. No. 17/321,315, filed May 14, 2021, and U.S. Provisional Patent Application No. 63/312,771, filed Feb. 22, 2022, which are incorporated herein by reference in their entireties.

[0292] Table 3 below provide examples of possible layups of one or more of the composite parts of the golf club head disclosed herein. These layups show possible unidirectional plies unless noted as woven plies. The construction shown is for a quasi-isotropic layup. A single layer ply has a thickness of ranging from about 0.065 mm to about 0.080 mm for a standard FAW of 70 gsm with about 36% to about 40% resin

content. The thickness of each individual ply may be altered by adjusting either the FAW or the resin content, and therefore the thickness of the entire layup may be altered by adjusting these parameters.

TABLE 3

ply 1	ply 2	ply 3	ply 4	ply 5	ply 6	ply 7	ply 8	AW g/m ²
0	-60	+60						290-360
0	-45	+45	90					390-480
0	+60	90	60	0				490-600
0	+45	90	-45	0				490-600
90	+45	0	-45	90				490-600
+45	90	0	90	-45				490-600
+45	0	90	0	-45				490-600
-60	-30	0	+30	60	90			590-720
0	90	+45	-45	90	0			590-720
90	0	+45	-45	0	90			590-720
0	90	45	-45	-45	45	0/90		680-840
						woven		
90	0	45	-45	-45	45	90/0		680-840
						woven		
+45	-45	90	0	0	90	-45/45		680-840
						woven		
0	90	45	-45	-45	45	90 UD		680-840
0	90	45	-45	0	-45	45	0.90	780-960
						woven		
90	0	45	-45	0	-45	45	90,0	780-960
						woven		

[0293] The Area Weight (AW) is calculated by multiplying the density times the thickness. For the plies shown above made from composite material the density is about 1.5 g/cm³ and for titanium the density is about 4.5 g/cm³.

[0294] In general, a composite face plate or composite face insert may have a peak thickness that varies between about 3.8 mm and 5.15 mm. In general, the composite face plate is formed from multiple composite plies or layers. The usual number of layers for a composite striking face is substantial, e.g., forty or more, preferably between 30 to 75 plies, more preferably, 50 to 70 plies, even more preferably 55 to 65 plies.

[0295] In an example, a first composite face insert can have a peak thickness of 4.1 mm and an edge thickness of 3.65 mm, including 12 Q's and 2 C's, resulting in a mass of 24.7 g. In another example, a second composite face insert can have a peak thickness of 4.25 mm and an edge thickness of 3.8 mm, including 12 Q's and 2 C's, resulting in a mass of 25.6 g. The additional thickness and mass is provided by including additional plies in one or more of the Q's or C's, such as by using two 4-ply Q's instead of two 3-ply Q's. In yet another example, a third composite face insert can have a peak thickness of 4.5 mm and an edge thickness of 3.9 mm, including 12 Q's and 3 C's, resulting in a mass of 26.2 g. Additional and different combinations of Q's and C's can be provided for a composite strike plate (e.g., face insert) with a mass between about 20 g and about 30 g, or between about 15 g and about 35 g. In some examples, wherein the strike plate, such as the strike plate 943, has a total mass between 22 grams and 28 grams.

[0296] FIG. 28A is a section view of a heel portion 41 of the strike plate 943. The heel portion 941 can include a notch 920. In embodiments with a chamfer on an inside edge of the strike plate 943, no chamfer 950 is provided on the notch 920. The notch 920 can have a notch edge thickness 944 less than the edge thickness 945 of the strike plate 943 (see, e.g., FIG. 28B). For example, the notch edge thickness 944 can be between 1.5 mm and 2.1 mm, preferably 1.8 mm.

[0297] FIG. 28B is a section view of a toe portion 942 of the strike plate 943. The toe portion 942 includes a chamfer 951 on the inside edge of the strike plate 943. In some embodiments, the edge thickness 945 can be between about 3.35 mm and about 4.2 mm, preferably 3.65 mm \pm 0.1 mm, 3.8 mm \pm 0.1 mm, or 3.9 mm \pm 0.1 mm.

[0298] FIG. 29 is a section view of a polymer layer 900 of the strike plate 943. The polymer layer 900 can be provided on the outer surface of the strike plate 943 to provide for better performance of the strike plate 943, such as in wet conditions. Exemplary polymer layers are described in U.S. patent application Ser. No. 13/330,486 (patented as U.S. Pat. No. 8,979,669), which is incorporated by reference. The polymer layer 900 may include polyurethane and/or other polymer materials. The polymer layer may have a polymer maximum thickness 960 between about 0.2 mm and 0.7 mm or about 0.3 mm and about 0.5 mm, preferably 0.40 mm \pm 0.05 mm. The polymer layer may have a polymer minimum thickness 970 between about 0.05 mm and 0.15 mm, preferably 0.09 mm \pm 0.02 mm. The polymer layer can be configured with alternating maximum thicknesses 960 and minimum thicknesses 970 to create score lines on the strike plate 943. Further, in some embodiments, teeth and/or another texture may be provided on the thicker areas of the polymer layer 900 between the score lines.

[0299] In some examples, the crown insert, such as the crown insert 108, and the sole insert, such as the sole insert 110, are made of a carbon-fiber reinforced polymeric material. In one example, the crown insert is made of layers of unidirectional tape, woven cloth, and composite plies.

[0300] Referring to FIG. 4, the golf club head 100 has a face-back dimension (FBD) defined as the distance between a hypothetical plane 169, passing through the center face 183 of the strike face 145 and parallel to the strike face 145, and a rearmost point on the golf club head 100 in a face-back direction 165 perpendicular to the hypothetical plane 169. As defined herein, the center face 183 is located at 0% of the face-back dimension (FBD) and the rearmost point is located at 100% of the face-back dimension (FBD). Under this definition, the golf club head 100 can be divided into a face section that extends, in the face-back direction 165, from 0% of the face-back dimension (FBD) to 25% of the face-back dimension (FBD), a middle section that extends, in the face-back direction 165, from 25% to 75% of the face-back dimension (FBD), and a back section that extends, in the face-back direction 165, from 75% to 100% of the face-back dimension (FBD). According to some examples, at least 95% by weight of the middle section is made of a material having a density between 0.9 g/cc and 4.0 g/cc. In certain examples, at least 95% by weight of the middle section is made of material having a density between 0.9 g/cc and 2.0 g/cc. In some examples, at least 95% by weight of the middle section and at least 95% by weight of the back section are made of a material having a density between 0.9 g/cc and 2.0 g/cc, excluding any attached weights and any housings for the attached weights. No more than 20% by weight of the middle section and no more than 20% by weight of the back section are made of a material having a density between 4.0 g/cc and 20.0 g/cc, according to various examples.

[0301] In some examples, the golf club head 100 includes one or more of the following materials: carbon steel, stainless steel (e.g. 17-4 PH stainless steel), alloy steel, Fe—Mn—Al alloy, nickel-based ferroalloy, cast iron, super alloy

steel, aluminum alloy (including but not limited to 3000 series alloys, 5000 series alloys, 6000 series alloys, such as 6061-T6, and 7000 series alloys, such as 7075), magnesium alloy, copper alloy, titanium alloy (including but not limited to 6-4 titanium, 3-2.5, 6-4, SP700, 15-3-3-3, 10-2-3, Ti 9-1-1, ZA 1300, or other alpha/near alpha, alpha-beta, and beta/near beta titanium alloys) or mixtures thereof.

[0302] In one example, when forming part of the golf club heads disclosed herein, such as when forming part of the strike plate, the titanium alloy is a 9-1-1 titanium alloy. Titanium alloys comprising aluminum (e.g., 8.5-9.5% Al), vanadium (e.g., 0.9-1.3% V), and molybdenum (e.g., 0.8-1.1% Mo), optionally with other minor alloying elements and impurities, herein collectively referred to as “9-1-1 Ti”, can have less significant alpha case, which renders HF acid etching unnecessary or at least less necessary compared to faces made from conventional 6-4 Ti and other titanium alloys. Further, 9-1-1 Ti can have minimum mechanical properties of 820 MPa yield strength, 958 MPa tensile strength, and 10.2% elongation. These minimum properties can be significantly superior to typical cast titanium alloys, such as 6-4 Ti, which can have minimum mechanical properties of 812 MPa yield strength, 936 MPa tensile strength, and ~6% elongation. In certain examples, the titanium alloy is 8-1-1 Ti.

[0303] In another example, when forming part of the golf club heads disclosed herein, such as when forming part of the strike plate, the titanium alloy is an alpha-beta titanium alloy comprising 6.5% to 10% Al by weight, 0.5% to 3.25% Mo by weight, 1.0% to 3.0% Cr by weight, 0.25% to 1.75% V by weight, and/or 0.25% to 1% Fe by weight, with the balance comprising Ti (one example is sometimes referred to as “1300” or “ZA1300” titanium alloy). The alpha-beta titanium alloy or ZA1300 titanium alloy has a first ultimate tensile strength of at least 1,000 MPa in some examples and at least 1,100 MPa in other examples. An ultimate tensile strength of the material forming the body 102, other than the strike face 145, can be less than the first ultimate tensile strength by at least 10%. In another representative example, the alloy may comprise 6.75% to 9.75% Al by weight, 0.75% to 3.25% or 2.75% Mo by weight, 1.0% to 3.0% Cr by weight, 0.25% to 1.75% V by weight, and/or 0.25% to 1% Fe by weight, with the balance comprising Ti. In yet another representative example, the alloy may comprise 7% to 9% Al by weight, 1.75% to 3.25% Mo by weight, 1.25% to 2.75% Cr by weight, 0.5% to 1.5% V by weight, and/or 0.25% to 0.75% Fe by weight, with the balance comprising Ti. In a further representative example, the alloy may comprise 7.5% to 8.5% Al by weight, 2.0% to 3.0% Mo by weight, 1.5% to 2.5% Cr by weight, 0.75% to 1.25% V by weight, and/or 0.375% to 0.625% Fe by weight, with the balance comprising Ti. In another representative example, the alloy may comprise 8% Al by weight, 2.5% Mo by weight, 2% Cr by weight, 1% V by weight, and/or 0.5% Fe by weight, with the balance comprising Ti (such titanium alloys can have the formula Ti-8Al-2.5Mo-2Cr-1V-0.5Fe). As used herein, reference to “Ti-8Al-2.5Mo-2Cr-1V-0.5Fe” refers to a titanium alloy including the referenced elements in any of the proportions given above. Certain examples may also comprise trace quantities of K, Mn, and/or Zr, and/or various impurities.

[0304] Ti-8Al-2.5Mo-2Cr-1V-0.5Fe can have minimum mechanical properties of 1150 MPa yield strength, 1180 MPa ultimate tensile strength, and 8% elongation. These

minimum properties can be significantly superior to other cast titanium alloys, including 6-4 Ti and 9-1-1 Ti, which can have the minimum mechanical properties noted above. In some examples, Ti-8Al-2.5Mo-2Cr-1V-0.5Fe can have a tensile strength of from about 1180 MPa to about 1460 MPa, a yield strength of from about 1150 MPa to about 1415 MPa, an elongation of from about 8% to about 12%, a modulus of elasticity of about 110 GPa, a density of about 4.45 g/cm³, and a hardness of about 43 on the Rockwell C scale (43 HRC). In particular examples, the Ti-8Al-2.5Mo-2Cr-1V-0.5Fe alloy can have a tensile strength of about 1320 MPa, a yield strength of about 1284 MPa, and an elongation of about 10%. The Ti-8Al-2.5Mo-2Cr-1V-0.5Fe alloy, particularly when used to cast golf club head bodies, promotes less deflection for the same thickness due to a higher ultimate tensile strength compared to other materials. In some implementations, providing less deflection with the same thickness benefits golfers with higher swing speeds because over time the face of the golf club head will maintain its original shape over time.

[0305] In yet certain examples, the golf club head **100** is made of a non-metal material with a density less than about 2 g/cm³, such as between about 1 g/cm³ to about 2 g/cm³. The non-metal material may include a polymer, such as fiber-reinforced polymeric material. The polymer can be either thermoset or thermoplastic, and can be amorphous, crystalline and/or a semi-crystalline structure. The polymer may also be formed of an engineering plastic such as a crystalline or semi-crystalline engineering plastic or an amorphous engineering plastic. Potential engineering plastic candidates include polyphenylene sulfide ether (PPS), polyethelipide (PEI), polycarbonate (PC), polypropylene (PP), acrylonitrile-butadiene styrene plastics (ABS), polyoxymethylene plastic (POM), nylon 6, nylon 6-6, nylon 12, polymethyl methacrylate (PMMA), polyphylene oxide (PPO), polybothene terephthalate (PBT), polysulfone (PSU), polyether sulfone (PES), polyether ether ketone (PEEK) or mixtures thereof. Organic fibers, such as fiberglass, carbon fiber, or metallic fiber, can be added into the engineering plastic, so as to enhance structural strength. The reinforcing fibers can be continuous long fibers or short fibers. One of the advantages of PSU is that it is relatively stiff with relatively low damping which produces a better sounding or more metallic sounding golf club compared to other polymers which may be overdamped. Additionally, PSU requires less post processing in that it does not require a finish or paint to achieve a final finished golf club head.

[0306] One exemplary material from which any one or more of the sole insert **110**, the crown insert **108**, the cast cup **103**, the ring **106**, and/or the strike face, such as the strike plate **243**, can be made from is a thermoplastic continuous carbon fiber composite laminate material having long, aligned carbon fibers in a PPS (polyphenylene sulfide) matrix or base. A commercial example of a fiber-reinforced polymer, from which the sole insert **110**, the crown insert **108**, and/or the strike face can be made, is TEPEX® DYNALITE 207 manufactured by Lanxess®. TEPEX® DYNALITE 207 is a high strength, lightweight material, arranged in sheets, having multiple layers of continuous carbon fiber reinforcement in a PPS thermoplastic matrix or polymer to embed the fibers. The material may have a 54% fiber volume, but can have other fiber volumes (such as a volume of 42% to 57%). According to one example, the material weighs 200 g/m². Another commercial example of

a fiber-reinforced polymer, from which the sole insert **110**, crown insert **108**, and/or the strike face is made, is TEPEX® DYNALITE 208. This material also has a carbon fiber volume range of 42 to 57%, including a 45% volume in one example, and a weight of 200 g/m². DYNALITE 208 differs from DYNALITE 207 in that it has a TPU (thermoplastic polyurethane) matrix or base rather than a polyphenylene sulfide (PPS) matrix.

[0307] By way of example, the fibers of each sheet of TEPEX® DYNALITE 207 sheet (or other fiber-reinforced polymer material, such as DYNALITE 208) are oriented in the same direction with the sheets being oriented in different directions relative to each other, and the sheets are placed in a two-piece (male/female) matched die, heated past the melt temperature, and formed to shape when the die is closed. This process may be referred to as thermoforming and is especially well-suited for forming the sole insert **110**, the crown insert **108**, and/or the strike face. After the sole insert **110**, the crown insert **108**, and/or the strike face are formed (separately, in some implementations) by the thermoforming process, each is cooled and removed from the matched die. In some implementations, the sole insert **110**, the crown insert **108**, and/or the strike face has a uniform thickness, which facilitates use of the thermoforming process and ease of manufacture. However, in other implementations, the sole insert **110**, the crown insert **108**, and/or the strike face may have a variable thickness to strengthen select local areas of the insert by, for example, adding additional plies in select areas to enhance durability, acoustic properties, or other properties of the respective inserts.

[0308] In some examples, any one or more of the sole insert **110**, the crown insert **108**, the cast cup **103**, the ring **106**, and/or the strike face, such as the strike plate **243**, can be made by a process other than thermoforming, such as injection molding or thermosetting. In a thermoset process, any one or more of the sole insert **110**, the crown insert **108**, the cast cup **103**, the ring **106**, and/or the strike face, such as the strike plate **243**, may be made from “prepreg” plies of woven or unidirectional composite fiber fabric (such as carbon fiber composite fabric) that is preimpregnated with resin and hardener formulations that activate when heated. The prepreg plies are placed in a mold suitable for a thermosetting process, such as a bladder mold or compression mold, and stacked/oriented with the carbon or other fibers oriented in different directions. The plies are heated to activate the chemical reaction and form the crown insert **126** and/or a sole insert. Each insert is cooled and removed from its respective mold.

[0309] The carbon fiber reinforcement material for any one or more of the sole insert **110**, the crown insert **108**, the cast cup **103**, the ring **106**, and/or the strike face, such as the strike plate **243**, made by the thermoset manufacturing process, may be a carbon fiber known as “34-700” fiber, available from Grafil, Inc., of Sacramento, California, which has a tensile modulus of 234 Gpa (34 Msi) and a tensile strength of 4500 Mpa (650 Ksi). Another suitable fiber, also available from Grafil, Inc., is a carbon fiber known as “TR50S” fiber which has a tensile modulus of 240 Gpa (35 Msi) and a tensile strength of 4900 Mpa (710 Ksi). Exemplary epoxy resins for the prepreg plies used to form the thermoset crown and sole inserts include Newport 301 and 350 and are available from Newport Adhesives & Composites, Inc., of Irvine, California. In one example, the prepreg sheets have a quasi-isotropic fiber reinforcement of 34-700

fiber having an areal weight between about 20 g/m² to about 200 g/m² preferably about 70 g/m² and impregnated with an epoxy resin (e.g., Newport 301), resulting in a resin content (R/C) of about 40%. For convenience of reference, the plipary composition of a prepreg sheet can be specified in abbreviated form by identifying its fiber areal weight, type of fiber, e.g., 70 FAW 34-700. The abbreviated form can further identify the resin system and resin content, e.g., 70 FAW 34-700/301, R/C 40%.

