MULTI-CORE GOLF BALL HAVING INCREASED INITIAL VELOCITY

The present invention relates to a golf ball (300) comprising: an inner core (310), the inner core (310) consisting essentially of at least one highly neutralized polymer; an outer core layer (320), the outer core layer (320) substantially surrounding the inner core (310) and being made primarily of a thermoset rubber; an inner cover layer (330), the inner cover layer (330) substantially surrounding the outer core layer (320); and an outer cover layer (340), the outer cover layer (340) substantially surrounding the inner cover layer (330); wherein the golf ball (300) has an initial velocity measured at a club head speed of about 125 mph of at least about 174 mph, wherein the inner core (310) has a surface Shore D hardness of at least about 60; the outer core layer (320) has a surface Shore D hardness of from about 50 to about 60; the inner cover layer (330) has a surface Shore D hardness of at least 60; and the outer cover layer (340) has a surface Shore D hardness of from about 50 to about 60. It is an object of the present invention to provide a golf ball that is usable for both professional and hobby golfers and thus for a high range of club speeds.
CROSS-REFERENCE TO RELATED APPLICATION


BACKGROUND

[0003] The present invention relates generally to golf balls. In particular, the present disclosure relates to golf balls with a core made of up at least two structural components with certain values of its initial velocity off the tee, and certain relationships among the initial velocity values.

[0004] Golf is an increasing popular sport at both the professional and amateur levels. Generally, a mass produced golf ball should be able to meet the requirements of golfers of a wide variety of ability levels. One important difference between recreational golfers and professional golfers is the speed at which they swing the club during a drive, known as club head speed. Recreational players usually have a driver club head speed of lower than 100 mph. On the other hand, professional players usually have a driver club head speed of higher than 125 mph.

[0005] The golf club speed is related to a golf ball’s initial velocity. Initial velocity is the measure of a golf ball’s instantaneous speed immediately after being struck by a golf club off of the tee. Initial velocity is often related to the distance the shot will travel. Golfers generally prefer golf balls that achieve a higher initial velocity in order for their shots to achieve longer distances.

[0006] Some premium balls currently known and commercially available can satisfy the needs of low club head speed players, and mid club head speed players. However, these balls may not have a good initial velocity under a head speed of 125 mph or more.

[0007] Therefore, there is a need in the art for a golf ball that satisfies the need of golfers having different ability levels by achieving a bigger difference of golf ball initial velocity between low and high head speed.

SUMMARY

[0008] Generally, this disclosure relates to golf balls having at least two core structural components, where the golf ball achieves a wide range of initial velocities under different club head speeds. Furthermore, this disclosure relates to golf balls that achieve a high initial velocity under high club head speeds.

[0009] In one aspect, this disclosure provides a golf ball comprising: an inner core, the inner core comprising a thermoplastic resin; an outer core layer, the outer core substantially surrounding the inner core and comprising a thermoset rubber; and at least one cover layer; wherein the inner core has a compression deformation of from about 3.5 mm to about 4.1 mm, the outer core layer has a compression deformation of from about 2.7 mm to about 3.3 mm, and the outer core layer has a thickness of at least 4.8 mm; and wherein the golf ball has a first initial velocity measured at a club head speed of about 80 mph, the golf ball has a second initial velocity measured at a club head speed of about 125 mph, the initial velocities being otherwise measured under the same conditions, and the difference between the second initial velocity and the first initial velocity is at least about 85 mph.

[0010] In another aspect, this disclosure provides a golf ball comprising: an inner core, the inner core being formed primarily of at least one thermoplastic highly neutralized polymer, and the inner core has a diameter of from about 20 mm to about 26 mm; an outer core layer, the outer core substantially surrounding the inner core and being made primarily of a thermoset rubber, and the outer core layer has a thickness of from about 5 mm to about 9 mm; an inner cover layer, the inner cover layer substantially surrounding the outer core layer; and an outer cover layer, the outer cover layer substantially surrounding the inner cover layer; wherein the inner core has a compression deformation of from about 3.5 mm to about 4.1 mm, the outer core layer has a compression deformation of from about 2.7 mm to about 3.3 mm, and a ratio of the compression deformation of the inner core to the compression deformation of the outer core layer is from about 1.1 to about 1.3; the inner core having a first COR, the outer core having a second COR, the second COR being greater than the first COR and having a value of at least 0.8; and wherein the golf ball has a first initial velocity measured at a club head speed of about 80 mph, the golf ball has a second initial velocity measured at a club head speed of about 125 mph, the initial velocities being otherwise measured under the same conditions, and the difference between the second initial velocity and the first initial velocity is at least about 85 mph.

[0011] Finally, in a third aspect, this disclosure provides a golf ball comprising an inner core, the inner core consisting...
essentially of at least one highly neutralized polymer; an outer core layer, the outer core substantially surrounding the
inner core and being made primarily of a thermoset rubber; and at least one cover layer, wherein the golf ball has a first
initial velocity measured at a club head speed of about 80 mph, the golf ball has a second initial velocity measured at a
club head speed of about 125 mph, the initial velocities being otherwise measured under the same conditions, and the
difference between the second initial velocity and the first initial velocity is at least about 85 mph.

[0012] Other systems, methods, features and advantages of the invention will be, or will become, apparent to one of
ordinary skill in the art upon examination of the following figures and detailed description. It is intended that all such
additional systems, methods, features and advantages be included within this description and this summary, be within
the scope of the invention, and be protected by the following claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The invention can be better understood with reference to the following drawings and description. The compo-
nents in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the
invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

FIG. 1 is a cut-away cross-sectional view of a first golf ball in accordance with this disclosure.
FIG. 2 is a cut-away cross-sectional view of a second golf ball in accordance with this disclosure.

DETAILED DESCRIPTION

[0014] Generally, this disclosure provides golf balls having an inner core and an outer core that achieve favorable
initial velocity properties.

[0015] Except as otherwise discussed herein below, any golf ball discussed herein may generally be any type of golf
ball known in the art. Namely, unless the present disclosure indicates to the contrary, a golf ball may generally be of any
construction conventionally used for golf balls, and may be made of any of the various materials known to be used in
golf ball manufacturing. Furthermore, it is understood that any feature disclosed herein (including but not limited to
various embodiments shown in the FIGS. and various chemical formulas or mixtures) may be combined with any other
features disclosed here in any combination or subcombination, as may be desired.

[0016] FIG. 1 shows a first embodiment of a golf ball 100 in accordance with this disclosure. Golf ball 100 is a three
piece golf ball, meaning that it includes three structural layers. Namely, golf ball 100 includes inner core 110, outer core
layer 120 substantially surrounding inner core 110, and cover layer 130 substantially surrounding outer core layer 120.
Three piece golf ball may also include other layers, such as paint layers or clear coating layers that are generally
considered ornamental finishing layers rather than structural layers.

[0017] FIG. 2 shows a second embodiment of a golf ball 300 in accordance with this disclosure. Golf ball 300 is a four
piece golf ball, meaning that it includes four structural layers. Namely, golf ball 300 includes inner core 310, outer core
layer 320 substantially surrounding inner core 310, inner cover layer 330 substantially surrounding outer core layer, and
outer cover layer 340 substantially surrounding inner cover layer 330. As mentioned above, four piece golf balls may
also include other layers, such as paint layers or clear coating layers that are generally considered ornamental finishing
layers rather than structural layers.

[0018] Golf balls in accordance with this disclosure generally include at least two inner layers. Inner core 110 and
outer core layer 120, or inner core 310 and outer core layer 320, are generally considered the inner layers. In addition
to the three piece golf ball 100 and four piece golf ball 300, golf balls in accordance with this disclosure may also include
one or more additional layers not shown in the figures. For example, an additional layer may be added between inner
core 310 and outer cover layer 340. For example, in other embodiments, an additional cover layer may be inserted
between inner cover layer 330 and outer cover layer 340. In other embodiments, an additional core layer may be inserted
between inner core layer 310 and outer cover layer 320. Such additional layers made be added by a person having
ordinary skill in the art of golf ball manufacturing in accordance with industry practice.