[0310] In some examples, polymers used in the manufacturing of the golf club head 100 may include without limitation, synthetic and natural rubbers, thermoset polymers such as thermoset polyurethanes or thermoset polyureas, as well as thermoplastic polymers including thermoplastic elastomers such as thermoplastic polyurethanes, thermoplastic polyureas, metallocene catalyzed polymer, unimodalethylene/carboxylic acid copolymers, unimodal ethylene/carboxylic acid/carboxylate terpolymers, bimodal ethylene/carboxylic acid copolymers, bimodal ethylene/carboxylic acid/carboxylate terpolymers, polyamides (PA), polyketones (PK), copolyamides, polyesters, copolyesters, polycarbonates, polyphenylene sulfide (PPS), cyclic olefin copolymers (COC), polyolefins, halogenated polyolefins [e.g. chlorinated polyethylene (CPE)], halogenated polyalkylene compounds, polyalkenamer, polyphenylene oxides, polyphenylene sulfides, diallylphthalate polymers, polyimides, polyvinyl chlorides, polyamide-ionomers, polyurethane ionomers, polyvinyl alcohols, polyarylates, polyacrylates, polyphenylene ethers, impact-modified polyphenylene ethers, polystyrenes, high impact polystyrenes, acrylonitrile-butadiene-styrene copolymers, styrene-acrylonitriles (SAN), acrylonitrile-styrene-acrylonitriles, styrene-maleic anhydride (S/MA) polymers, styrenic block copolymers including styrene-butadiene-styrene (SBS), styrene-ethylene-butylene-styrene, (SEBS) and styrene-ethylene-propylene-styrene (SEPS), styrenic terpolymers, functionalized styrenic block copolymers including hydroxylated, functionalized styrenic copolymers, and terpolymers, cellulosic polymers, liquid crystal polymers (LCP), ethylene-propylene-diene terpolymers (EPDM), ethylene-vinyl acetate copolymers (EVA), ethylene-propylene copolymers, propylene elastomers (such as those described in U.S. Pat. No. 6,525,157, to Kim et al, the entire contents of which is hereby incorporated by reference), ethylene vinyl acetates, polyureas, and polysiloxanes and any and all combinations thereof.

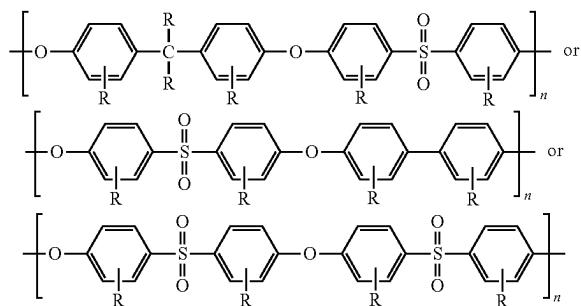
[0311] Of these preferred are polyamides (PA), polyphthalimide (PPA), polyketones (PK), copolyamides, polyesters, copolyesters, polycarbonates, polyphenylene sulfide (PPS), cyclic olefin copolymers (COC), polyphenylene oxides, diallylphthalate polymers, polyarylates, polyacrylates, polyphenylene ethers, and impact-modified polyphenylene ethers. Especially preferred polymers for use in the golf club heads of the present invention are the family of so called high performance engineering thermoplastics which are known for their toughness and stability at high temperatures. These polymers include the polysulfones, the polyethelipides, and the polyamide-imides. Of these, the most preferred are the polysufones.

[0312] Aromatic polysulfones are a family of polymers produced from the condensation polymerization of 4,4'-dichlorodiphenylsulfone with itself or one or more dihydric phenols. The aromatic polysulfones include the thermoplastics sometimes called polyether sulfones, and the general

structure of their repeating unit has a diaryl sulfone structure which may be represented as-arylene-SO₂-arylene-. These units may be linked to one another by carbon-to-carbon bonds, carbon-oxygen-carbon bonds, carbon-sulfur-carbon bonds, or via a short alkylene linkage, so as to form a thermally stable thermoplastic polymer. Polymers in this family are completely amorphous, exhibit high glass-transition temperatures, and offer high strength and stiffness properties even at high temperatures, making them useful for demanding engineering applications. The polymers also possess good ductility and toughness and are transparent in their natural state by virtue of their fully amorphous nature. Additional key attributes include resistance to hydrolysis by hot water/steam and excellent resistance to acids and bases. The polysulfones are fully thermoplastic, allowing fabrication by most standard methods such as injection molding, extrusion, and thermoforming. They also enjoy a broad range of high temperature engineering uses.

[0313] Three commercially important polysulfones are a) polysulfone (PSU); b) Polyethersulfone (PES also referred to as PESU); and c) Polyphenylene sulfone (PPSU).

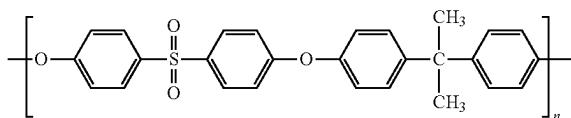
[0314] Particularly important and preferred aromatic polysulfones are those comprised of repeating units of the structure —C₆H₄SO₂-C₆H₄O— where C₆H₄ represents a m- or p-phenylene structure. The polymer chain can also comprise repeating units such as —C₆H₄-, C₆H₄-O—, —C₆H₄-(lower-alkylene)-C₆H₄-O—, —C₆H₄-O-C₆H₄-O—, —C₆H₄-S-C₆H₄-O—, and other thermally stable substantially-aromatic difunctional groups known in the art of engineering thermoplastics. Also included are the so called modified polysulfones where the individual aromatic rings are further substituted in one or substituents including



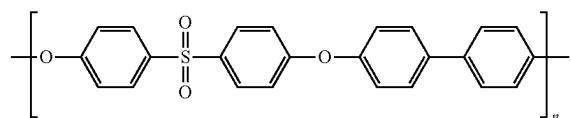
wherein R is independently at each occurrence, a hydrogen atom, a halogen atom or a hydrocarbon group or a combination thereof. The halogen atom includes fluorine, chlorine, bromine and iodine atoms. The hydrocarbon group includes, for example, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₃-C₂₀ cycloalkyl group, a C₃-C₂₀ cycloalkenyl group, and a C₆-C₂₀ aromatic hydrocarbon group. These hydrocarbon groups may be partly substituted by a halogen atom or atoms, or may be partly substituted by a polar group or groups other than the halogen atom or atoms. As specific examples of the C₁-C₂₀ alkyl group, there can be mentioned methyl, ethyl, propyl, isopropyl, amyl, hexyl, octyl, decyl and dodecyl groups. As specific examples of the C₂-C₂₀ alkenyl group, there can be mentioned propenyl, isopropenyl, butenyl, isobut enyl, pentenyl and hexenyl groups. As specific examples of the C₃-C₂₀ cycloalkyl group, there can be mentioned cyclopentyl and cyclohexyl groups. As specific

examples of the C3-C20 cycloalkenyl group, there can be mentioned cyclopentenyl and cyclohexenyl groups. As specific examples of the aromatic hydrocarbon group, there can be mentioned phenyl and naphthyl groups or a combination thereof.

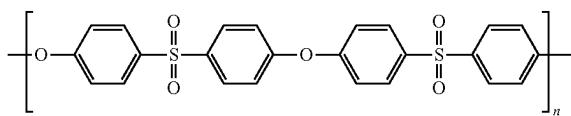
[0315] Individual preferred polymers include (a) the polysulfone made by condensation polymerization of bisphenol A and 4,4'-dichlorodiphenyl sulfone in the presence of base, and having the main repeating structure



and the abbreviation PSF and sold under the tradenames Udel®, Ultrason® S, Eviva®, RTP PSU, (b) the polysulfone made by condensation polymerization of 4,4'-dihydroxydiphenyl and 4,4'-dichlorodiphenyl sulfone in the presence of base, and having the main repeating structure



and the abbreviation PPSF and sold under the tradenames RADEL® resin; and (c) a condensation polymer made from 4,4'-dichlorodiphenyl sulfone in the presence of base and having the principle repeating structure



and the abbreviation PPSF and sometimes called a “polyether sulfone” and sold under the tradenames Ultrason® E, LNPTM, Veradel®PESU, Sumikaece, and VICTREX® resin,” and any and all combinations thereof.

[0316] In some examples, one exemplary material from which any one or more of the sole insert 110, the crown insert 108, the cast cup 103, the ring 106, and/or the strike face, such as the strike plate 243, can be made from is a composite material, such as a carbon fiber reinforced polymeric material, made of a composite including multiple plies or layers of a fibrous material (e.g., graphite, or carbon fiber including turbostratic or graphitic carbon fiber or a hybrid structure with both graphitic and turbostratic parts present). Examples of some of these composite materials for use in the and their fabrication procedures are described in U.S. patent application Ser. No. 10/442,348 (now U.S. Pat. No. 7,267,620), Ser. No. 10/831,496 (now U.S. Pat. No. 7,140,974), Ser. Nos. 11/642,310, 11/825,138, 11/998,436, 11/895, 195, 11/823,638, 12/004,386, 12,004,387, 11/960,609, 11/960,610, and 12/156,947, which are incorporated herein by reference in their entirety. The composite material may be manufactured according to the methods described at least in

U.S. patent application Ser. No. 11/825,138, the entire contents of which are herein incorporated by reference.

[0317] Alternatively, short or long fiber-reinforced formulations of the previously referenced polymers can be used. Exemplary formulations include a Nylon 6/6 polyamide formulation, which is 30% Carbon Fiber Filled and available commercially from RTP Company under the trade name RTP 285. This material has a Tensile Strength of 35000 psi (241 MPa) as measured by ASTM D 638; a Tensile Elongation of 2.0-3.0% as measured by ASTM D 638; a Tensile Modulus of 3.30×10⁶ psi (22754 MPa) as measured by ASTM D 638; a Flexural Strength of 50000 psi (345 MPa) as measured by ASTM D 790; and a Flexural Modulus of 2.60×10⁶ psi (17927 MPa) as measured by ASTM D 790.

[0318] Other materials also include is a polyphthalimide (PPA) formulation which is 40% Carbon Fiber Filled and available commercially from RTP Company under the trade name RTP 4087 UP. This material has a Tensile Strength of 360 MPa as measured by ISO 527; a Tensile Elongation of 1.4% as measured by ISO 527; a Tensile Modulus of 41500 MPa as measured by ISO 527; a Flexural Strength of 580 MPa as measured by ISO 178; and a Flexural Modulus of 34500 MPa as measured by ISO 178.

[0319] Yet other materials include is a polyphenylene sulfide (PPS) formulation which is 30% Carbon Fiber Filled and available commercially from RTP Company under the trade name RTP 1385 UP. This material has a Tensile Strength of 255 MPa as measured by ISO 527; a Tensile Elongation of 1.3% as measured by ISO 527; a Tensile Modulus of 28500 MPa as measured by ISO 527; a Flexural Strength of 385 MPa as measured by ISO 178; and a Flexural Modulus of 23,000 MPa as measured by ISO 178.

[0320] Especially preferred materials include a polysulfone (PSU) formulation which is 20% Carbon Fiber Filled and available commercially from RTP Company under the trade name RTP 983. This material has a Tensile Strength of 124 MPa as measured by ISO 527; a Tensile Elongation of 2% as measured by ISO 527; a Tensile Modulus of 11032 MPa as measured by ISO 527; a Flexural Strength of 186 MPa as measured by ISO 178; and a Flexural Modulus of 9653 MPa as measured by ISO 178.

[0321] Also, preferred materials may include a polysulfone (PSU) formulation which is 30% Carbon Fiber Filled and available commercially from RTP Company under the trade name RTP 985. This material has a Tensile Strength of 138 MPa as measured by ISO 527; a Tensile Elongation of 1.2% as measured by ISO 527; a Tensile Modulus of 20685 MPa as measured by ISO 527; a Flexural Strength of 193 MPa as measured by ISO 178; and a Flexural Modulus of 12411 MPa as measured by ISO 178.

[0322] Further preferred materials include a polysulfone (PSU) formulation which is 40% Carbon Fiber Filled and available commercially from RTP Company under the trade name RTP 987. This material has a Tensile Strength of 155 MPa as measured by ISO 527; a Tensile Elongation of 1% as measured by ISO 527; a Tensile Modulus of 24132 MPa as measured by ISO 527; a Flexural Strength of 241 MPa as measured by ISO 178; and a Flexural Modulus of 19306 MPa as measured by ISO 178.

[0323] Any one or more of the sole insert 110, the crown insert 108, the cast cup 103, the ring 106, and/or the strike face, such as the strike plate 243, can have a complex three-dimensional shape and curvature corresponding generally to a desired shape and curvature of the golf club head

100. It will be appreciated that other types of club heads, such as fairway wood-type club heads, hybrid club heads, and iron-type club heads, may be manufactured using one or more of the principles, methods, and materials described herein.

[0324] Referring to FIGS. 33, 34, and 42, according to some examples, a method 550 of making the golf club heads of the present disclosure, such as the golf club head 100, includes (block 552) laser ablating a first-part surface 520 of a first part 502 of a golf club head such that a first-part ablated surface 522 is formed in the first part 502. The method 550 also includes (block 554) laser ablating a second-part surface 524 of a second part 504 of the golf club head 100 such that a second-part ablated surface 526 is formed in the second part 504. The method 550 additionally includes (block 556) bonding together the first-part ablated surface 522 and the second-part ablated surface 526. Generally, the method 550 helps to produce bonding surfaces (i.e., faying surfaces) of a golf club head with features that promote strong and reliable bonds between the bonding surfaces. More specifically, the features formed by ablating the bonding surfaces of the golf club head with a laser promote an increase in the pattern uniformity and surface energy of the bonding surfaces, which helps to strengthen the bond between the bonding surfaces and increase the overall reliability and performance of the golf club head. Also, ablating the bonding surfaces with a laser enables the repeatability of surface characteristics across multiple parts and batches of parts. As defined herein, each one of the first-part ablated surface 522 and/or the second-part ablated surface 526 can be a single continuous surface or multiple spaced apart (e.g., intermittent) surfaces.

[0325] Conventional processes for bonding together surfaces of a golf club head, including surface preparation via non-laser ablation methods, may not provide a sufficient pattern uniformity and surface energy for producing strong and reliable bonds. For example, chemical ablation and media-blast ablation processes are unable to achieve pattern uniformities and surface energies of bonding surfaces that are achievable by the laser ablation of the present disclosure. The patterns of peaks and valleys on bonding surfaces ablated via a chemical ablation process or a media-blast ablation process are irregular and inconsistent, which leads to lower and non-uniform bonding strength across a bond between the bonding surfaces.

[0326] As shown in FIG. 33, a first-part laser 506 is configured to generate a first-part laser beam 508 and direct the first-part laser beam 508 at the first-part surface 520 of the first part 502. The first-part laser beam 508 impacts the first-part surface 520, which sublimates a portion of the first-part surface 520 up to a desired depth. More specifically, the energy of the first-part laser beam 508 is sufficient to transition the portion of the first-part surface 520 from a solid state directly to a gas state. In some examples, the desired depth is between 5 micrometers and 100 micrometers, between 20 micrometers and 50 micrometers, or approximately 30 micrometers. The gas sublimated from the first-part surface 520 can be suctioned away, such as by a vacuum pump (not shown).

[0327] The depth of the portion of the first-part surface 520 that is sublimated (e.g., removed) is dependent on the material of the first-part surface 520 and the characteristics of the first-part laser beam 508. The characteristics of the first-part laser beam 508 include the intensity (e.g., optical

power per unit area) of, the pulse frequency of, and the duration of the impact on the first-part surface 520 by the first-part laser beam 508. After the portion of the first-part surface 520 is removed, the first-part ablated surface 522 is exposed. Accordingly, generally speaking, the first-part laser beam 508 removes a top surface of the first part 502 so that a fresh surface of the first part 502 is exposed. The first-part ablated surface 522 (e.g., fresh surface or exposed surface) is relatively free of contaminants (e.g., oxides, moisture, etc.) present on the first-part surface 520.

[0328] Similarly, as shown in FIG. 34, a second-part laser 510 is configured to generate a second-part laser beam 512 and direct the second-part laser beam 512 at the second-part surface 524 of the second part 504. The second-part laser beam 512 impacts the second-part surface 524, which sublimates a portion of the second-part surface 524 up to a desired depth. More specifically, the energy of the second-part laser beam 512 is sufficient to transition the portion of the second-part surface 524 from a solid state directly to a gas state. The gas sublimated from the second-part surface 524 can be suctioned away, such as by a vacuum pump (not shown). The depth of the portion of the second-part surface 524 that is sublimated is dependent on the material of the second-part surface 524 and the characteristics of the second-part laser beam 512. Like the first-part laser beam 508, the characteristics of the second-part laser beam 512 include the intensity (e.g., optical power per unit area) of, the pulse frequency of, and the duration of the impact on the second-part surface 524 by the second-part laser beam 512. Generally, the first-part laser beam 508 and the second-part laser beam 512 are highly focused beams of laser radiation. After the portion of the second-part surface 524 is removed, the second-part ablated surface 526 is exposed. Accordingly, generally speaking, the second-part laser beam 512 removes a top surface of the second part 504 so that a fresh surface of the second part 504 is exposed. The second-part ablated surface 526 is relatively free of contaminants present on the second-part surface 524.

[0329] In certain examples of the method 550, the first-part laser beam 508 is moved along the first-part surface 520 at a first-part rate to form the first-part ablated surface 522 in the first part 502. Similarly, in some examples, the second-part laser beam 510 is moved along the second-part surface 524 at a second-part rate to form the second-part ablated surface 526 in the second part 504. In this manner, a laser beam with a relatively small footprint can be used to form an ablated surface with a relatively larger surface area. Moreover, in various examples, a laser beam can be split into separate sub-beams, using optics, to move along and form separate portions of an ablated surface. Also, according to some examples, multiple laser beams generated from multiple lasers can be used to form an ablated surface in a single part. The rate at which a laser beam moves along a corresponding part is dependent on the type of material of the part. For example, a given laser beam may need to be moved along a given part at a faster rate, compared to another part, when the material of the given part sublimates faster than the material of the other part. In contrast, a given laser beam may need to be moved along a given part at a slower rate, compared to another part, when the material of the given part sublimates slower than the material of the other part.