[0019] Although each of these structural layers is shown as being spherical, in other embodiments the layers may
have other non-spherical shapes. FIG. 1 and 2 are shown for illustrative purposes, and are not necessarily to scale.
Various aspects of a golf ball in accordance with this disclosure may have relative proportions and sizes other than are
shown in FIG. 1 and 2.

[0020] Each of the layers making up the golf ball construction shown in the FIG. 1 and 2, and their associated physical
properties, will be discussed herein below. As used herein, unless otherwise stated, the following physical properties
are defined and measured as follows.

[0021] The term “compression deformation” as used herein indicates the deformation amount of the ball under a force.
Specifically, the compression deformation value of a golf ball or some component of a golf ball is defined as the difference
between the amount of deformation under a 10kg load and the amount of deformation under a 130 kg load.
The term "hardness" as used herein is measured generally in accordance with ASTM D-2240. The hardness of a golf ball is measured on the land area of a curved surface of a molded ball. The hardness of a golf ball sub-component is measured on the curved surface of the molded sub-component. The hardness of a material is measured in accordance with ASTM D-2240 (on a plaque).

The term "coefficient of restitution" ("COR") as used herein is measured according to the following method: a golf ball or golf ball sub-component is fired by an air cannon at an initial velocity of 40 m/sec, and a speed monitoring device is located over a distance of 0.6 to 0.9 meters from the cannon. When the golf ball or golf ball sub-component strikes a steel plate positioned about 1.2 meters away from the air cannon, the golf ball or golf ball sub-component rebounds through the speed-monitoring device. The COR is the return velocity divided by the initial velocity. All COR values discussed herein are measured at an initial velocity of 40 m/sec unless otherwise indicated.

The term "flexural modulus" as used herein is the measurement of a material in accordance with ASTM D-790.

As used herein, a polymer composition "comprises" a specific material if the composition includes at least a non-trivial, measureable, amount of that type of material. In contrast, a polymer composition "consists essentially of" a specific type of material if no other polymeric molecules are present in mixture with the material. Polymer compositions commonly include additives, fillers, unreacted monomers and oligomers, and other trace non-polymeric ingredients, which are not necessarily excluded by "consisting essentially of" language. A component is "formed primarily of" a polymer composition when that polymer composition is the main polymeric ingredient, making up at least 50.1% of the component.

The inner core layer:

In the present disclosure, the inner core refers to an inner core such as inner core 110 or inner core 310. The inner core is the innermost central structural component in the golf ball, and includes golf ball center 260 (or golf ball center 460). Generally, the inner core may be formed primarily of a thermoplastic resin, instead of being formed of a thermoset rubber composition as in conventional golf balls. The thermoplastic resin, while not subject to any particular limitation, is exemplified by nylons, polyarylates, ionomer resins, a highly neutralized ionomeric resin or highly neutralized polymers (HNP's), polypropylene resins, polyurethane based thermoplastic elastomers and polyester-based thermoplastic elastomers. Commercial products such as Surlyn AD8512 (an ionomer resin available from DuPont), Himilan 1706 and Himilan 1707 (both ionomer resins available from DuPont-Mitsui Polychemicals), HPF resins (highly neutralized polymers from Dupont), Rilsan BMNO (a nylon resin available from Arkema) and U-polymer U-8000 (a polyarylate resin available from Unitika) may be used to form the inner core.

In particular embodiments, the thermoplastic resin may be highly neutralized acid polymers (HNPs). Suitable highly neutralized acid polymers include, but are not limited to, HPF resins such as HPF1000, HPF2000, HPF AD1024, HPF AD1027, HPF AD1030, HPF AD1035, HPF AD1040, all produced by E. I. Dupont de Nemours and Company.

The acid moieties of the HNP's, typically ethylene-based ionomers, may be neutralized to greater than about 70%, or greater than about 90%, or near 100%, or to 100%. The HNP's may be also blended with a second polymer component, which, if containing an acid group, may be neutralized in a conventional manner, by the organic fatty acids, or by both. The second polymer component, which may be partially or fully neutralized, may comprise ionomeric copolymers and terpolymers, ionomer precursors, thermoplastics, polyamides, polycarbonates, polystyres, polyurethanes, polyureas, thermoplastic elastomers, polybutadiene rubber, balata, metallocone-catalyzed polymers (grafted and non-grafted), single-site polymers, high-crystalline acid polymers, cationic ionomers, and the like. HNP polymers may typically have a material hardness (plaque hardness) of between about 20 and about 80 Shore D, and a flexural modulus of between about 3,000 psi and about 200,000 psi.

In one embodiment of the present disclosure, the HNP's may be ionomers and/or their acid precursors that are highly neutralized acid polymers including, but not limited to, HPF resins such as HPF1000, HPF2000, HPF AD1024, HPF AD1027, HPF AD1030, HPF AD1035, HPF AD1040, all produced by E. I. Dupont de Nemours and Company. The acid moieties of the HNP's, typically ethylene-based ionomers, may be neutralized to greater than about 70%, or greater than about 90%, or near 100%, or to 100%. The HNP's may be also blended with a second polymer component, which, if containing an acid group, may be neutralized in a conventional manner, by the organic fatty acids, or by both. The second polymer component, which may be partially or fully neutralized, may comprise ionomeric copolymers and terpolymers, ionomer precursors, thermoplastics, polyamides, polycarbonates, polystyres, polyurethanes, polyureas, thermoplastic elastomers, polybutadiene rubber, balata, metallocone-catalyzed polymers (grafted and non-grafted), single-site polymers, high-crystalline acid polymers, cationic ionomers, and the like. HNP polymers may typically have a material hardness (plaque hardness) of between about 20 and about 80 Shore D, and a flexural modulus of between about 3,000 psi and about 200,000 psi.

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In one embodiment of the present disclosure, the HNP's may be ionomers and/or their acid precursors that are neutralized, either fully or partially, with organic acid copolymers or the salts thereof. The acid copolymers are preferably α-olefin, such as ethylene, C₃-C₈ α,β-ethylenically unsaturated carboxylic acid, such as acrylic and methacrylic acid, copolymers. They may optionally contain a softening monomer, such as alkyl acrylate and alkyl methacrylate, wherein the alkyl groups have from 1 to 8 carbon atoms.

The acid copolymers may be described as E/X/Y copolymers where E is ethylene, X is an α,β-ethylenically unsaturated carboxylic acid, and Y is a softening comonomer. In a preferred embodiment, X may be acrylic or methacrylic acid and Y may be a C₁₋₈ alkyl acrylate or methacrylate ester. X may be present in an amount from about 1 to about 35 weight percent of the polymer, or from about 5 to about 30 weight percent of the polymer, or from about 10 to about 20 weight percent of the polymer. Y may be present in an amount from about 0 to about 50 weight percent of the polymer, or from about 5 to about 25 weight percent of the polymer, or from about 10 to about 20 weight percent of the polymer.

Specific acid-containing ethylene copolymers include, but are not limited to, ethylene/acrylic acid/n-butyl acrylate, ethylene/methacrylic acid/n-butyl acrylate, ethylene/methacrylic acid/iso-butyl acrylate, ethylene/acrylic acid/iso-butyl acrylate, ethylene/methacrylic acid/iso-butyl methacrylate, ethylene/acrylic acid/methyl methacrylate, ethylene/acrylic acid/methyl acrylate, ethylene/methacrylic acid/methyl acrylate, ethylene/methacrylic acid/methyl methacrylate, and
The outer core layer.