[0330] The rate of sublimation, and thus the rate of movement of a laser beam along a part, is dependent on the type of laser generating the laser beam and the characteristics of

the generated laser beam. Different types of lasers generate different types of laser beams. For example, a carbon-dioxide laser generates a laser beam that is different than the one generated by a fiber laser. Likewise, an Nd—YAG (neodymium-doped yttrium aluminum garnet) laser generates a laser beam that is different than the ones generated by a carbon-dioxide laser and fiber laser, respectively. Additionally, in some examples, a laser can be selectively controlled to adjust characteristics of the generated laser. For example, a laser can be selectively controlled to adjust one or both of an intensity or pulse frequency of the generated laser. Generally, the higher the intensity of the laser beam or the higher the pulse frequency of the laser beam, the higher the rate of sublimation.

[0331] After the first part **502** is laser ablated, to form the first-part ablated surface **522**, and the second part **504** is laser ablated, to form the second-part ablated surface **526**, the first-part ablated surface **522** and the second-part ablated surface **526** are bonded together. Referring to FIG. 35, the first-part ablated surface **522** and the second-part ablated surface **526**, when facing each other, are bonded together along a bondline **528** to form a bonded joint. The bondline **528** is defined as the structure, including, but not limited to, the material, between the first-part ablated surface **522** and the second-part ablated surface **526**. Accordingly, in certain examples, the first-part ablated surface **522** and the second-part ablated surface **526** are directly bonded together along the bondline **528**. In other words, in such examples, other than the material of the bondline **528**, no other intervening layer is interposed between the first-part ablated surface **522** and the second-part ablated surface **526**. In some examples, the bondline **528** includes the bonding tape **174** when the first-part ablated surface **522** and the second-part ablated surface **526** are adhesively bonded. The bonding tape **174** has a maximum thickness and a minimum thickness, or alternatively an average thickness, along the bondline **528**.

[0332] In some examples, the type of the first-part laser **506**, the rate of movement of the first laser beam **508** (i.e., first-part rate), and/or the characteristics of the first-part laser beam **508** is dependent on the type of material of the first part **502**. Similarly, in some examples, the type of the second-part laser **510**, the rate of movement of the second-part laser beam **512** (i.e., second-part rate), and/or the characteristics of the second-part laser beam **512** is dependent on the type of material of the second part **504**.

[0333] According to certain examples, the first part **502** is made of a first material and the second part is made of a second material, where the first material is different than the second material. In one example, the first part **502** is made of a first type of metallic material and the second part **504** is made of a second type of metallic material. In another example, the first part **502** is made of a first type of non-metallic material and the second part **504** is made of a second type of non-metallic material. In yet a further example, the first part **502** is made of a non-metallic material and the second part **504** is made of a metallic material. In the above examples, at least one of the type of the first-part laser **506**, the rate of movement of the first-part laser beam **508**, or the characteristics of the first-part laser beam **508** is different than the type of the second-part laser **510**, the rate of movement of the second-part laser beam **512**, or the characteristics of the second-part laser beam **512**, respectively. According to some examples, the type of the first-part laser **506** is different than that of the second-part laser **510**

(e.g., such that the first-part laser **506** is different than and separate from the second-part laser **510**). In some examples, the first-part rate is different than the second-part rate. In one example, the intensity of the first-part laser beam **508** is different than the second-part laser beam **512**. Additionally, or alternatively, according to certain examples, the pulse frequency of the first-part laser beam **508** is different than the pulse frequency of the second-part laser beam **512**.

[0334] According to some examples, the first material is a fiber-reinforced polymeric material and the second material is a metallic material. In one example, the fiber-reinforced polymeric material is at least one of a glass-fiber-reinforced polymeric material or a carbon-fiber-reinforced polymeric material, such as one of those described above, and the metallic material is a titanium alloy, such as a cast titanium material. In these examples, at least one of: the first-part laser **506** is a carbon dioxide laser and the second-part laser **510** is a fiber laser; the first-part rate is slower than the second-part rate; the intensity of the first-part laser beam **508** is less than the intensity of the second-part laser beam **512**; or the pulse frequency of the first-part laser beam **508** is less than the pulse frequency of the second-part laser beam **512**. When the first-part rate is slower than the second-part rate, in some examples, the first-part rate is between 600 mm/s and 800 mm/s (e.g., 700 mm/s), and the second-part rate is between 600 mm/s and 800 mm/s (e.g., 700 mm/s). When the intensity of the first-part laser beam **508** is less than the intensity of the second-part laser beam **512**, in certain examples, the intensity of the first-part laser beam **508** is between 40 watts and 60 watts, and the intensity of the second-part laser beam **512** is between 40 watts and 60 watts. When the pulse frequency of the first-part laser beam **508** is less than the pulse frequency of the second-part laser beam **512**, in some examples, the pulse frequency of the first-part laser beam **508** is between 40 kHz and 60 kHz, and the pulse frequency of the second-part laser beam **512** is between 40 kHz and 60 kHz.

[0335] When either the first material of the first part **502** or the second material of the second part **504** is a fiber-reinforced polymeric material, which includes a plurality of reinforcement fibers embedded in a resin or epoxy matrix, the corresponding first-part surface **520** or the second-part surface **524** is defined entirely by the resin or epoxy matrix of the fiber-reinforced polymeric material. Accordingly, the first-part laser beam **508** or the second-part laser beam **512** impacts and ablates only the resin or epoxy matrix, without ablating the reinforcement fibers embedded therein. Moreover, in some examples, the first part **502** or the second part **504** is made of plies of a carbon-fiber-reinforced polymeric material sandwiched between opposing outer plies of a glass-fiber-reinforced polymeric material. In such examples, the corresponding laser beam impacts and ablates only the resin or epoxy matrix of the glass-fiber-reinforced polymeric material.

[0336] As presented previously, due the ability to precisely control the energy, pulse frequency, and directionality of a laser, laser ablation of a surface can result in a fresh (e.g., relatively uncontaminated) surface having a high uniformity of peaks and valleys, and a high surface energy. Generally, each pulse of the laser beam sublimates and removes a localized portion of the surface being ablated. The removed portion of the surface defines a valley (e.g., dimple or depression) that has a shape that corresponds with a cross-sectional shape of the laser beam and a depth that

corresponds with the intensity and frequency of the laser beam. Because the laser beam is moved relative to the surface being ablated, each pulse of the laser beam contacts a different portion of the surface, which results in disparate and spaced apart valleys corresponding with the removed portions. Because the portions of the surface between the removed portions are not removed, the unremoved portions of the surface define peaks between diagonal ones of the valleys. In this manner, as the laser beam is moved relative to the surface, a pattern of peaks and valleys in the surface is formed.

[0337] Referring to FIG. 33, sublimation of the first-part surface 520 results in a first-part ablated surface 522 having a first-part ablation pattern of peaks and valleys. Similarly, referring to FIG. 34, sublimation of the second-part surface 524 results in a second-part ablated surface 526 having a second-part ablation pattern of peaks and valleys. Example of an ablation pattern of peaks of valleys, which can be representative of the first-part ablation pattern and the second-part ablation pattern, are shown in FIGS. 36, 37, 45, and 46.

[0338] An ablation pattern 540 includes a plurality of peaks 542 spaced apart by a plurality of valleys 544. Generally, the laser beam is moved and pulsed such that the valleys are located relative to each other to form a desired pattern. The pattern of valleys can be symmetrical or non-symmetrical. Moreover, the spacing between valleys can be uniform or non-uniform. In one example, such as shown in FIGS. 36, 45, and 46, the ablation pattern 540 is symmetrical and the spacing between the valleys of the ablation pattern 540 is uniform. As shown in FIG. 36, in one example of a symmetrical pattern, the valleys of the ablation pattern 540 are uniformly spaced and closely spaced together, which means each valley is contiguous with at least one adjacent valley and at least one adjacent peak of the pattern of peaks and valleys. In the illustrated example of FIG. 36, some valleys, of the ablation pattern 540 of peaks and valleys, are contiguous with four adjacent valleys and four adjacent peaks. Likewise, in the illustrated example of FIG. 36, some peaks, of the ablation pattern 540 of peaks and valleys, are contiguous with four adjacent peaks and four adjacent valleys.

[0339] In some examples, each one of the valleys 544 is separated from an adjacent one of the valleys 544, across one of the peaks 542 and along a length L (or width) of the part, by a valley-to-valley distance Dvv. The valley-to-valley distance Dvv is defined as the distance from a center point of one of the valleys 544 and the center point of an adjacent one of the valleys 544. Moreover, each one of the valleys 544 has a valley depth dv measured from a hypothetical boundary 546 that is generally co-planar with the surface prior to being laser ablated. Referring to FIGS. 45 and 46, each one of the valleys 544 has a major dimension D1 (e.g., maximum dimension) and a minor dimension D2 (e.g., minimum dimension). The major dimension D1 is equal to or less than the minor dimension D2. For example, with reference to FIG. 45, when each one of the valleys 544 is substantially circular, the major dimension D1 is equal to the minor dimension D2. However, in other examples, as shown in FIG. 46, each one of the valleys 544 has a non-circular shape (e.g., an oval shape) such that the major dimension D1 is greater than the minor dimension D2. In some examples, such as when the surface, ablated by the laser beam, is flat, the resulting ablation pattern includes

valleys 544 that are circular. However, according to certain examples, such as when the surface, ablated by the laser beam, is curved or contoured, the curvature of the surfaces causes the valleys 544 of the resulting ablation pattern to have an oval shape.

[0340] In some examples, the major dimension D1 of at least one of the valleys 544 is between 40 micrometers and 80 micrometers, and the minor dimension D2 is equal to the major dimension D1 or may vary by as much as 10% or 20% or by 10-20 micrometers. Additionally, or alternatively, the valley-to-valley distance Dvv between two valleys 544 can range from 80%-200% (preferably at least 120%) of the major dimension D1 of any one of the two valleys 544. As defined herein, in relation to the valleys 544, a first valley is adjacent a second valley when the second valley is the nearest neighbor to the first valley. Moreover, in some examples, such as those with uniform spacing between valleys, a given valley can be considered to be adjacent to multiple valleys. The center point of a valley 544 is defined as the location of greatest depth of the valley 544, which will typically be half of the major dimension inwards from an outer perimeter of the valley 544. The outer perimeter (e.g., perimeter) of a valley 544 is defined as the transition region where a change in the valley depth dv of the valley 544, versus an unablated surface, is no more than 5 micrometers, preferably between 0 to 2 micrometers versus an unablated surface.

[0341] According to one example, the uniformity of an ablation pattern of peaks and valleys, as used herein, can be defined in terms of the variation of the size of the valleys of the ablation pattern. As previously mentioned, the substantially non-controllable ablation pattern left behind by some ablation process, such as media-blast ablation processes, include valleys of widely disparate sizes, shapes, and spacing. The ability to precisely control the energy, pulse frequency, and directionality of the laser results in an ablation pattern where all the valleys of the pattern have a uniform size. The uniformity of the sizes of the valleys of the ablation pattern formed by the laser beam can be expressed by the percent difference in the size of one valley of the ablation pattern relative to any other one (e.g., all other ones) of the valleys of the ablation pattern. The percent difference, as pertaining to the size of the valleys, is equal to the ratio (expressed as a percentage) of the size of one valley in the pattern and the size of any other one of the valleys in the pattern. The lower the percent difference in the size of the valleys of the ablation pattern, the higher the uniformity of the ablation pattern. In some examples, the percent difference of the size of one valley of a given pattern and the size of any other one of the valleys of the given pattern is no more than 20%. In other words, the size of one valley is within 20% of the size of any other one, or all other ones, of the valleys. In other examples, the percent difference of the size of one valley of a given pattern and the size of any other one of the valleys of the given pattern is no more than 10%.

[0342] The size of a valley can be expressed as a cross-sectional area, the major dimension D1, the minor dimension D2, the depth dv, or other characteristic of the size of the valley. In certain examples, the major dimension D1 or the minor dimension D2 of one valley is within 20% of the corresponding major dimension D1 or the minor dimension D2 of any other one, or all other ones, of the valleys. According to one example, the major dimension D1 of one valley is within 20% of the major dimension D1 of any other

one, or all other ones, of the valleys, and the minor dimension D2 of the one valley is within 20% of the minor dimension D2 of any other one, or all other ones, of the valleys. In certain examples, the major dimension D1 or the minor dimension D2 of one valley is within 10% of the corresponding major dimension D1 or the minor dimension D2 of any other one, or all other ones, of the valleys. According to one example, the major dimension D1 of one valley is within 10% of the major dimension D1 of any other one, or all other ones, of the valleys, and the minor dimension D2 of the one valley is within 10% of the minor dimension D2 of any other one, or all other ones, of the valleys. Although the above examples reference the major dimension D1 and the minor dimension D2 of the valleys, other characteristics of the size of the valleys, such as cross-sectional area and depth, can be interchanged with the major dimension D1 and the minor dimension D2.

[0343] Additionally, or alternatively, in some examples, the uniformity of an ablation pattern of peaks and valleys, as used herein, can be defined in terms of the variation of the distance between adjacent valleys of the ablation pattern. The ability to precisely control the energy, pulse frequency, and directionality of the laser results in an ablation pattern where all the valleys of the pattern are uniformly spaced apart from each other. The uniformity of the distance between the valleys of the ablation pattern formed by the laser beam can be expressed by the percent difference in the distance between two adjacent valleys of the ablation pattern relative to the distance between any other two adjacent valleys (e.g., all adjacent valleys) of the ablation pattern. The percent difference, as pertaining to the distances between valleys, is equal to the ratio (expressed as a percentage) of the distance between two adjacent valleys in the pattern and the distance between any other two adjacent valleys in the pattern. The lower the percent difference in the distances between the valleys of the ablation pattern, the higher the uniformity of the ablation pattern. In some examples, the percent difference of the distances between two adjacent valleys of a given pattern and the difference between any other two adjacent valleys of the given pattern is no more than 20%. In other words, the distance between two adjacent valleys is within 20% of the distance between any other two adjacent valleys. In other examples, the percent difference of the distances between two adjacent valleys of a given pattern and the difference between any other two adjacent valleys of the given pattern is no more than 10%.

[0344] Corresponding with the uniformity of the peaks and valleys of the ablation pattern on the ablated surfaces of the parts disclosed herein, laser ablating a surface of a part of the golf club head also promotes a higher surface energy compared to surfaces treated using other types of ablation processes. As presented above, a higher surface energy of surfaces to be bonded enables a stronger and more reliable bond between the surfaces. The surface energy of a surface is inversely proportional to the water contact angle of the surface. In other words, the lower the water contact angle of the surface, the higher the surface energy of that surface. The water contact angle is defined as the angle (through the water) a drop of water, on a surface, makes with the surface. The lower the water contact angle, the higher the wettability of the surface, which promotes the adhesiveness of the adhesive and the ability of the adhesive to bond to the surface. Accordingly, the lower the water contact angle, the better the bond, and the higher the strength of the bond. In

some examples, the water contact angle can be measured by using a goniometer or other measuring device. According to Table 4 below, the water contact angle for various laser ablated surfaces of several examples of a golf club head, prior to forming a bonded joint, are shown.

TABLE 4

	Crown-Hosel	Crown-Toe	Sole-Hosel	Sole-Toe
Example 1	14°	6°	10°	5°
Example 2	16°	12°	10°	6°
Example 3	14°	13°	10°	10°
Example 4	11°	13°	10°	2°
Example 5	16°	13°	10°	12°
Example 6	14°	21°	10°	6°
Example 7	14°	14°	10°	6°
Example 8	15°	15°	16°	15°
Example 9	18°	18°	9°	10°
Example 10	18°	17°	8°	2°

[0345] In Table 4, the crown-hosel surface is a portion of the front-ledge ablated surface 179A of the body 102 that is closer to the crown portion 119 than the sole portion 117, and closer to the hosel 120 than the toe portion 114; the crown-toe surface is a portion of the front-ledge ablated surface 179A of the body 102 that is closer to the crown portion 119 than the sole portion 117, and closer to the toe portion 114 than the hosel 120; the sole-hosel surface is a portion of the front-ledge ablated surface 179A of the body 102 that is closer to the sole portion 117 than the crown portion 119, and closer to the hosel 120 than the toe portion 114; and the sole-toe surface is a portion of the front-ledge ablated surface 179A of the body 102 that is closer to the sole portion 117 than the crown portion 119, and closer to the toe portion 114 than the hosel 120. Accordingly, with reference to Table 4, in some examples, the second-part ablated surface 526, or any laser ablated surface of the golf club head 100, has a water contact angle between 2° and 25°, or between 5° and 18°. According to yet certain examples, the water contact angle of an ablated surface of the golf club head 100 is less than 50°, less than 45°, less than 40°, less than 35°, less than 30°, less than 25°, or less than 20°. In some examples, the water contact angle of an ablated surface of the golf club head 100 is greater than zero degrees and less than 30° or greater than zero degrees and less than 25°. In certain examples, the water contact angle of an ablated surface of the golf club head 100 is between 1° and 18°.

[0346] Referring to FIGS. 38, 40, and 41, in some examples, the first part 502 is the strike plate 143 of the golf club head 100 and the second part 504 is the body 102 of the golf club head 100. In certain examples, the strike plate 143 can be made of a fiber-reinforced polymeric material and the body 102 can be made of a different material, such as a cast titanium material, non-cast titanium material, an aluminum material, a steel material, a tungsten material, a plastic material, and/or the like. The strike plate 143 is made of a plurality of stacked plies of fiber-reinforced polymeric material in certain examples. In one example, the strike plate 143 is made of between 35-70 stacked plies of fiber-reinforced polymeric material (each having continuous fibers at a given angle) and has a thickness between 3.5 mm and 6.0 mm, inclusive. The angle of the fibers of the plies can vary from ply-to-ply. Alternatively, the strike plate 143 can be made of a metallic material, such as a titanium alloy, and the body 102 can be made of the same metallic material or a different

metallic material, such as a different titanium alloy. Also, the body 102, as presented above, can be made of multiple, separately formed and subsequently attached, pieces where each piece is made of a different material.

[0347] When the first part 502 is the strike plate 143 of the golf club head 100, the first-part surface 520 includes the interior surface 166 or rear surface of the strike plate 143, which is opposite the strike face 145 of the strike plate 143. Accordingly, as shown in FIG. 38, the first laser 506 generates the first-part laser beam 508 and directs the first-part laser beam 508 to impact the interior surface 166 within and along a designated first-part bond area 548, at least partially on the interior surface 166, to form a strike-plate-interior ablated surface 179C. Accordingly, only a portion (e.g., outer peripheral portion) of the entire interior surface 166 of the strike plate 143 is laser ablated, with the remaining portion of the interior surface 166 being non-ablated. The first-part ablated surface 522 includes, at least partially, the strike-plate-interior ablated surface 179C. In some examples, the first-part surface 520 also includes a peripheral edge surface 167 of the strike plate 145 and the first laser 506 generates the first-part laser beam 508 and directs the first-part laser beam 508 to impact (e.g., an entirety of) the peripheral edge surface 167 such that a strike-plate-edge ablated surface 179D is formed. Accordingly, the first-part ablated surface 522 can further include the strike-plate-edge ablated surface 179D and the designated first-part bond area 548 can further include the peripheral edge surface 167. The strike-plate-interior ablated surface 179C and the strike-plate-edge ablated surface 179D have the same ablation pattern in certain examples. In some examples, an orientation of the strike plate 143 relative to the first-part laser 506 is adjusted when laser ablating the peripheral edge surface 167, compared to when laser ablating the interior surface 166, because of the angle of the peripheral edge surface 167 relative to the interior surface 166.

[0348] When the second part 504 is the body 102, the second-part surface 524 includes the plate-opening recessed ledge 147 of the body 102. Accordingly, as shown in FIG. 39, the second laser 510 generates the second-part laser beam 512 and directs the second-part laser beam 512 to impact the plate-opening recessed ledge 147, within and along a designated second-part bond area, to form a front-ledge ablated surface 179A. The second-part ablated surface 526 includes, at least partially, the front-ledge ablated surface 179A. In some examples, the second-part surface 524 also includes the sidewall 146, extending about the plate-opening recessed ledge 147, and the second laser 510 generates the second-part laser beam 512 and directs the second-part laser beam 512 to impact (e.g., an entirety of) the sidewall 146 such that a front-sidewall ablated surface 179B is formed. Accordingly, the second-part ablated surface 526 can further include the front-sidewall ablated surface 179B and the designated second-part bond area can further include the sidewall 146. The front-ledge ablated surface 179A and the front-sidewall ablated surface 179B have the same ablation pattern in certain examples. In some examples, an orientation of the body 102 relative to the second-part laser 510 is adjusted when laser ablating the sidewall 146, compared to when laser ablating the plate-opening recessed ledge 147, because of the angle of the sidewall 146 relative to the plate-opening recessed ledge 147.

[0349] In view of the foregoing, according to some examples, such as with the golf club head 300 of FIG. 18, the second-part ablated surface 526 is defined by the ablated surfaces of two sub-components (e.g., the upper cup piece 304A and the lower cup piece 304B) made of different materials. Therefore, when the second-part ablated surface 526 is laser ablated, the different materials defining the second-part ablated surface 526 can be laser ablated in a single, continuous step. A first material of the different materials can define a first surface area of the second-part ablated surface 526 and the second material of the different materials can define a second surface area of the second-part ablated surface. The first surface area and the second surface area can be different in some examples. According to certain examples, the first surface area is greater than the second surface area, and the first material, defining the first surface area, has a lower density than the second material, defining the second surface area. Both the upper cup piece 304A and the lower cup piece 304B include a front ledge and a sidewall (similar to the plate opening recessed ledge 147 and the sidewall 146), which can be laser ablated to define the second-part ablated surface 526.

[0350] Referring to FIGS. 10-13, in some examples, the first part 502 is one of the crown insert 108 or the sole insert 110, and the second part 504 is the body 102. In certain examples, the crown insert 108 and/or the sole insert 110 can be made of a fiber-reinforced polymeric material and the body 102 can be made of a different material, such as a cast titanium material, non-cast titanium material, an aluminum material, a steel material, a tungsten material, a plastic material, and/or the like. Alternatively, the crown insert 108 and/or the sole insert 110 can be made of a metallic material, such as a titanium alloy, and the body 102 can be made of the same metallic material or a different metallic material, such as a different titanium alloy.

[0351] When the first part 502 is the crown insert 108, the first-part surface 520 includes an interior surface 108A of the crown insert 108. Accordingly, the first laser 506 generates the first-part laser beam 508 and directs the first-part laser beam 508 to impact the interior surface 108A of the crown insert 108 within and along a designated first-part bond area 548, at least partially on the interior surface 108A of the crown insert 108, to form a crown-insert ablated surface 108B. The first-part ablated surface 522 includes, at least partially, the crown-insert ablated surface 108B. Accordingly, only a portion (e.g., outer peripheral portion) of the entire interior surface of the crown insert 108 is laser ablated, with the remaining portion of the interior surface of the crown insert 108 being non-ablated. In some examples, the bond area on the interior surface 108A of the crown insert 108 will range from 2,000 mm² to 2,500 mm², such as at least 2,248 mm². Moreover, in certain examples, a total surface area of the interior surface 108A of the crown insert 108 is between 7,000 mm² and 12,000 mm² or between 9,000 mm² and 11,000 mm² (e.g., a minimum surface area between 7,000 mm² and 9,000 mm²), such as between 9,379 mm² and 10,366 mm² (e.g., around 9,873 mm²). In some examples, a percentage of the total surface area of the interior surface 108A occupied by the bond area on the interior surface 108A of the crown insert 108 is no more than 25%, 30%, 35%, or 40% and no less than 10%, 15%, 20%, or 25%. According to certain examples, the percentage of the total surface area of the interior surface 108A occupied by the bond area on the interior surface 108A of the crown

insert **108** is between 20% and 25%, such as 22%, between 20% and 27%, or between 22% and 25%.

[0352] In some examples, the bond area on the interior surface **110A** of the sole insert **110** will range from 1,800 mm² to 2,200 mm², such as at least 2,076 mm². Moreover, in certain examples, a total surface area of the interior surface **110A** of the sole insert **110** is between 7,000 mm² and 12,000 mm² or between 9,000 mm² and 11,000 mm² (e.g., a minimum surface area between 7,000 mm² and 9,000 mm²), such as between 8,182 mm² and 9,043 mm² (e.g., around 8,613 mm²). In some examples, a percentage of the total surface area of the interior surface **110A** occupied by the bond area on the interior surface **110A** of the sole insert **110** is no more than 25%, 30%, 35%, or 40% and no less than 10%, 15%, 20%, or 25%. According to certain examples, the percentage of the total surface area of the interior surface **110A** occupied by the bond area on the interior surface **110A** of the sole insert **110** is between 20% and 27%, between 22% and 25%, or between 21% and 26%, such as 24%.

[0353] In some examples, the bond area on the interior surface of the strike plate **143** will range from 1,770 mm² to 2,170 mm², such as at least 1,976 mm². Moreover, in certain examples, a total surface area of the interior surface of the strike plate **143** is less than 7,000 mm², such as between 1,500 mm² and 7,000 mm², between 3,200 mm² and 4,700 mm², or between 3,572 mm² and 3,949 mm² (e.g., around 3,761 mm²). In some examples, a percentage of the total surface area of the interior surface of the strike plate **143** occupied by the bond area on the interior surface of the strike plate **143** is no more than 55%, 60%, 65%, or 70% and no less than 30%, 35%, 40%, or 45%. According to certain examples, the percentage of the total surface area of the interior surface of the strike plate **143** occupied by the bond area on the interior surface of the strike plate **143** is between 47% and 58%, such as 52%.

[0354] In some examples, the first-part surface **520** also includes a peripheral edge surface of the crown insert **108** and the first laser **506** generates the first-part laser beam **508** and directs the first-part laser beam **508** to impact (e.g., an entirety of) the peripheral edge surface of the crown insert **108** such that a crown-insert-edge ablated surface **108C** is formed. Accordingly, the first-part ablated surface **522** can further include the crown-insert-edge ablated surface **108C** and the designated first-part bond area **548** can further include the peripheral edge surface of the crown insert **108**. The crown-insert ablated surface **108B** and the crown-insert-edge ablated surface **108C** can have the same ablation pattern in certain examples. In some examples, an orientation of the crown insert **108** relative to the first-part laser **506** is adjusted when laser ablating the peripheral edge surface of the crown insert **108**, compared to when laser ablating the interior surface **108A**, because of the angle of the peripheral edge surface relative to the interior surface **108A**.

[0355] When the first part **502** is the crown insert **108**, the second-part surface **524** includes the crown-opening recessed ledge **168**. Accordingly, the second laser **510** generates the second-part laser beam **512** and directs the second-part laser beam **512** to impact the crown-opening recessed ledge **168** within and along a designated second-part bond area, at least partially on the crown-opening recessed ledge **168**, to form a top-ledge ablated surface **141A**. The second-part ablated surface **526** includes, at least partially, the top-ledge ablated surface **141A**. In some

examples, the second-part surface **524** also includes a top recessed-ledge sidewall, circumferentially surrounding and defining a depth of the crown-opening recessed ledge **168**, and the second laser **510** generates the second-part laser beam **512** and directs the second-part laser beam **512** to impact (e.g., an entirety of) the top recessed-ledge sidewall such that a top-ledge ablated surface **141B** is formed. Accordingly, the second-part ablated surface **526** can further include the top-ledge ablated surface **141B** and a designated second-part bond area can further include the top recessed-ledge sidewall. The top-ledge ablated surface **141A** and the top-ledge ablated surface **141B** can have the same ablation pattern in certain examples. In some examples, an orientation of the body **102** relative to the second-part laser **510** is adjusted when laser ablating the top recessed-ledge sidewall, compared to when laser ablating the crown-opening recessed ledge **168**, because of the angle of the top recessed-ledge sidewall relative to the crown-opening recessed ledge **168**.

[0356] In view of the foregoing, according to some examples, the second-part ablated surface **526** is defined by the ablated surfaces of two sub-components (e.g., the cast cup **104** and the ring **106**) made of different materials. Therefore, when the second-part ablated surface **526** is laser ablated, the different materials defining the second-part ablated surface **526** can be laser ablated in a single, continuous step.

[0357] When the first part **502** is the sole insert **110**, the first-part surface **520** includes an interior surface **110A** of the sole insert **110**. Accordingly, the first laser **506** generates the first-part laser beam **508** and directs the first-part laser beam **508** to impact the interior surface **110A** of the sole insert **110** within and along a designated first-part bond area **548**, at least partially on the interior surface **110A** of the crown insert **110**, to form a sole-insert ablated surface **110B**. The first-part ablated surface **522** includes, at least partially, the sole-insert ablated surface **110B**. Accordingly, only a portion (e.g., outer peripheral portion) of the entire interior surface of the sole insert **110** is laser ablated, with the remaining portion of the interior surface of the sole insert **110** being non-ablated. In some examples, the first-part surface **520** also includes a peripheral edge surface of the sole insert **110** and the first laser **506** generates the first-part laser beam **508** and directs the first-part laser beam **508** to impact (e.g., an entirety of) the peripheral edge surface of the sole insert **110** such that a sole-insert-edge ablated surface **110C** is formed. Accordingly, the first-part ablated surface **522** can further include the sole-insert-edge ablated surface **110C** and the designated first-part bond area **548** can further include the peripheral edge surface of the sole insert **110**. The sole-insert ablated surface **110B** and the sole-insert-edge ablated surface **110C** can have the same ablation pattern in certain examples. In some examples, an orientation of the sole insert **110** relative to the first-part laser **506** is adjusted when laser ablating the peripheral edge surface of the sole insert **110**, compared to when laser ablating the interior surface **110A**, because of the angle of the peripheral edge surface relative to the interior surface **110A**.

[0358] Furthermore, when the first part **502** is the sole insert **110**, the second-part surface **524** includes the sole-opening recessed ledge **170**. Accordingly, the second laser **510** generates the second-part laser beam **512** and directs the second-part laser beam **512** to impact the sole-opening recessed ledge **170** within and along a designated second-

part bond area, at least partially on the sole-opening recessed ledge 170, to form a bottom-ledge ablated surface 142A. The second-part ablated surface 526 includes, at least partially, the bottom-ledge ablated surface 142A. In some examples, the second-part surface 524 also includes a bottom recessed-ledge sidewall, circumferentially surrounding and defining a depth of the sole-opening recessed ledge 170, and the second laser 510 generates the second-part laser beam 512 and directs the second-part laser beam 512 to impact (e.g., an entirety of) the bottom recessed-ledge sidewall such that a bottom-sidewall ablated surface 142B is formed. Accordingly, the second-part ablated surface 526 can further include the bottom-sidewall ablated surface 142B and the designated second-part bond area can further include the bottom recessed-ledge sidewall. The bottom-ledge ablated surface 142A and the bottom-sidewall ablated surface 142B can have the same ablation pattern in certain examples. In some examples, an orientation of the body 102 relative to the second-part laser 510 is adjusted when laser ablating the bottom recessed-ledge sidewall, compared to when laser ablating the sole-opening recessed ledge 170, because of the angle of the bottom recessed-ledge sidewall relative to the sole-opening recessed ledge 170.

[0359] As disclosed above, in some examples, an orientation of a part being laser ablated can be adjusted relative to the laser that is ablating the part. In one example, as shown by directional arrows, with dashed lines, in FIG. 39, the part is held stationary and the orientation of the laser or the directionality of the laser beam is changed relative to the part. The orientation of the laser can be changed by moving the laser, such as via a numerically-controlled robot, or adjusting the directionality of the laser beam generated by the laser, such as by using electronically controllable optical components.

[0360] According to another example, as shown by directional arrows, with solid lines, in FIG. 39, the laser is held stationary (or the directionality of the laser beam is held constant), and the orientation of the part is adjusted or the part is moved relative to the laser beam. The orientation of the part can be adjusted by fixing the part to an adjustable platform, that can be translationally moved or rotated to translationally move or rotate the part relative to the laser beam.

[0361] Although in some examples, the methods disclosed herein may be performed manually, in other examples, the methods are automated. As used herein, automated means operated at least partially by automatic equipment, such as computer-numerically-controlled (CNC) machines. The process of controlling the laser, including the directionality and/or characteristics of the laser beam, and/or controlling the orientation/position of the part relative to the laser beam is automated in some examples. For example, an electronic controller can control the laser and part-adjustment components (e.g., motors, cylinders, gears, rails, etc.) that hold and adjust the orientation/position of the part.

[0362] Because the golf club head 100 has both a crown insert 108 and a sole insert 110 attached to the body 102, in some examples, the method 550 can be performed to make a golf club head that has more than one first part 502 coupled to the second part 504. In other words, in at least one example, the golf club head 100 includes at least two first parts 502 coupled to the second part 504. Moreover, because the golf club head 100 also includes a strike plate 148 attached to the body 102, in certain examples, the method

550 can be performed to make a golf club head that has at least three first parts 502 coupled to the second part 504.

[0363] As described above, the body 102 of the golf club head 100 includes multiple pieces that are attached together to form a multi-piece construction. For example, referring to FIGS. 14 and 15, the body 102 of the golf club head 100 includes the cast cup 104 and the ring 106. Accordingly, in some examples, the method 550 can be performed to make a body of a golf club head that includes the first part 502 and the second part 504. The first part 502 is the ring 106 and the second part 504 is the cast cup 104 in certain examples. As disclosed above, the ring 106 and the cast cup 104 can be made of different materials. For example, the ring 106 can be made of a metallic material or a plastic material having a relatively lower density than the material of the cast cup 104, which can be made of a cast titanium material.

[0364] When the first part 502 is the ring 106 and the second part 504 is the cast cup 104, the first-part surface 520 includes the toe cup-engagement surface 152A and the heel cup-engagement surface 152B. Accordingly, the first laser 506 generates the first-part laser beam 508 and directs the first-part laser beam 508 to impact the toe cup-engagement surface 152A and the heel cup-engagement surface 152B within and along a designated first-part bond area, at least partially on the toe cup-engagement surface 152A and the heel cup-engagement surface 152B, to form a toe cup-engagement ablated surface 148C and a heel cup-engagement surface 148D, respectively. The first-part ablated surface 522 includes, at least partially, the toe cup-engagement ablated surface 148C and the heel cup-engagement surface 148D. The toe cup-engagement ablated surface 148C and the heel cup-engagement surface 148D can have the same ablation pattern in certain examples.

[0365] Correspondingly, when the first part 502 is the ring 106 and the second part 504 is the cast cup 104, the second-part surface 524 includes the toe ring-engagement surface 150A and the heel ring-engagement surface 150B. Accordingly, the second laser 510 generates the second-part laser beam 512 and directs the second-part laser beam 512 to impact the toe ring-engagement surface 150A and the heel ring-engagement surface 150B within and along a designated second-part bond area, at least partially on the toe ring-engagement surface 150A and the heel ring-engagement surface 150B, to form a toe ring-engagement ablated surface 148A and a heel ring-engagement surface 148B, respectively. The first-part ablated surface 522 includes, at least partially, the toe ring-engagement ablated surface 148A and the heel ring-engagement surface 148B. The toe ring-engagement ablated surface 148A and the heel ring-engagement surface 148B can have the same ablation pattern in certain examples.

[0366] After the ring 106 is bonded to the cast cup 104, the ring 106 and the cast cup 104 can collectively define a second part 504 to which a first part 502 is bonded according to the method 550. In other words, the second part 504 can have a multi-piece construction. In fact, with reference to FIG. 18, the cast cup can have a multi-piece construction, such that one piece of the cast cup is the first part 502 and another piece of the cast cup is the second part 504, such that the multiple pieces (e.g., made of the same or different materials) of the cast cup have ablated surfaces bonded together after the manner of the method 550.