The outer core layer in the present disclosure generally refers to an outer core such as outer core 120 shown in Fig. 1, or outer core 320 shown in Fig. 2. The outer core layer may be formed of a compression-molded thermoset rubber composition composed of polybutadiene as the base rubber. Here, the polybutadiene has a cis-1,4 bond content of at least 60%, preferably at least 80%, more preferably at least 90%, and most preferably at least 95%.

It is recommended that the polybutadiene have a Mooney viscosity (ML1+4 (100°C)) of at least 30, or at least 35, or at least 40, or at least 50, or at least 52, but not more than 100, or not more than 80, or not more than 70, or not more than 60.

The term "Mooney viscosity" used herein refers to an industrial indicator of viscosity as measured with a Mooney
The molecular weight distribution Mw/Mn (where Mw stands for the weight-average molecular weight, and Mn stands for the number-average molecular weight) of the above polybutadiene may be at least 2.0, or at least 2.2, or at least 2.4, or at least 2.6, but not more than 6.0, or not more than 5.0, or not more than 4.0, or not more than 3.4. Generally, if the Mw/Mn is too small, the workability may worsen. On the other hand, if the Mw/Mn is too large, the rebound of the golf ball may decrease.

Rubbers other than the above-described polybutadiene may be included and used together with the polybutadiene. Illustrative examples of other rubbers include polybutadiene rubbers (BR), styrene-butadiene rubbers (SBR), natural rubbers, polyisoprene rubbers, and ethylene-propylene-diene rubbers (EPDM). These may be used singly or as combinations of two or more thereof.

The outer core layer may be formed by compression molding a rubber composition prepared by blending a base rubber with ingredients typically included with a rubber compound in a golf ball layer. Such ingredients include crosslinkers, such as unsaturated carboxylic acids or a metal salt thereof; a peptizer such as an organosulfur compound; a filler, particularly an inorganic filler; and an antioxidant.

Rubbers other than the above-described polybutadiene may be included and used together with the polybutadiene. Illustrative examples of other rubbers include polybutadiene rubbers (BR), styrene-butadiene rubbers (SBR), natural rubbers, polyisoprene rubbers, and ethylene-propylene-diene rubbers (EPDM). These may be used singly or as combinations of two or more thereof.

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suitable weight and a good rebound.

[0057] In some embodiments, the rubber composition may include as a cross-linker an organic peroxide having a relatively short half-life. Specifically, the half-life at 155°C of the organic peroxide may be at least 5 seconds, or at least 10 seconds, or at least 15 seconds. In some embodiments, the organic peroxide may have a half-life at 155°C of not more than 120 seconds, or not more than 90 seconds, or not more than 60 seconds.

[0058] Examples of such organic peroxides include 1,1-bis(hexylperoxy) cyclohexane (trade name, Perhexa HC), 1,1-bis(t-hexylperoxy)-3,3,5-trimethylcyclohexane (trade name, Perhexa TMH), 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane (trade name, Perhexa 3M) and 1-bis(t-butylperoxy)cyclohexane (trade name, Perhexa C), all of which are available from NOF Corporation.

[0059] To enable a good rebound and durability to be achieved, such an organic peroxide may be included per 100 parts by weight of the base rubber in an amount of at least 0.2 part by weight, or at least 0.3 part by weight, but may be included in an amount of not more than 3 parts by weight, or not more than 2 parts by weight, or not more than 1.5 parts by weight, or not more than 1 part by weight. If the amount included is too high, the rebound and durability may decline. On the other hand, if the amount included is too low, the time required for crosslinking may increase, possibly resulting in a large decline in productivity and also a large decline in compression.

[0060] An antioxidant may be included in the above rubber composition, if desired in some embodiments. Illustrative examples of the antioxidant include commercial products such as Nocrac NS-6 and Nocrac NS-30 (both available from Ouchi Shinko Chemical Industry Co., Ltd.), and Yoshinox 425 (Yoshitomi Pharmaceutical Industries, Ltd.). To achieve a good rebound and durability, the antioxidant may be included in an amount per 100 parts by weight of the base rubber of at least 0.03 part by weight, or at least 0.05 part by weight, but may be included in an amount of not more than 0.4 part by weight, or not more than 0.3 part by weight, or not more than 0.2 part by weight.

[0061] Sulfur may also be added to the rubber composition as a vulcanization agent in some embodiments. Such sulfur is exemplified by the product manufactured by Tsurumi Chemical Industry Co., Ltd. under the trade name Sulfur Z. The amount of sulfur included per 100 parts by weight of the base rubber may be at least 0.005 parts by weight, or at least 0.01 parts by weight, but may be included in an amount of not more than 0.5 part by weight, or not more than 0.4 part by weight, or not more than 0.1 part by weight. By adding sulfur, the core hardness profile may be increased. However, adding too much sulfur may result in undesirable effects during hot molding, such as explosion of the rubber composition, or may considerably lower the rebound.

[0062] The outer core layer may be made by a compression molding process. Suitable vulcanization conditions include, a vulcanization temperature of between 130°C and 190°C, and a vulcanization time of between 5 and 20 minutes. To obtain the desired rubber crosslinked body for use as the core in the present invention, the vulcanizing temperature may be at least 140°C.

[0063] When the outer core layer of the present disclosure is produced by vulcanizing and curing the rubber composition in the above-described way, advantageous use may be made of a method in which the vulcanization step is divided into two stages: first, the outer core layer material may be placed in an outer core layer-forming mold and subjected to an initial vulcanization so as to produce a pair of semi-vulcanized hemispherical cups, following which a prefabricated inner core layer may be placed in one of the hemispherical cups and covered by the other hemispherical cup, in which state complete vulcanization is carried out.

[0064] The surface of the inner core layer placed in the hemispherical cups may be roughened before the placement to increase adhesion between the inner core layer and the outer core layer. In some embodiments, the inner core layer's surface is pre-coated with an adhesive (known to the skilled practitioner) before placing the inner core layer in the hemispherical cups to enhance the durability of the golf ball and enable a high rebound.

[0065] To protect the inner core and to have a good resilience, the outer core layer may have a thickness of at least 4.8 mm. In some embodiments, the outer core layer may have a thickness of from 5 mm to 9 mm. The outer core layer (with inner core layer inside) may have a diameter of from 34 mm to 39 mm. To have a good flight performance, the outer core layer (with the inner core layer inside) may have a high coefficient of restitution of at least 0.800. In some embodiments, the outer core layer (with the inner core layer inside) has the higher coefficient of restitution than inner core layer alone, inner cover layer (with outer core and inner core layer inside), or finished golf ball. Also, the outer core layer preferably may have a compression deformation of from about 2.7 mm to about 3.3 mm.

[0066] In the present disclosure, the ratio of the compression deformation of the inner core layer (D inner) to that of the outer core layer (D outer): (D inner)/(D outer) may be from about 1.1 to about 1.3. If the ratio is less than about 1.1, the ball may be too soft to have a good flight performance. However, if the number is more than about 1.3, the hardness difference of the inner core layer and outer core layer may be so big as to deteriorate the durability of the golf ball.

The cover layer(s).

[0067] In the present disclosure, the cover layer may include one or more structural cover layers. FIG. 1 shows a single cover layer 130, while FIG. 2 shows an inner cover layer 320 and an outer cover layer 330. All such embodiments
may be referred to herein as "the cover layer." Generally, the cover layer is the outermost structural component of the golf ball, and includes golf ball surface 270 (or golf ball surface 470).

[0068] Generally, the material making up the cover layer is not subject to any particular limitation; the cover may be formed using a known cover material. Specific examples of the cover layer material include known thermoplastic resins, ionomeric resins, highly neutralized polymers, and thermoplastic and thermoset polyurethanes. Alternatively, use may be made of polyurethane-based, polyamide-based and polyester-based thermoplastic elastomers. Conventional injection molding may be advantageously used to form the cover layer.