[0367] As used herein, dashed leader lines are used to indicate features in a prior state. For example, a surface

referenced by a dashed leader line indicates that surface prior to being modified into a surface referenced by a solid leader line. This methodology is helpful in understanding the correlation between a surface before and after being ablated.

[0368] In some examples, the step of laser ablating the first-part surface **520** or the step of laser ablating the second-part surface **524** is performed to remove alpha case from a corresponding one of the first part **502** or the second part **504**. In such examples, the corresponding one of the first part **502** or the second part **504** is made of a titanium alloy that is prone to developing a layer of alpha case on the first-part surface **520** or the second-part surface **524**, respectively, during manufacturing (e.g., casting) of the corresponding part (see, e.g., U.S. Pat. No. 10,780,327, issued Sep. 22, 2020, which is incorporated herein by reference). The corresponding one of the first-part surface **520** or the second-part surface **524** is ablated to a depth sufficient to remove the layer of alpha case from the corresponding part. Using the laser ablation method disclosed herein enables the alpha case to be removed with more precision, efficiency, and lower waste materials than conventional methods, such as chemical etching, computer numerically-controlled (CNC) machine, or abrasion techniques.

[0369] Referring to FIGS. 43 and 44, in alternative examples, only one of the two surfaces forming the bondline **528** is laser ablated. According to one example, a method **560** of making the golf club heads of the present disclosure, such as the golf club head **100**, includes (block **562**) laser ablating the second-part surface **524** of the second part **504** of the golf club head **100** such that the second-part ablated surface **526** is formed in the second part **504**. The method **560** additionally includes (block **564**) bonding together the first-part surface **520**, of the first part **502** of the golf club head **100**, and the second-part ablated surface **526** of the second part **504**. In other words, instead of the second-part ablated surface **526** being bonded to a first-part ablated surface of the first part **502**, the second-part ablated surface **526** of the second part **504** is bonded to a non-ablated surface (i.e., the first-part surface **520**) of the first part **502**.

[0370] In certain examples, the second part **504** in the method **560** is made of a titanium alloy, such as a cast alloy, and the first part **502** in the method **560** is made of a fiber-reinforced polymeric material. For example, the first part **502** can be the strike plate **143**, the second part **504** can be the body **102**, and the second-part ablated surface **526** can define the plate-opening recessed ledge **147** of the body **102**. However, unlike the strike plate **143** shown in FIG. 38, the interior surface **166** of the strike plate **143** used in the method **560** is not laser ablated. Instead, the interior surface **166** of the strike plate **143** is untreated or treated using a different type of surface treatment, such as media blasting or chemical etching. According to another example, the first part **502** can be one of the crown insert **108** or the sole insert **110**, the second part **504** can be the body **102**, and the second-part ablated surface **526** can define one of the top plate-opening recess ledge or the sole-opening recessed ledge.

[0371] According to some examples, the method **560** is used to make a golf club head similar to the golf club head **100**, except the strike plate **143**, the crown insert **108**, and/or the sole insert **110** does not have a laser-ablated surface. Instead, in some examples, only the body **102**, which can be made of a cast titanium alloy, includes laser-ablated surfaces. According to one example, the body **102** includes the

top-ledge ablated surface **141A**, the bottom-ledge ablated surface **141B**, and the front-ledge ablated surface **179A**, but the crown insert **108** does not include the crown-insert ablated surface **108B**, the sole insert **110** does not include the sole-insert ablated surface **110B**, and the strike plate **143** does not include the strike-plate-interior ablated surface **179C**.

[0372] Each bonded joint of the golf club head **100** is defined by two bonded surfaces (e.g., faying surfaces). Because a bonded joint has two equal and opposite bonded surfaces, a surface area of each bonded joint (i.e., bond area of each bonded joint) is defined as the surface area of just one of the two bonded surfaces. In other words, as defined herein, the bond area of each bonded joint does not include the surface area of both bonded surfaces of the bonded joint. Accordingly, as used herein, the bond area of a bonded joint, defined between two surfaces of the golf club head disclosed herein, is the surface area of the portion of any one (but just one) of the two surfaces of the bonded joint that is covered by or in direct contact with an adhesive between the two surfaces. In view of this definition, the bond area is equal to the surface area of one of two surfaces of the adhesive (e.g., the bonding tape **174**) defining the bonded joint. Accordingly, as used herein, the maximum surface area of a side of the bonding tape **174**, bonded to a part to form a bonded joint with the part, is equal to the bond area of the bonded joint, as described in detail below.

[0373] In some examples, at least one of the two bonded surfaces of at least one bonded joint of the golf club head **100** is a laser ablated surface. Accordingly, the bond area of a bonded joint defined by a laser ablated surface can be the surface area of the laser ablated surface. Therefore, unless otherwise noted, a surface area of an ablated surface is equal to the bond area of the bonded joint defined by the laser ablated surface. Moreover, the bond area of a bonded joint defined by a non-ablated surface (e.g., the first-part surface **520** of FIG. 44) and an ablated surface is the surface area of the portion of the non-ablated surface that is bonded to the ablated surface or the portion of the non-ablated surface that is covered by or in direct contact with the bonding tape **174**. Accordingly, a non-ablated surface can have a total surface area that is larger than the surface area of the portion of the non-ablated surface bonded to the ablated surface of a bonded joint.

[0374] As defined herein, the surface area of a laser ablated surface is the area of the portion of the surface covered by the pattern of peaks and valleys formed by the laser beam. Accordingly, the surface area of a laser ablated surface can be calculated as a length times a width of the portion of the surface that includes the pattern of peaks and valleys, or calculated by the combined surface area of the peaks and valleys of the pattern of peaks and valleys. Moreover, because in some examples, the bonded surfaces of a bonded joint are contoured, to provide a more convenient way of calculating the area of the bonded surfaces, as defined herein, the surface area of a surface is a projected surface area, which is the surface area of the surface projected onto a hypothetical plane substantially facing the surface.

[0375] Generally, a total bond area of the golf club head **100** is higher than conventional golf club heads. Moreover, a high percentage, such as 50%-100%, of the total bond area of the golf club head **100** is defined by laser ablated surfaces bonded together using the bonding tape **174**. According to

one example, the second-part ablated surface **526** of the golf club head **100** has a surface area between 800 mm² and 2,880 mm². In this, or other examples, the second-part ablated surface **526** of the golf club head **100** has a surface area of at least 1,560 mm², of at least 1,770 mm², of at least 2,062 mm², or of at least 2,600 mm². As defined previously, the first-part surface **520** or the first-part ablated surface **522** of the golf club head **100** can have corresponding surface areas because they would define the side of a bonded joint opposite the second-part ablated surface **526**. Referring to Table 5 below, areas of some features and the bond area (in mm²) of bonded surfaces of bonded joints of several examples of the golf club heads disclosed herein, which can be the same as or different than the examples of Table 4, is shown.

TABLE 5

	Exam- ple 1	Exam- ple 2	Exam- ple 3
Plate Opening Area	2266	1674	1330-2720
Front-Ledge Ablated Surface Area	1010	—	800-1220
Front-Sidewall Ablated Surface Area	806	—	640-970
Strike Face Ablated Surface Area	1073	1073	850-1290
Lower Cup Piece Ablated Surface Area	—	599	470-720
Lower Cup Piece Ledge Ablated Surface Area	—	267	210-330
Lower Cup Piece Sidewall Ablated Surface Area	—	222	170-270
Ring-Engagement Ablated Surface Area	80	—	60-100
Cup-Engagement Ablated Surface Area	112	—	80-140
Cup Top-Ledge Ablated Surface Area	1424	—	1130-2000
Cup Bottom-Ledge Ablated Surface Area	1000	—	800-1200
Ring Top-Ledge Ablated Surface Area	935	—	740-1130
Ring Bottom-Ledge Ablated Surface Area	1420	—	1130-1710

[0376] In some examples, the forward sole-opening recessed ledge **170A** (e.g., the cup bottom-ledge ablated surface area of Table 5) defines a bond area of about 1,054 mm², the forward crown-opening recessed ledge **168A** (e.g., the cup top-ledge ablated surface area of Table 5) defines a bond area of about 1,910 mm², the toe ring-engagement surface **150A** and the heel ring-engagement surface **150B** (e.g., the ring-engagement ablated surface area of Table 5) or the toe cup-engagement surface **152A** and the heel cup-engagement surface **152B** (e.g., the cup-engagement ablated surface area of Table 5) are about 98 mm², the plate-opening recessed ledge **147** and the sidewall **146** (e.g., the front-ledge ablated surface area and the front-sidewall ablated surface area) define a bond area of about 2,240 mm², a total bond area defined by the cast cup **104** is 5,300 mm². According to the same or alternative examples, the rearward crown-opening recessed ledge **168B** (e.g., the ring top-ledge ablated surface area of Table 5) defines a bond area of about 928 mm², the rearward sole-opening recessed ledge **170B** (e.g., the ring bottom-ledge ablated surface area of Table 5) defines a bond area of about 1,222 mm², and a total bond area defined by the ring **106** is 2,250 mm².

[0377] In view of the foregoing, in some examples, the golf club head **100** includes a single component or piece (e.g., the ring **106**) that is bonded to three other components or pieces of the golf club head **100** where a total bonded area between these four components or pieces of the golf club head **100** is between 1,950 mm² and 2,500, mm², or more preferably between 2,100 mm² and 2,400 mm². According to some examples, the golf club head **100** includes a single component or piece (e.g., the cast cup **104**) that is bonded to

three other components or pieces of the golf club head **100** where a total bonded area between these four components or pieces of the golf club head **100** is between 2,250 mm² and 3,400, mm², or more preferably between 2,900 mm² and 3,200 mm². According to yet some examples, the golf club head **100** includes a single component or piece (e.g., the cast cup **104**) that is bonded to four other components or pieces of the golf club head **100** where a total bonded area between these five components or pieces of the golf club head **100** is between 4,750 mm² and 6,200, mm², or more preferably between 4,900 mm² and 5,500 mm². In certain examples, the golf club head includes a single component or piece (e.g., the upper cup piece **304A**) that is bonded to five other components or pieces of the golf club head **100** where a total bonded area between these six components or pieces of the golf club head **100** is between 5,500 mm² and 7,000, mm², or more preferably between 5,700 mm² and 6,300 mm².

[0378] The golf club heads of the present disclosure have a high bond area, between multiple pieces of the golf club heads, relative to a volume of the golf club heads. In other words, for a given size of a golf club head, the amount of bonded area is significantly higher than for conventional golf club heads. According to some examples, the volume of a golf club head, such as the golf club head **100**, disclosed herein is between 450 cc and 600 cc, and more preferably between 450 cc and 470 cc. Moreover, in certain examples, a bond-volume ratio, or a ratio of a combined bond area of the plurality of bonded joints of the golf club head to a volume of the golf club head is at least 3.75 mm²/cc and at most 15.5 mm²/cc (e.g., at least 9.1 mm²/cc and at most 14.0 mm²/cc). In some examples, the bond-volume ratio of at least some of the examples of golf club heads disclosed herein is at least 7.9 mm²/cc and at most 13.7 mm²/cc (e.g., at least 8.1 mm²/cc and at most 12.2 mm²/cc). In yet some examples, the bond-volume ratio of at least some of the examples of golf club heads disclosed herein is at least 3.75 mm²/cc and at most 7.5 mm²/cc (e.g., at least 4.8 mm²/cc and at most 7.1 mm²/cc).

[0379] According to some alternative examples, a bond-volume ratio, or a ratio of a combined bond area of the plurality of bonded joints of the golf club head to a volume of the golf club head is at least 10 mm²/cc and at most 18.8 mm²/cc (e.g., at least 10 mm²/cc and at most 15.5 mm²/cc or at least 11.6 mm²/cc and at most 17.7 mm²/cc). In some examples, the bond-volume ratio of at least some of the examples of golf club heads disclosed herein is at least 10.5 mm²/cc and at most 15.3 mm²/cc, at least 11.6 mm²/cc and at most 18.8 mm²/cc, or at least 12.1 mm²/cc and at most 17.5 mm²/cc.

[0380] The golf club head disclosed herein is made of multiple pieces adhesively bonded together. Accordingly, in some examples, the golf club head disclosed herein includes multiple pieces coupled together via the bonding tape **174** such that no portions or pieces of the golf club head are welded together.

[0381] The bond area of a bonded joint is defined by a width (W_{BA}) and a length (L_{BA}) of the bonded joint (see, e.g., FIG. 15). In other words, the surface area of a side of the bonding tape **174** is defined by the width (W_{BA}) and the length (L_{BA}) of the bonded joint. The width W_{BA} can be variable along the length L_{BA} of a bonded joint. Generally, the length L_{BA} of the bond area of a bonded joint is greater than the width W_{BA} of the bond area of the bonded joint. The bonded joint can be continuous such that a length L_{BA} of the

bond area of the bonded joint is continuous. However, in some examples, the bonded joint is non-continuous or intermittent such that the length L_{BA} of the bond area of the bonded joint is a summation of the lengths of the intervals of the bonded joint. Although the width W_{BA} and the length L_{BA} of the bonded area of only two bonded joints (e.g., the bonded area associated with the forward crown-opening recessed ledge 168A and the rearward crown-opening recessed ledge 168B) are shown in FIG. 15, it is recognized that, although not specifically labeled, the bonded area of each one of the bonded joints of the golf club head 100 has a corresponding width W_{BA} and length L_{BA} , similar to those shown in FIG. 15, that are not labeled for ease in showing and labeling other features of the golf club head 100. Additionally, regarding the length L_{BA} , as defined herein, the length L_{BA} of the bond area of a bonded joint is the maximum length of the bond area. Accordingly, where a bond area can be considered to have two different lengths, such as a maximum length (e.g., along an outer perimeter of the bond area, such as shown in FIG. 15) and a minimum length (e.g., along an inner perimeter of the bond area), the length L_{BA} of the bond area is defined herein to be the largest or maximum length of the bond area.

[0382] According to some examples, the bond area of, or the bonding tape 174 forming, at least one bonded joint of the golf club head 100 has a length L_{BA} , which can be a continuous or segmented length, of between 174 mm and 405 mm, such as at least 250 mm. For example, the combined bond area defined by the forward crown-opening recessed ledge 168A and the rearward crown-opening recessed ledge 168B has a length L_{BA} of at least 268 mm, of at least 300 mm, at least 316 mm, at least 353 mm, or at least 370 mm. As another example, the combined bond area defined by the forward sole-opening recessed ledge 170A and the rearward sole-opening recessed ledge 170B has a length L_{BA} of at least 281 mm, of at least 314 mm, at least 331 mm, at least 350 mm, or at least 367 mm. According to yet another example, the bond area defined by the plate-opening recessed ledge 147 has a length L_{BA} of at least 174 mm, of at least 194 mm, at least 205 mm, at least 250 mm, or at least 262 mm. According to some examples, a combined length of the plurality of bonded joints is at least 723 mm and at most 1,094 mm, such as between 852 mm and 953 mm.

[0383] Unless otherwise noted, the bonding tape 174 has a length and a width the same as, or substantially equal to, the bond length or the bond width of the bonded joint. For example, in some instances, the width of the bonding tape 174 is between, and inclusive or, 1 mm and 9 mm, between, and inclusive of, 2 mm and 7 mm, between, and inclusive of, 2 mm and 5 mm, or between, and inclusive of, 2.5 mm and 3.5 mm. Moreover, like the bond area of the bonded joints of the golf club head 100, the width of the bonding tape 174 can be variable along a length of the bonding tape 174. Additionally, for a given surface of a bonded joint (e.g., a surface of a ledge), the bonding tape 174 can adhere to a certain percentage of the total surface area of that given surface. In some examples, the percentage is less than 100% or less than 99%, is between, and inclusive of, 75% and 99% or between, and inclusive of 85% and 99%. The total surface area of a bonded surface can be equal to the total surface area covered by the part bonded to the bonded surface.

[0384] In some examples, a length-area ratio, equal to a ratio of the length L_{BA} to the bond area of a bonded joint of,

or the length to the surface area of the bonding tape 174 forming, the bond defined by the forward crown-opening recessed ledge 168A and the rearward crown-opening recessed ledge 168B is between 0.13 and 0.16, such as around 0.15. In yet some examples, the length-area ratio of the bond, defined by the bonding tape 174, between the forward sole-opening recessed ledge 170A and the rearward sole-opening recessed ledge 170B is between 0.13 and 0.16, such as around 0.15.

[0385] In yet some examples, the length-area ratio of the bond, defined by the bonding tape 174, between the forward sole-opening recessed ledge 170A and the rearward sole-opening recessed ledge 170B is between 0.13 and 0.16, such as around 0.15.

[0386] In yet some examples, the length-area ratio of the bond, defined by the bonding tape 174, between plate-opening recessed ledge 147 is between 0.10 and 0.13, such as around 0.11.

[0387] As previously disclosed, at least one bonded joint of the golf club heads disclosed herein is formed by the bonding tape 174. More specifically, the bonding tape 174 is situated between two parts and adhesively bonds together the two parts. The shape of the bonding tape 174 corresponds with the shape of the bonded surfaces (e.g., ablated surfaces) of the two parts that are bonded together. In some examples, the shape of the bonding tape 174 is substantially identical to the shape of at least one of the bonded surfaces of the two parts bonded together. Moreover, when the shape of the bonding tape 174 is substantially identical to the shape of the at least one of the bonded surfaces, the size of the bonding tape 174 can be identical to or smaller than the size of the at least one of the bonded surfaces. The bonding tape 174 is not flowable in a precured state (i.e., before the bonding tape 174 is cured). In other words, in a precured state, the bonding tape 174 has a fixed shape (e.g., without pressure, does not flow or conform to the outline of a container). In some examples, as shown in FIG. 47, the bonding tape 174 forms part of a bonding tape package 254 that is cut from a sheet 250. The shape of the bonding tape package 254, cut from the sheet 250, corresponds with the shape of the intended bonded surfaces. Where the bonded surfaces are continuous (e.g., form an annulus), the bonding tape package 254 can also form a continuous shape. Alternatively, as shown, to help with handling and manufacturing of the golf club head, the bonding tape package 254 can be cut into segments that collectively form an annulus shape or non-annulus shape as the case may be. Cuts 252, defining the shape of the bonding tape package 254, can be formed in the sheet 250 via any of various techniques, such as laser cutting, die cutting, grinding, water jet cutting, drilling, and the like.