[0069] When the cover layer used in the present disclosure is relatively soft, the spin performance on approach shots may improve, thus enabling increased controllability to be achieved. Furthermore, in some situations, a relatively soft cover layer might also enable longer shot distance. When the cover layer is relatively hard, in addition to a distance-increasing effect, an even lower spin rate may be achieved, enabling the distance to be substantially improved.

[0070] In cases where the cover layer used in the disclosure is formed to be relatively soft, the material making up the cover layer may be an ionomeric resin, a highly neutralized ionomeric resin composition, a polyurethane based thermoplastic elastomer, or a polyester-based thermoplastic elastomer.

[0071] When the cover layer is composed of a single layer, such as cover layer 130 shown in FIG. 1, the cover layer thickness 230 may be at least about 0.5 mm, or at least about 0.6 mm, or at least about 0.7 mm, or at least 0.8 mm, but not more than 2.0 mm. Thickness 230 may also be not more than about 1.7 mm, or not more than about 1.4 mm, or not more than about 1.2 mm. Also, the cover hardness, expressed as the Shore D hardness, may be at least 35, or at least 45, or at least 50, or at least 55, but not more than 60.

[0072] In some embodiments, as shown in FIG. 2, the cover layer may comprise two or more layers. In such embodiments, outer cover layer 340 may be softer than inner cover layer 330. The hardness of inner cover layer 330, expressed as the Shore D hardness, may be at least about 55, or at least about 60, or at least about 65, but may be not more than about 75. The hardness of outer cover layer 340 may be from about 50 to about 60 in Shore D hardness. The material Shore D hardness of the outer cover layer (as measured on a plaque) may be less than 40.

[0073] In the present disclosure, inner cover layer 330 may have a thickness 430 of less than 2 mm. In some embodiments, inner cover layer 330 may have a thickness 430 of less than 1.5 mm. In some embodiments, inner cover layer 330 may have a thickness 430 of less than 1 mm. Thickness 430 of inner cover layer 330 may also be at least about 0.5 mm, or at least about 0.7 mm, or at least about 0.9 mm, or at least about 1.1 mm.

[0074] While inner cover layer 330 may be relatively thin, outer cover layer 340 may have a thickness 440 of from about 0.8 mm to about 2 mm. In some embodiments, outer cover layer 340 may have a thickness 440 of from about 1.0 mm to about 2.0 mm. Outer cover layer 340 may have a thickness 440 which is greater than thickness 430 of inner cover layer 330.

[0075] In some embodiments, the cover layer or outer cover layer 340 may comprise a crosslinked thermoplastic polyurethane elastomer including crosslinks formed from allyl ether side groups, and said crosslinked thermoplastic polyurethane elastomer is a reaction product formed from reacting an organic isocyanate with a mixture of the following reactants:

(a) an unsaturated diol of formula (1):

\[
\text{HO} \left( \text{H}_2\text{C} \right)_x \text{(CH}_2)_y \text{OH}
\]

(b) a chain extender, having at least two reaction sites with isocyanates and having a molecular weight of less than about 450;

(c) a long chain polyol having a molecular weight of between about 500 and about 4,000; and

(d) a sufficient amount of free radical initiator, so as to be capable of generating free radicals that induce crosslinking structures in the hard segments by free radical initiation.
In specific embodiments, the unsaturated diol may include an allyl ether group as the side chain. For example, the unsaturated diol may be represented by formula (2) shown below:

\[ \text{HO-}
\begin{array}{c}
\text{(H}_2\text{C})_x \\
\text{C-(CH}_2)_{y}\text{OH}
\end{array}
\]

(2)

\[ \text{R} \]

in which R is a substituted or unsubstituted alkyl group, and x and y are integers independently having values of 1 to 4. In particular embodiments, x and y may both have values of 1, 2, 3 or 4. In other embodiments, x and y may each have different values from 1 to 4.