[0388] Referring to FIG. 48, the bonding tape package 254, and thus the sheet 250, includes a laminated structure having the bonding tape 174 sandwiched between a first release layer 256A and a second release layer 256B. In a pre-cured state, the bonding tape 174 is made of a tacky material. The first release layer 256A and the second release layer 256B help to keep the bonding tape 174 from sticking to itself or other objects, such as during transportation, storage, and handling of the bonding tape 174. Accordingly, the first release layer 256A and the second release layer 256B are made from a low-stick material. In some examples, the first release layer 256A and the second release layer 256B are made from a polymeric material, such as polyeth-

ylene or polyethylene terephthalate. In one example, the first release layer **256A** is made of a material that is different than the second release layer **256B**. According to some instances, the first release layer **256A** is made of polyethylene and the second release layer **256B** is made of polyethylene terephthalate.

[0389] The bonding tape **174** of the bonding tape package **254** has a thickness t_1 . Additionally, the first release layer **256A** has a thickness t_2 and the second release layer **256B** has a thickness t_3 . In some examples, the thickness t_1 of the bonding tape **174** is greater than the thickness t_2 of the first release layer **256A** and the thickness t_3 of the second release layer **256B**. In one example, the thickness t_2 of the first release layer **256A** is different than the thickness t_3 of the second release layer **256B**. According to one example, the thickness t_1 of the bonding tape **174** is between, and inclusive of, 90 μm and 550 μm (e.g., 100 μm or 150 μm), between, and inclusive of, 250 μm and 330 μm , or between, and inclusive of, 300 μm and 390 μm , the thickness t_2 of the first release layer **256A** is about 100 μm , and the thickness t_3 of the second release layer **256B** is about 75 μm .

[0390] The bonding tape **174** is made of an adhesive material. According to some examples, the adhesive material of the bonding tape **174** is a thermo-activated adhesive. In other words, the adhesion strength of the bonding tape **174** is maximized after the bonding tape **174** is cured (i.e., heated to a predetermined temperature for a predetermined period of time). The predetermined temperature is associated with a curing temperature and curing period of the adhesive material. In some examples, the bonding tape **174** is made of a thermosetting material, such as a thermosetting acrylic material. According to certain examples, the curing temperature (and associated curing period) of the bonding tape **174** is between, and inclusive of, 90° C. (120 minutes) and 120° C. (20 minutes), or between, and inclusive of, 100° C. (60 minutes) and 115° C. (35 minutes), such as 110° C. (40 minutes). In some other examples, the curing temperature (associated curing period) of the bonding tape **174** is at least 100° C. or at least 120° C. (between, and inclusive of, 60 minutes and 180 minutes), such as between, and inclusive of, 120° C. and 230° C. or between, and inclusive of, 140° C. and 190° C. During curing, the thermosetting material undergoes an irreversible chemical change by producing cross-linked polymer chains. Moreover, after curing, a temperature necessary to reflow the bonding tape **174** is at least 160° C., at least 180° C., at least 200° C., or at least 220° C.

[0391] In some examples, the adhesive material of the bonding tape **174** can be left in a pre-cured state, at room temperature, for up to 24 hours without compromising the adhesion properties of the bonding tape **174**. Accordingly, the use of the bonding tape **174** enables flexibility in the handling and storage of the bonding tape **174**, including parts bonded by the bonding tape **174**, and flexibility in the timing of the manufacturing steps of the golf club head. For example, because the bonding tape **174** can be exposed in a pre-cured state at room temperature for periods of time longer than some conventional adhesives, some steps, such as the temporary adhesion of the bonding tape **174** to a part, can be performed well before the bonding tape **174** is actually cured. Additionally, in some examples, the unique properties of the bonding tape **174** allow the bonding tape **174** to be applied to parts at one facility and cured at another facility. Being able to prep parts with bonding tape **174** well in advance of curing the bonding tape **174** can promote

speed and efficiency in assembling a golf club head, which can broaden the locations in which the golf club head manufacturing can be finalized (e.g., on-site at a retailer).

[0392] After the bonding tape **174** is cured, the shear strength of the bonding tape **174**, which is a measure of the ability of the bonding tape **174** to resist separation of parts bonded by the bonding tape **174**, is at least 10 MPa (e.g., between, and inclusive of, 11 MPa and 21 MPa), at least 11 MPa, at least 12 MPa, at least 13 MPa, at least 26 MPa, at least 30 MPa, or at least 35 MPa. To promote adhesion between the bonding tape **174** and parts forming the bond, pressure should be applied to the parts such that, when the bonding tape **174** is being cured, opposing compression forces from the parts are acting on the bonding tape **174**. In other words, while the bonding tape **174** is being cured, the parts forming the bond should be compressed against the bonding tape **174**. Ideally, the pressure applied to the parts should be uniform to promote a uniform adhesion of the bonding tape **174** along the parts, and thus a uniform adhesion strength along the bond. However, uniformly compressing one part toward another part, particularly when the parts are contoured or have complex shapes, can be difficult. Described herein are examples of systems, apparatuses, and methods that promote uniform compression of bonded parts, while the bonding tape **174** between the bonded parts is being cured, in an accurate, a reliable, a clean, and an efficient manner. Moreover, as described in more detail, the use of the bonding tape **174**, as opposed to a flowable adhesive, enables the uniform compression of bonded parts using the systems, apparatuses, and methods described herein.

[0393] Referring to FIGS. 49-52, according to one example, a system for manufacturing a golf club head, such as the golf club head **100**, includes a tape-retention fixture **260**. The system also includes a vacuum device **268** and at least one tube **266** fluidically connected to the vacuum device **268**. The vacuum device **268** can be any of various vacuum devices or suction devices that are selectively operable to generate a negative pressure differential or pressure drop. The tape-retention fixture **260** also includes conduits **264** open to a recess **262** formed in the tape-retention fixture **260**. The pattern (e.g., the size, spacing, and areal density) of conduits **264** can vary along the recess **262** based on characteristics (e.g., the width) of the bonding tape package **254**. From the recess **262**, the conduits **264** pass through the tape-retention fixture **260** where they are fluidically coupled to the at least one tube **266**. In the illustrated example, the system includes three tubes **266**, the conduits **264** are arranged into three sets of conduits **264**, and each one of the three sets of conduits are fluidically coupled with a corresponding one of the three tubes **266** (such as via one of three manifolds formed in the tape-retention fixture **260**). Fluidic coupling between the conduits **264**, the tubes **266** and the vacuum device **268** enables the vacuum device **268** to selectively control the pressure in the conduits **264** and the tubes **266**.

[0394] The recess **262** has a shape corresponding with the shape of the bonding tape package **254**, cut from the sheet **250**. In this manner, the bonding tape package **254** can be seated in the recess **262**, as shown in FIG. 50. In certain examples, an automated robot can be used to secure and insert the tape package **254** into the recess **262**. A depth of the recess **262** is such that a portion of the bonding tape package **254** protrudes from the recess **262** when the bond-

ing tape package 254 is seated in the recess 262. When the bonding tape package 254 is seated in the recess 262, the first release layer 256A and the second release layer 256B are attached to the bonding tape 174. In the illustrated example, the bonding tape package 254 is seated in the recess 262 such that the second release layer 256B is positioned within the recess 262 and the first release layer 256A just outside the recess 262. In this manner, the second release layer 256B faces inwardly toward the recess 262 and contacts a bottom of the recess 262, to directly cover the conduits 264, and the first release layer 256A faces outwardly away from the recess 262.

[0395] With the bonding tape package 254 seated in the recess 262, activation of the vacuum device 268 reduces the pressure in the conduits 264. Because the bonding tape package 254 covers the openings of the conduits 264 in the recess 262, the drop in pressure in the conduits 264 urges the bonding tape package 254 against the bottom of the recess 262, via a suction force, which helps to retain the bonding tape package 254 in the recess 262. When the bonding tape package 254 is urged against the bottom of the recess 262, which is shown in FIG. 50, the first release layer 256A is removed from the bonding tape 174, as shown in FIG. 51. Because the bonding tape package 254 is retained in the recess 262, via the suction force, and the peel off force of the first release layer 256A is less than the suction force, the first release layer 256A can be peeled off the bonding tape 174 without removing the bonding tape package 254 from the recess 262.

[0396] After the first release layer 256A is removed, a surface of the bonding tape 174, facing away from the recess, is exposed. While retaining the bonding tape package 254 in the recess 262, via the suction force, a part can be pressed against the exposed surface of the bonding tape 174, as shown in FIG. 52, which temporarily adheres the bonding tape 174 to the part via the tackiness of the bonding tape 174. The recess 262 can be configured to have an outer peripheral shape that matches the outer peripheral shape of the part, such that the recess acts as a guide to align the part relative to the bonding tape 174. When the part is temporarily adhered to the exposed surface of the bonding tape 174, the vacuum device 268 is selectively controlled to release the suction force, which allows the bonding tape package 254 to be removed from the recess 262 by lifting the part away from the recess 262. As shown in FIG. 53, the bonding tape package 254 is temporarily adhered to an interior surface of the part such that the second release layer 256B is accessible. When ready, the second release layer 256B can be removed to expose another surface of the bonding tape 174 in preparation for pressing newly exposed surface of the bonding tape 174 against a second part, which temporarily adheres the bonding tape 174 to the second part via the tackiness of the bonding tape 174, as shown in FIG. 56. In this manner, the bonding tape 174 forms a temporary bond between two parts, which enables the parts to be handled and prepared for permanent bonding without shifting of the parts relative to each other. It is noted that the parts, which are temporarily bonded together, are pre-formed parts (i.e., parts that have been formed into a permanent form or shape in preparation for final assembly).

[0397] The tape-retention fixture 260, including the conduits 264 and the recess 262, can be configured to accommodate one of many parts of a golf club head. For a golf club head that has multiple bonded joints joining together mul-

iple sets of parts, additional tape-retention fixtures 260 can be employed and configured to accommodate other parts of the golf club head. In the illustrated example of FIGS. 49-52, the tape-retention fixture 260 is specifically configured to temporarily adhere the bonding tape 174 to the crown insert 108 of the golf club head 100. More specifically, as shown in FIG. 53, the bonding tape package 254 is temporarily adhered to an interior surface 108A of the crown insert 108, which, as shown in FIGS. 55 and 57A, is then temporarily adhered to the crown-opening recessed ledge 168 in preparation for permanently bonding the crown insert 108 to the crown-opening recessed ledge 168. The interior surface 108A is opposite an exterior surface 108E of the crown insert 108.

[0398] However, in other examples, with reference to FIGS. 54 and 56, the tape-retention fixture 260 can be specifically configured to temporarily adhere the bonding tape 174 to the sole insert 110 of the golf club head 100. More specifically, as shown in FIG. 54, the bonding tape package 254 is temporarily adhered to an interior surface 110A of the sole insert 110, which, as shown in FIG. 56, is then temporarily adhered to the sole-opening recessed ledge 170 in preparation for permanently bonding the sole insert 110 to the sole-opening recessed ledge 170. The interior surface 110A is opposite an exterior surface 110E of the sole insert 110.

[0399] In yet other examples, with reference to FIGS. 40 and 41, the tape-retention fixture 260 can be specifically configured to temporarily adhere the bonding tape 174 to the strike plate 143 of the golf club head 100. More specifically, the bonding tape package 254 is temporarily adhered to the interior surface 166 of the strike plate 143, which is then temporarily adhered to the plate-opening recessed ledge 147 in preparation for permanently bonding the strike plate 143 to the plate-opening recessed ledge 147.

[0400] According to some examples, with reference to FIGS. 14 and 15, the tape-retention fixture 260 can be specifically configured to temporarily adhere the bonding tape 174 to the ring 106 of the golf club head 100. More specifically, the bonding tape 174 of respective ones of bonding tape packages 254 are temporarily adhered to the toe cup-engagement surface 152A and the heel cup-engagement surface 152B of the ring 106, which is then temporarily adhered to the toe ring-engagement surface 150A and the heel ring-engagement surface 150B, respectively, of the cast cup 104 in preparation for permanently bonding the ring 106 to the cast cup 104. When permanently bonded, for example, a heel-side ring strip 182A of the bonding tape 174 is between the heel cup-engagement surface 152B and the heel ring-engagement surface 150B, and a toe-side ring strip 182B of the bonding tape 174 is between the toe cup-engagement surface 152A and the toe ring-engagement surface 150A.

[0401] Although in the illustrated examples above, the bonding tape 174 is used to bond together multiple parts of a driver-type golf club head, in other examples, bonding tape can be used to bond together multiple parts of other types of golf club heads in the same or a similar manner as described above. According to one example, as shown in FIG. 63, bonding tape is used to bond together multiple parts of a fairway-metal type golf club head 1100. The golf club head 1100 has a forward portion 1112 and a sole portion 1117. Additionally, the golf club head 1110 includes a body 1102 that defines a crown opening 1162 at a crown portion of the

golf club head 1110 and a plate opening 1149 at the forward portion 1112 of the golf club head 1110.

[0402] The golf club head 1110 further includes a crown insert 1108 that is attached to the body 1102 over the crown opening 1162 so as to cover the crown opening 1162. The crown insert 1108 is adhered to the body 1102 over the crown opening 1162 by a crown-opening strip 1174 of bonding tape 1174. The crown-opening strip 1174 can be a single continuous strip of bonding tape 1174 or multiple strips of bonding tape 1174. In the illustrated example, the crown-opening strip 1174 is a single continuous strip in the shape of an outer periphery of the crown insert 1108. When attached, the crown-opening strip 1174 is interposed between the crown insert 1108 and the body 1102 to adhere the crown insert 1108 to the body 1102. In some examples, the crown insert 1108 is made of a non-metal material, such as a fiber-reinforced polymeric material as described above.

[0403] The golf club head 1110 also includes a strike plate 1143 that is attached to the body 1102 over the plate opening 1149 so as to cover the plate opening 1149. In some examples, the strike plate 1143 includes a wrap-around portion that effectively wraps around a strike face 1145, thus forming part of the crown portion, a toe portion, a heel portion, and the sole portion 1117 of the golf club head 1100. The strike plate 1143 is adhered to the body 1102 over the plate opening 1149 by a plate-opening strip 1176 of bonding tape 1174. The plate-opening strip 1176 can be a single continuous or non-continuous strip of bonding tape 1174 or multiple strips of bonding tape 1174. In the illustrated example, the plate-opening strip 1176 is a single, non-continuous strip in the shape of an outer periphery of the strike plate 1143. When attached, the plate-opening strip 1176 is interposed between the strike plate 1143 and the body 1102 to adhere the strike plate 1143 to the body 1102.

[0404] According to certain examples, the strike plate 1145 is made of a non-metal material, such as a fiber-reinforced polymeric material as described above, and the body 1102 is made of a metallic material. In some examples, the strike plate 1145 is made of a first metallic material and the body 1102 is made of a second metallic material. In one example, the strike plate 1145 is made of a titanium alloy and the body 1102 is made of a steel alloy. According to another example, the strike plate 1145 is made of a steel alloy and the body 1102 is made of a titanium alloy. Typically, when a strike plate and a body are made of a metallic material, the metallic materials are welded together and when one of the metallic materials is heat treated, the other of the metallic materials experiences a less than ideal heat treatment (such as a second heat treatment, an over-treatment, or an undertreatment). However, the bonding tape 1174 eliminates the need for a weldment, and thus the body 1102 and the strike plate 1145 can be heat treated separately, under different individualized heat treatment conditions conducive to the particular types of metallic materials of the body 1102 and the strike plate 1145. Although the metal-to-metal adhesive bond facilitated by the bonding tape 1174 is shown associated with a fairway-metal type golf club head, in other examples, the bonding tape 1174 can facilitate a metal-to-metal adhesive bond between a strike plate and a body of other types of golf club heads, such as driver-type golf club heads, iron-type golf club heads (e.g., having an interior volume of at least 5 cubic centimeters (such as between, and inclusive of, 5 cc and 20 cc), hybrid-type golf

club heads, and the like. Accordingly, the golf club heads of the present disclosure have an interior volume of at least 5 cc, and up to 600 cc.

[0405] In certain examples, the golf club head 1100 also includes a sole slot 1191 and a slot cover 1190 attached to the sole portion 1117 over the sole slot 1191, thus covering the sole slot 1191. The slot cover 1190 is adhered to the body 1102 over the sole slot 1191 by a slot strip 1179 of bonding tape 1174. The slot strip 1179 can be a single continuous or non-continuous strip of bonding tape 1174 or multiple strips of bonding tape 1174. In the illustrated example, the slot strip 1179 is a single, continuous strip in the shape of an outer periphery of the sole slot 1191. When attached, the slot strip 1179 is interposed between the slot cover 1190 and the body 1102 to adhere the slot strip 1179 to the body 1102. In some examples, a portion of the strike plate 1143 defines a portion of the sole slot 1191, and the slot cover 1190 is also adhered to the portion of the strike plate 1143 that defines the sole slot 1191 via the slot strip 1179. The slot cover 1190 is made of a polymeric material (e.g., thermoplastic polyurethane) in some examples. In certain examples, the slot cover 1190 is flat.

[0406] According to another example, as shown in FIG. 64, bonding tape is used to bond together multiple parts of an iron-metal type golf club head 1200. The golf club head 1200 has a forward portion 1212 and a rear portion 1218. Additionally, the golf club head 1210 includes a body 1202 that defines a rear opening 1249 of the rear portion 1218 of the golf club head 1210. The golf club head 1210 also includes a rear badge 1292 (e.g., rear insert, rear cover, rear plate, etc.) that is attached to the body 1202 over the rear opening 1249 so as to cover the rear opening 1249. In certain examples, a rear ledge 1295, formed in the rear portion 1218, defines the rear opening 1249. The rear badge 1292 is adhered to the body 1202 over the rear opening 1249 by a rear-opening strip 1276 of bonding tape 1274. The rear-opening strip 1276 can be a single continuous or non-continuous strip of bonding tape 1274 or multiple strips of bonding tape 1274. In the illustrated example, the rear-opening strip 1276 is a single, non-continuous strip in the shape of an outer periphery of the rear badge 1292. When attached, the rear-opening strip 1276 is interposed between the rear badge 1292 and the body 1202 to adhere the rear badge 1292 to the body 1202.

[0407] In some examples, the body 1202 is made of a metallic material (e.g., steel) and the rear badge 1292 is made of a non-metallic material (e.g., a polymer). In alternative examples, both the body 1202 and the rear badge 1292 are made of a metallic material.

[0408] Referring to FIGS. 65-69, in some examples, a golf club head includes a crown made of a fiber-reinforced polymeric material that wraps around a transition between the crown and the strike face, such that the fiber-reinforced polymeric material is directly adjacent or abuts the strike face. FIGS. 65-69 illustrate an exemplary golf club head 4600 that includes a face plate 4610 and an oversized crown 4620, also referred to as a crown panel, that extends to the front of the club head adjacent to the upper side of the face plate 4610, and in some embodiments forms a topline and/or rear perimeter portion of the club head. The oversized crown 4620 is adhered to the body portion 4602 with bonding tape 174, such as described above, and the face plate 4610 can be adhered to the body portion 4602 with bonding tape 174. The crown 4620 and face plate 4610 can comprise nonme-

talic composite materials, in some embodiments, such that the topline is formed where a portion of the composite material of the crown extends to be adjacent to a portion of the face plate. While much of this disclosure is related to relationships of the crown **4620**, the face plate **4610**, and the associated support structure, it is important to appreciate at the outset that the disclosure and relationships also apply to a sole plate **4640** having a portion wrapping around the front of the club head to be adjacent the face plate **4610** (see, e.g., FIGS. 67-69), which may occur at the toe of the face plate **4610**, as seen in FIGS. 68 and 69, at the heel of the face plate **4610**, as seen in FIG. 68, at the lower portion of the face plate **4610**, as seen in FIGS. 67 and 69, and any combinations thereof. Similarly, the disclosure and relationships also apply to individual plates that may form only a portion of the skirt, and may be located at the toe or heel, and may not constitute a portion of the sole. The sole plate **4640** can be adhered to the body portion **4602** with bonding tape **174**, such as described above.

[0409] The club head include a body **4602** that includes a hosel portion and provides a primary structural support for the club head, and various other components are coupled to the body, which may include the face plate **4610** and the crown **4620**, and in some embodiments a sole plate **4640**, one or more weights, and/or other features. In some embodiments, the body includes a front body portion (labeled as **4602**) and a rear ring portion attached together (e.g., welded, bonded, or mechanically attached) at the heel and toe ends, or integrally formed. Whether attached together or integrally formed, the front body portion **4602** and the rear ring portion compose a frame that serves as the supporting structure for the attachment of other components, which may include the crown **4620**, the face plate **4610**, and/or the sole plate **4640**. Further, as disclosed later in detail, the face plate **4610** may be attached to, or integrally formed with the frame and/or front body portion **4602** and therefore the use of the term plate is not to imply a separate component, although it may be a separate component as disclosed in more detail later. Similarly, the sole plate **4640** may be attached to, or integrally formed with the frame, front body portion **4602**, and/or rear ring portion, and therefore the use of the term plate is not to imply a separate component, although it may be as disclosed in more detail later.

[0410] While many of the disclosed embodiments relate to interfaces associated with a crown **4620** bonded to the frame and wrapping toward the face plate **4610**, all of the disclosed relationships apply equally to one, or more, sole panels **4640** wrapping toward the face plate **4610**, skirt panels wrapping toward the face plate **4610** at the heel and/or toe, and/or the rear ring portion **4630** wrapping toward the face plate **4610**. For instance, FIG. 65 illustrates a sole insert **4640** that wraps around the front body portion **4602** to terminate adjacent the face plate **4610** at the toe side of the club head. In this embodiment a toe-side crown-to-face junction point **4800** is illustrated, but now there is also a first sole-to-face junction point **4910** and a second sole-to-face junction point **4920**. In this embodiment the first sole-to-face junction point **4910** occurs where the sole insert **4640** is adjacent to the face plate **4610** and the front body portion **4602**. Similarly, in this embodiment the second sole-to-face junction point **4920** occurs where the sole insert **4640** is adjacent to the face plate **4610** and the front body portion **4602**. Additionally, the sole insert **4640** may wrap around to be adjacent the face plate **4610** in multiple distinct regions, as seen in the shaded

regions of FIG. 68. Thus, as seen in FIG. 68, the sole insert **4640** may additionally have a third sole-to-face junction point **4930** and a fourth sole-to-face junction point **4940**.

[0411] After at least two parts of the golf club head **100** are temporarily bonded together by the bonding tape **174**, when in an uncured state, the at least two parts of the golf club head **100** are permanently bonded together, by converting the bonding tape **174** into a cured state, via the application of heat and pressure. Referring to FIGS. 58-62, according to some examples, pressure is applied to the golf club head **100** in a uniform manner with a vacuum bag **274** when the golf club head **100** is sealed within the vacuum bag **274**. In some examples, such as shown in FIGS. 58 and 59, the vacuum bag **274** is a reusable vacuum bag **294**. However, in alternative examples, as shown in FIGS. 60 and 61, the vacuum bag **274** is a disposable vacuum bag **292**. In either case, with the golf club head **100** inside the vacuum bag **274**, the vacuum bag **274** is sealable and fluidically coupled to a vacuum device **269**, which is configured to reduce the pressure within the vacuum bag **274**, to a pressure below ambient or environmental conditions, when the vacuum bag **274** is sealed with the golf club head **100** inside. Reducing the pressure within the vacuum bag **274** creates a pressure differential between air outside the vacuum bag **274** and inside the vacuum bag **274**. The pressure differential causes the vacuum bag **274** to collapse onto the golf club head **100** and to apply a pressure onto the golf club head **100** proportional to the pressure differential. Because the pressure differential is uniform about the vacuum bag **274**, the pressure applied onto the golf club head **100** is correspondingly uniform. Accordingly, the pressure applied to the bonding tape **174** also is uniform.

[0412] It is noted that when the vacuum bag **274** is used to apply a uniform pressure to the golf club head **100**, the parts of the golf club head **100** being bonded together are in a fully-formed state (i.e., parts that have been formed into a permanent form or shape in preparation for final assembly). For example, for parts that are made of a fiber-reinforced polymeric material, the fiber-reinforced material has been previously shaped and cured into a final shape. Accordingly, the collapsed vacuum bag **274** is used solely to apply pressure to the bonding tape **174** and, with the parts of the golf club head **100** in a fully-formed state, does not shape or contribute to the formation of the individual parts.

[0413] As shown in FIGS. 58 and 59, in some examples, the pressure differential, which can be measured by a pressure gauge **272**, is between, and inclusive of, 30 cmHg and 70 cmHg, between, and inclusive of, 40 cmHg and 60 cmHg, or substantially 50 cmHg.

[0414] Referring back to FIGS. 58 and 59, the reusable vacuum bag **270** is configured for repeated use. Accordingly, the reusable vacuum bag **270** is made from a material and has a thickness that is suitable for repeated use. In one example, the reusable vacuum bag **270** is made of polyethylene or other similar plastic material. Alternatively, the reusable vacuum bag **270** can be made of a rubber or rubber-like material, such as silicone. Moreover, in certain examples, the reusable vacuum bag **270** has a thickness of between, and inclusive of, 60 microns and 100 microns, between, and inclusive of, 70 microns and 90 microns, or substantially 80 microns. The reusable vacuum bag **270** can have a vacuum port **290** that is built into the vacuum bag **270**. The vacuum port **290** is configured to receive a

coupling from the vacuum device 269 in a selectively releasable and repeated manner.

[0415] As shown in FIGS. 60 and 61, the disposable vacuum bag 274 is configured for single use. Accordingly, the disposable vacuum bag 274 can be made from a material that is less durable than the reusable vacuum bag 270. For example, the disposable vacuum bag 274 can be made of a plastic material that is thinner than the reusable vacuum bag 270. Moreover, in some examples, the vacuum device 269 can be specifically configured for use with the disposable vacuum bag 274. In one example, the vacuum device 269 can be similar to a shrink-wrap machine that creates the pressure differential and seals an opening of the disposable vacuum bag 274 after the pressure differential is met. Accordingly, in some examples, the disposable vacuum bag 274 is a shrink-wrap or a heat-shrink material.

[0416] When the vacuum bag 274 is collapsed against and applies pressure onto the golf club head 100, according to the pressure differential created by the vacuum device 269, the golf club head 100 is heated to at least the curing temperature of the bonding tape 174. As stated above, the concurrent application of the pressure and heat cures the bonding tape 174 between parts to permanently bond the parts together. Referring to FIG. 62, in some examples, with the vacuum bag 274 collapsed against and applying pressure to the golf club head 100, the vacuum bag 274 and golf club head 100 is located in an enclosed cavity 227 of an oven 276. The oven 276 includes a heating element 278 that is configured to heat the enclosed cavity 277 and thus apply heat 280 to the golf club head 100 in the vacuum bag 274 when positioned in the enclosed cavity 227. Although a disposable vacuum bag 274, collapsed against the golf club head 100, is shown in the oven 276, in other examples, a reusable vacuum bag 270, collapsed against the golf club head 100, can be used instead. Moreover, although the oven 276 can be used to apply the heat 280 to the golf club head 100, when pressurized by the vacuum bag 274, in other examples, heat can be applied in ways other than an oven.

[0417] In alternative examples, rather than collapse the vacuum bag 274 by reducing the pressure within the vacuum bag 274, the pressure outside the vacuum bag 274 can be increased to create the necessary pressure differential to collapse the vacuum bag 274 onto the golf club head 100. For example, in some examples, the oven 276 is fluidically coupled to a vacuum device, which is selectively operable to increase the pressure within the enclosed cavity 227 when a vacuum bag 274, sealed to enclose the golf club head 100 within the vacuum bag 274, is positioned within the enclosed cavity 227. In this manner, the oven 276, acting as an autoclave, can concurrently apply heat and create the pressure differential necessary to cure the bonding tape 174.

[0418] Because of the unique characteristics of the bonding tape 174, compared to flowable adhesives, the bonding tape 174 can be cured, via pressure and heat, with little to no bleeding or flowing of the bonding tape 174 out of the bonded joint during pressurization and heating of the bonding tape 174. Accordingly, the pressure necessary to cure the bonding tape 174 can be applied via the vacuum bag 274. In contrast, with conventional flowable adhesives, the application of pressure by a vacuum bag would cause the adhesives to flow out of the bonded joint and smear against the interior of the vacuum bag and the part. Such a result would create unnecessary delays, expense, and labor associated with removing excess adhesives from the part. Moreover, bleed-

ing of the adhesives onto the vacuum bag would prevent the vacuum bag from being reusable for pressurizing other parts. Additional advantages associated with the use of the bonding tape 174 include a reduction in the complexity of the bonding process and the necessary training required to implement the bonding process, which translates into lower training costs.

[0419] In some examples, for golf club heads with multiple parts bonded together via multiple bonded joints, such as the golf club head 100, all the bonded joints are formed concurrently by concurrently pressurizing and heating the bonding tape 174 forming the bonded joints. In other words, the bonding tape 174 of all the bonded joints of the golf club head 100 can be cured (e.g., pressurized and heated) in a single pressurization and heating step using one vacuum bag. For example, the strike plate 143, the crown insert 108, and the sole insert 110 can be bonded to the body 102 by curing the bonding tape 174 between them at the same time. However, in other examples, at least one bonded joint of the golf club head 100 can be formed in a first pressurizing and heating step, using a first vacuum bag, and at least another bonded joint of the golf club head 100 can be formed subsequently in a second pressurizing and heating step, using the first vacuum bag or a second vacuum bag. For example, the crown insert 108 and the sole insert 110 can be bonded to the body, by curing the bonding tape 174 between them at a first time, and the strike plate 143 can be bonded to the body 102, by curing the bonding tape 174 between them at a second time, different (e.g., later or earlier) than the first time. By staggering the curing of the bonding tape 174 in this manner, inspection of one or more bonded joints, from an inside of the golf club head 100, can be performed before the inside of the golf club head 100 is enclosed.

[0420] Although the bonding tape 174 does not flow during pressurization and heating of the bonding tape 174, it may expand. Unlike conventional, flowable adhesives, the expansion of bonding tape 174 is predictable and controllable. Accordingly, the size and positioning of the bonding tape 174, between the parts to be bonded, can be selected to accommodate the expansion of the bonding tape 174 and ensure the bonding tape 174 is properly distributed in the bonded joint without bleeding (e.g., squeeze out) from the bonded joint during pressurization and heating. Referring to FIG. 57A, in some examples, the bonding tape 174 is temporarily applied to a first part such that when the first part is temporarily bonded to a second part via the bonding tape 174, an offset OS is defined between an outer peripheral edge of the first part and an outer peripheral edge of the bonding tape 174. In some examples, the offset OS, defined between an outer peripheral edge of the first part and an outer peripheral edge of the bonding tape 174, is at least 0.25 mm, at least 0.5 mm, or at least 1.0 mm. According to these or other examples, the offset OS is no more than 2.5 mm, 3.0 mm, or 5.0 mm. The outer peripheral edge of the first part defines an outermost bondline between the first part and the second part. The amount of offset OS is dependent on at least the amount (e.g., surface area) of the bonding tape 174 forming the bonded joint.

[0421] In the example of FIG. 57A, the first part is the crown insert 108 and the second part is the body 102 such that the offset OS is associated with the crown insert 108 and an outer periphery 108D of the crown insert 108 (see also FIG. 53). According to another example, as shown in FIG. 54, the first part is the sole insert 110 and the second part is

the body 102 such that the offset OS is associated with the sole insert 110 and an outer periphery 110D of the sole insert 110. The offset OS associated with the crown insert 108 can be different than the offset OS associated with the sole insert 110. In some examples, the offset OS associated with the crown insert 108 is at least double that associated with the sole insert 110. In one example, the offset OS associated with the crown insert 108 is substantially 2 mm and the offset OS associated with the sole insert 110 is substantially 1 mm. Although not shown, the bonding tape 174 used to bond together the ring 106 and the cast cup 104 can be offset relative to one or both of the engagement surfaces of the ring 106 and the cast cup 104.

[0422] Referring to FIG. 57B, in some alternative examples, the bonding tape 174 is applied onto a part, in preparation for attachment to a second part, without an offset between the outer peripheral edge of the first part and the bonding tape 174. In such examples, a gap filler 197 can function as a physical barrier to prevent bleeding or squeeze out of the bonding tape 174 from the bonded joint during pressurization and heating. The gap filler 197 is positioned in a gap defined between the second part and the outer peripheries of the bonding tape 174 and the first part. In the example of FIG. 57B, the first part is the crown insert 108 and the second part is the body 102. Accordingly, the gap filler 197 is positioned between the outer periphery 108D of the crown insert 108 and a sidewall 168C of the crown-opening recessed ledge 168. With the gap filler 197 in this position, the bonding tape 174 is prevented from expanding or bleeding out of the bonded joint during pressurization and heating of the bonding tape 174.

[0423] The gap filler 197 is made from any of various materials capable of keeping its shape (e.g., not flowing or bleeding) when the bonding tape 174 is heating and pressurized during curing of the bonding tape 174. Accordingly, the material of the gap filler 196 is different than that of the bonding tape 174. In some example, the material of the gap filler 196 is also different than that of the first part and the second part. In one example, the gap filler 196 is made of a flowable material that is curable to become non-flowable, and remain relatively non-flowable when the bonding tape 174 is cured. According to some examples, the gap filler 196 is made of an adhesive material, such as an epoxy-based structural adhesive.

[0424] According to some examples, the gap filler 196 is injected into the gap between the second part and the outer peripheries of the bonding tape 174 and the first part, after the first part is temporarily adhered to the second part via the bonding tape 174 and before the bonding tape 174 is cured. The gap filler 196 is then cured. The curing conditions of the gap filler 196 are different than those of the bonding tape 174, such that curing of the gap filler 196 does not cure the bonding tape 174. In some examples, the gap filler 196 is cured at approximately room temperature for a predetermined period, such as at least 2 hours. After the gap filler 196 is cured, the bonding tape 174 is then pressurized and heated, as presented above, to cure the bonding tape 174 and form the bonded joint between the first part and the second part.

[0425] According to some examples, the golf club heads of the present disclosure are configured to be swung at a swing speed such that each collision with a golf ball imparts a force onto the strike face of the golf club heads in the range of 10,000 g to 20,000 g, where g is equal to the force per unit

mass due to gravity. The bonding tape of the golf club heads, as described herein, is configured to withstand (e.g., maintain an adequate adhesive bond between bonded parts of the golf club head to maintain proper performance characteristics of the golf club head after) repeated impacts with a golf ball at swing speeds of at least 70 miles per hour (mph) (e.g., between, and inclusive of, 70 mph and 100 mph).

[0426] Although not specifically shown, the golf club head 100 of the present disclosure may include other features to promote the performance characteristics of the golf club head 100. For example, the golf club head 100, in some implementations, includes movable weight features similar to those described in more detail in U.S. Pat. Nos. 6,773,360; 7,166,040; 7,452,285; 7,628,707; 7,186,190; 7,591,738; 7,963,861; 7,621,823; 7,448,963; 7,568,985; 7,578,753; 7,717,804; 7,717,805; 7,530,904; 7,540,811; 7,407,447; 7,632,194; 7,846,041; 7,419,441; 7,713,142; 7,744,484; 7,223,180; 7,410,425; and 7,410,426, the entire contents of each of which are incorporated herein by reference in their entirety.

[0427] In certain implementations, for example, the golf club head 100 includes slidable weight features similar to those described in more detail in U.S. Pat. Nos. 7,775,905 and 8,444,505; U.S. patent application Ser. No. 13/898,313, filed on May 20, 2013; U.S. patent application Ser. No. 14/047,880, filed on Oct. 7, 2013; U.S. Patent Application No. 61/702,667, filed on Sep. 18, 2012; U.S. patent application Ser. No. 13/841,325, filed on Mar. 15, 2013; U.S. patent application Ser. No. 13/946,918, filed on Jul. 19, 2013; U.S. patent application Ser. No. 14/789,838, filed on Jul. 1, 2015; U.S. Patent Application No. 62/020,972, filed on Jul. 3, 2014; Patent Application No. 62/065,552, filed on Oct. 17, 2014; and Patent Application No. 62/141,160, filed on Mar. 31, 2015, the entire contents of each of which are hereby incorporated herein by reference in their entirety.

[0428] According to some implementations, the golf club head 100 includes aerodynamic shape features similar to those described in more detail in U.S. Patent Application Publication No. 2013/0123040A1, the entire contents of which are incorporated herein by reference in their entirety.

[0429] In certain implementations, the golf club head 100 includes removable shaft features similar to those described in more detail in U.S. Pat. No. 8,303,431, the contents of which are incorporated by reference herein in in their entirety.

[0430] According to yet some implementations, the golf club head 100 includes adjustable loft/lie features similar to those described in more detail in U.S. Pat. Nos. 8,025,587; 8,235,831; 8,337,319; U.S. Patent Application Publication No. 2011/0312437A1; U.S. Patent Application Publication No. 2012/0258818A1; U.S. Patent Application Publication No. 2012/0122601A1; U.S. Patent Application Publication No. 2012/0071264A1; and U.S. patent application Ser. No. 13/686,677, the entire contents of which are incorporated by reference herein in their entirety.

[0431] Additionally, in some implementations, the golf club head 100 includes adjustable sole features similar to those described in more detail in U.S. Pat. No. 8,337,319; U.S. Patent Application Publication Nos. 2011/0152000A1, 2011/0312437, 2012/0122601A1; and U.S. patent application Ser. No. 13/686,677, the entire contents of each of which are incorporated by reference herein in their entirety.

[0432] In some implementations, the golf club head 100 includes composite face portion features similar to those

described in more detail in U.S. patent application Ser. Nos. 11/998,435; 11/642,310; 11/825,138; 11/823,638; 12/004,386; 12/004,387; 11/960,609; 11/960,610; and U.S. Pat. No. 7,267,620, which are herein incorporated by reference in their entirety.

[0433] According to one embodiment, a method of making a golf club head, such as the golf club head 100, includes one or more of the following steps: (1) forming a body having a sole opening, forming a composite laminate sole insert, injection molding a thermoplastic composite head component over the sole insert to create a sole insert unit, and joining the sole insert unit to the body; (2) forming a body having a crown opening, forming a composite laminate crown insert, injection molding a thermoplastic composite head component over the crown insert to create a crown insert unit, and joining the crown insert unit to the body; (3) forming a weight track, capable of supporting one or more slidable weights, in the body; (4) forming the sole insert and/or the crown insert from a thermoplastic composite material having a matrix compatible for bonding with the body; (5) forming the sole insert and/or the crown insert from a continuous fiber composite material having continuous fibers selected from the group consisting of glass fibers, aramide fibers, carbon fibers and any combination thereof, and having a thermoplastic matrix consisting of polyphenylene sulfide (PPS), polyamides, polypropylene, thermoplastic polyurethanes, thermoplastic polyureas, polyamide-amides (PAI), polyether amides (PEI), polyetheretherketones (PEEK), and any combinations thereof; (6) forming both the sole insert and the weight track from thermoplastic composite materials having a compatible matrix; (7) forming the sole insert from a thermosetting material, coating a sole insert with a heat activated adhesive, and forming the weight track from a thermoplastic material capable of being injection molded over the sole insert after the coating step; (8) forming the body from a material selected from the group consisting of titanium, one or more titanium alloys, aluminum, one or more aluminum alloys, steel, one or more steel alloys, polymers, plastics, and any combination thereof; (9) forming the body with a crown opening, forming the crown insert from a composite laminate material, and joining the crown insert to the body such that the crown insert overlies the crown opening; (10) selecting a composite head component from the group consisting of one or more ribs to reinforce the golf club head, one or more ribs to tune acoustic properties of the golf club head, one or more weight ports to receive a fixed weight in a sole portion of the golf club head, one or more weight tracks to receive a slidable weight, and combinations thereof; (11) forming the sole insert and the crown insert from a continuous carbon fiber composite material; (12) forming the sole insert and the crown insert by thermosetting using materials suitable for thermosetting, and coating the sole insert with a heat activated adhesive; and (13) forming the body from titanium, titanium alloy or a combination thereof to have the crown opening, the sole insert, and the weight track from a thermoplastic carbon fiber material having a matrix selected from the group consisting of polyphenylene sulfide (PPS), polyamides, polypropylene, thermoplastic polyurethanes, thermoplastic polyureas, polyamide-amides (PAI), polyether amides (PEI), polyetheretherketones (PEEK), and any combinations thereof; and (13) forming a frame with a crown opening, forming a crown

insert from a thermoplastic composite material, and joining the crown insert to the body such that the crown insert overlies the crown opening.

[0434] Additionally, in addition to the various features described herein, any of the golf club heads disclosed herein may also incorporate additional features, which can include any of the features disclosed in U.S. Patent Application Ser. No. 63/433,380, Ser. Nos. 18/082,735, 18/082,271, 63/292, 708, 17/547,519, 17/360,179, 17/560,054, 17/124,134, 17/531,979, 17/722,748, 17/505,511, 17/560,054, 17/389, 167, 17/006,561, 17/137,151, 16/806,254, 17/321,315, 17/696,664, 17/565,580, 17/727,963, 16/288,499, 17/530, 331, 17/586,960, 17/884,027, 13/842,011, 16/817,311, 17/355,642, 17/722,748, 17/132,645, 17/696,664, 17/884, 027, 17/390,615, 17/586,960, 17/691,649, 17/224,026, 17/560,054, 17/164,033, 17/107,474, 17/526,981, 16/352, 537, 17/156,205, 17/132,541, 17/565,580, 17/360,179, 17/355,642, 17/727,963, 17/824,727, 17/722,632, 17/712, 041, 17/696,664, 17/695,194, 17/691,649, 17/686,181, 63/305,777, 17/577,943, 17/570,613, 17/569,810, 17/566, 833, 17/565,580, 17/566,131, 17/566,263, 17/564,077, 17/560,054, 63/292,708, 17/557,759, 17/558,387, 17/645, 033, 17/547,519, 17/541,107, 17/530,331, 17/526,981, 17/526,855, 17/524,056, 17/522,560, 17/515,112, 17/513, 716, 17/505,511, 17/504,335, 17/504,327, 17/494,416, 17/493,604, 63/261,457, 17/479,785, 17/476,839, 17/477, 258, 17/476,025, 17/467,709, 17/403,516, 17/399,823, 17/390,615, 63/227,889, 17/389,167, 17/387,181, 17/378, 407, 17/368,520, 17/360,179, 17/355,642, 17/330,033, 17/235,533, 17/233,201, 17/228,511, 17/224,026, 17/216, 185, 17/198,030, 17/191,617, 17/190,864, 17/183,905, 17/183,057, 17/181,923, 17/171,678, 17/171,656, 17/164, 033, 17/156,205, 17/564,077, 17/124,134, 17/107,447, 63/292,708, 63/305,777, and 63/338,818, all of which are herein incorporated by reference in their entirety. Additionally, in addition to the various features described herein, any of the golf club heads disclosed herein may also incorporate additional features, which can include any of the features disclosed in U.S. Pat. Nos. 11,213,726, 8,777,776, 7,278, 928, 7,445,561, 9,409,066, 8,303,435, 7,874,937, 8,628,434, 8,608,591, 8,740,719, 8,777,776, 9,694,253, 9,683,301, 9,468,816, 8,777,776, 8,262,509, 7,901,299, 8,119,714, 8,764,586, 8,227,545, 8,066,581, 9,409,066, 10,052,530, 10,195,497, 10,086,240, 9,914,027, 9,174,099, and 11,219, 803, all of which are herein incorporated by reference in their entirety.

[0435] Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment. Similarly, the use of the term "implementation" means an implementation having a particular feature, structure, or characteristic described in connection with one or more embodiments of the present disclosure, however, absent an express correlation to indicate otherwise, an implementation may be associated with one or more embodiments.

[0436] In the above description, certain terms may be used such as "up," "down," "upper," "lower," "horizontal," "vertical," "left," "right," "over," "under" and the like. These terms are used, where applicable, to provide some clarity of

description when dealing with relative relationships. But, these terms are not intended to imply absolute relationships, positions, and/or orientations. For example, with respect to an object, an “upper” surface can become a “lower” surface simply by turning the object over. Nevertheless, it is still the same object. Further, the terms “including,” “comprising,” “having,” and variations thereof mean “including but not limited to” unless expressly specified otherwise. An enumerated listing of items does not imply that any or all of the items are mutually exclusive and/or mutually inclusive, unless expressly specified otherwise. The terms “a,” “an,” and “the” also refer to “one or more” unless expressly specified otherwise. Further, the term “plurality” can be defined as “at least two.” The term “about” in some embodiments, can be defined to mean within +/-5% of a given value.

[0437] Additionally, examples in this specification where one element is “coupled” to another element can include direct and indirect coupling. Direct coupling can be defined as one element coupled to and in some contact with another element. Indirect coupling can be defined as coupling between two elements not in direct contact with each other, but having one or more additional elements between the coupled elements. Further, as used herein, securing one element to another element can include direct securing and indirect securing. Additionally, as used herein, “adjacent” does not necessarily denote contact. For example, one element can be adjacent another element without being in contact with that element.

[0438] As used herein, the phrase “at least one of”, when used with a list of items, means different combinations of one or more of the listed items may be used and only one of the items in the list may be needed. The item may be a particular object, thing, or category. In other words, “at least one of” means any combination of items or number of items may be used from the list, but not all of the items in the list may be required. For example, “at least one of item A, item B, and item C” may mean item A; item A and item B; item B; item A, item B, and item C; or item B and item C. In some cases, “at least one of item A, item B, and item C” may mean, for example, without limitation, two of item A, one of item B, and ten of item C; four of item B and seven of item C; or some other suitable combination.

[0439] Unless otherwise indicated, the terms “first,” “second,” etc. are used herein merely as labels, and are not intended to impose ordinal, positional, or hierarchical requirements on the items to which these terms refer. Moreover, reference to, e.g., a “second” item does not require or preclude the existence of, e.g., a “first” or lower-numbered item, and/or, e.g., a “third” or higher-numbered item.

[0440] As used herein, a system, apparatus, structure, article, element, component, or hardware “configured to” perform a specified function is indeed capable of performing the specified function without any alteration, rather than merely having potential to perform the specified function after further modification. In other words, the system, apparatus, structure, article, element, component, or hardware “configured to” perform a specified function is specifically selected, created, implemented, utilized, programmed, and/or designed for the purpose of performing the specified function. As used herein, “configured to” denotes existing characteristics of a system, apparatus, structure, article, element, component, or hardware which enable the system, apparatus, structure, article, element, component, or hard-

ware to perform the specified function without further modification. For purposes of this disclosure, a system, apparatus, structure, article, element, component, or hardware described as being “configured to” perform a particular function may additionally or alternatively be described as being “adapted to” and/or as being “operative to” perform that function.

[0441] The present subject matter may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

1. A method of making a golf club head, the method comprising steps of:

interposing bonding tape between a first piece and a second piece of the golf club head such that the first piece is temporarily adhered to the second piece via a tackiness of the bonding tape;

positioning the first piece, the second piece, and the bonding tape, interposed between the first piece and the second piece, in a vacuum bag;

reducing a pressure within the vacuum bag, relative to a pressure external to the vacuum bag, such that the vacuum bag collapses onto the first piece and the second piece and compresses the bonding tape between the first piece and the second piece; and

heating the bonding tape, at least to a curing temperature of the bonding tape, when the pressure within the vacuum bag is reduced.

2. The method according to claim 1, wherein the step of interposing the bonding tape between the first piece and the second piece of the golf club head comprises temporarily coupling a bonding tape package, comprising the bonding tape, to a tape-retention fixture via a suction force.

3. The method according to claim 2, wherein the step of interposing the bonding tape between the first piece and the second piece of the golf club head further comprises removing a release layer, adhered to the bonding tape, from the bonding tape package when the bonding tape package is coupled to the tape-retention fixture via the suction force.

4. The method according to claim 3, wherein the step of interposing the bonding tape between the first piece and the second piece of the golf club head further comprises temporarily adhering the bonding tape to the first piece when the bonding tape package is coupled to the tape-retention fixture via the suction force and after the release layer is removed.

5. The method according to claim 4, wherein the step of interposing the bonding tape between the first piece and the second piece of the golf club head further comprises disabling the suction force and removing the first piece and the bonding tape package from the tape-retention fixture.

6. The method according to claim 5, wherein the step of interposing the bonding tape between the first piece and the second piece of the golf club head further comprises:

removing a second release layer, adhered to the bonding tape, from the bonding tape package when the first piece and the bonding tape package from the tape-retention fixture are removed from the tape-retention fixture; and

applying the second piece onto the bonding tape when the second release layer is removed.

7. The method according to claim 1, wherein, prior to reducing the pressure and heating the bonding tape, the bonding tape is a solid and is tacky at 25° C.
8. The method according to claim 1, wherein:
the first piece is a non-metal insert;
the second piece comprises at least one recessed ledge;
the bonding tape comprises a first surface and a second surface, opposite the first surface;
the step of interposing the bonding tape between the first piece and the second piece comprises attaching the first surface of the bonding tape to the non-metal insert and attaching the second surface of the bonding tape to the at least one recessed ledge; and
a total surface area of the second surface of the bonding tape, prior to attachment to the at least one recessed ledge, is less than 100% of a total surface area of the at least one recessed ledge.
9. The method according to claim 8, wherein the total surface area of the second surface of the bonding tape, prior to attachment to the at least one recessed ledge, is less than 99% of the total surface area of the at least one recessed ledge.
10. The method according to claim 8, wherein the total surface area of the second surface of the bonding tape, prior to attachment to the at least one recessed ledge, is between, and inclusive of, 75% and 99% of the total surface area of the at least one recessed ledge.
11. The method according to claim 8, wherein the total surface area of the second surface of the bonding tape, prior to attachment to the at least one recessed ledge, is between, and inclusive of, 85% and 99% of the total surface area of the at least one recessed ledge.
12. The method according to claim 8, wherein the total surface area of the at least one recessed ledge is a total surface area of the at least one recessed ledge covered by the non-metal insert.
13. The method according to claim 8, wherein, when the bonding tape is interposed between the first piece and the second piece, the bonding tape is offset from an outer perimeter of the at least one recessed ledge by at least 0.25 mm.
14. The method according to claim 8, wherein, when the bonding tape is interposed between the first piece and the second piece, the bonding tape is offset from the outer perimeter of the at least one recessed ledge by no more than 3.0 mm.
15. The method according to claim 1, wherein:
the golf club head comprises a body, comprising a plurality of openings;
the first piece is a strike plate;
the second piece is the body, such that, when the bonding tape is interposed between the first piece and the second piece, the strike plate covers one of the plurality of openings; and
when the pressure within the vacuum bag is reduced and the bonding tape is heated, at least one of the plurality of openings of the body is uncovered.

16. The method according to claim 1, wherein:
the first piece is a non-metal insert comprising an interior surface having a total surface area between, and inclusive of, 2,000 mm² and 13,000 mm²; and
the method further comprises temporarily adhering the bonding tape to the interior surface of the non-metal insert, via a tackiness of the bonding tape, before the bonding tape is interposed between the first piece and the second piece.
17. The method according to claim 16, wherein the bonding tape comprises a thermoset adhesive.
18. The method according to claim 16, wherein, when temporarily adhered to the interior surface of the non-metal insert, the bonding tape is at least 0.25 mm from an outer periphery of the non-metal insert.
19. The method according to claim 1, further comprising interposing second bonding tape between the second piece and a third piece of the golf club head such that the third piece is temporarily adhered to the second piece via the tackiness of the second bonding tape, wherein:
the first piece is one of a crown insert, a sole insert, or a strike plate of the golf club head;
the second piece is a body of the golf club head;
the third piece is a second one of the crown insert, the sole insert, or the strike plate;
the step of positioning the first piece, the second piece, and the bonding tape in the vacuum bag further comprises positioning the third piece, with the second bonding tape between the third piece and the second piece, in the vacuum bag;
reducing the pressure within the vacuum bag collapses the vacuum bag onto the third piece and the second piece such that the second bonding tape is compressed between the third piece and the second piece; and
heating the bonding tape comprises heating the bonding tape at least to a curing temperature of the second bonding tape when the pressure within the vacuum bag is reduced.
20. A golf club head, comprising:
a hollow interior cavity having an interior volume of at least 5 cubic centimeters;
a first piece, defining at least a first portion of the hollow interior cavity; and
a second piece, defining at least a second portion of the hollow interior cavity,
wherein:
the first piece is adhesively bonded to the second piece, via bonding tape, along a bonded joint;
the bonding tape has a thickness between 90 µm and 550 µm;
the bonding tape is a thermosetting adhesive material; and
the bonding tape has a width between, and inclusive of, 1 mm and 9 mm.
- 21-27. (canceled)

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