In some embodiments, the unsaturated diol of formula (1) or formula (2) may be trimethylolpropane monoallylether.


The cover layer or outer cover layer with the crosslinked thermoplastic polyurethane elastomer may have a flexural modulus of less than about 1,000 psi, or less than about 800 psi, or less than about 600 psi.

A golf ball in accordance with this disclosure, such as golf ball 100 shown in FIG. 1 or golf ball 300 shown in FIG. 2, may have various physical features and properties. For example, a golf ball may have a diameter that accords with USGA standards. Namely, a golf ball may have a diameter of not less than 42.67 mm (1.680 inches USGA standard), or in other embodiments the diameter may be not more than 44 mm, or not more than 43.8 mm, or not more than 43.5 mm, or not more than 43 mm.

The golf ball may also have a compression deformation of at least about 2.3 mm, or at least about 2.4 mm, or at least about 2.5 mm, or at least about 2.6 mm. The value of the compression deformation may be not more than about 5.0 mm, or not more than about 4.5 mm, or not more than about 4.0 mm, or not more than about 3.8 mm.

A golf ball in accordance with the present disclosure may have a COR of 0.80 or less, or 0.79 or less, or 0.78 or less.

The golf ball may also have certain initial velocities, and relationships among its initial velocities at different club head speeds. Generally, the golf ball may have a first initial velocity measured at a club head speed of about 80 mph, a second initial velocity measured at a club head speed of about 125 mph but otherwise under the same testing conditions, where the difference between the second initial velocity and the first initial velocity is at least about 85 mph.

In some embodiments, the initial velocity at certain club head speeds may have advantageous values. For example, the initial velocity of the golf ball when measured in response to a club head speed of 80 mph may be at least 87 mph. In another example, the initial velocity at a club head speed of 125 mph may be at least 173 mph. Such values may enable the golf ball to achieve desirable longer shot distances. Further initial velocities are shown and discussed in the Examples, below.

A golf ball in accordance with this disclosure may include a resilient material, or any other feature, as described in U.S. Patent Application serial no. 13/193,025 to Ichikawa, filed on July 28, 2011 and entitled "Golf Ball Having a Resilient Material." The disclose of this co-pending application is hereby incorporated by reference in its entirety to the extent that the disclosure does not conflict with the explicit teachings of the present disclosure.

A golf ball in accordance with this disclosure may include layers having certain flexural modulus and hardness values, or any other feature, as described in U.S. Patent Application serial no. 13/193,025 to Chen-Tai Liu filed on August 20, 2010, and entitle "Golf Ball Having Layers with Specified Moduli and Hardnesses." The disclose of this co-pending application is hereby incorporated by reference in its entirety to the extent that the disclosure does not conflict with the
explicit teachings of the present disclosure.

Examples

[0087] Manufacturing the Golf Ball: for examples of the present disclosure, the inner core layer was made from a material selected from Table 1; the outer core layer was made from a material selected from Table 2; the inner cover layer was made from a material selected from Table 3; and the outer cover layer was made from a material selected from Table 4. The amount of the materials listed in Tables 1, 2, 3 and 4 is shown in parts by weight (pbw) or percentages by weight.

<table>
<thead>
<tr>
<th>Table 1 - Inner Core Layer Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin: A</td>
</tr>
<tr>
<td>HPF 2000 60</td>
</tr>
<tr>
<td>HPF AD 1035 40</td>
</tr>
</tbody>
</table>

[0088] HPF 2000 and HPF AD 1035 are trade names of ionomeric resins by E. I. DuPont de Nemours and Company.

<table>
<thead>
<tr>
<th>Table 2 - Outer Core Layer Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber compound: B</td>
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<tr>
<td>TAIPOL™ BR0150 100</td>
</tr>
<tr>
<td>Zinc diacrylate 29</td>
</tr>
<tr>
<td>Zinc oxide 9</td>
</tr>
<tr>
<td>Barium sulfate 11</td>
</tr>
<tr>
<td>Peroxide 1</td>
</tr>
</tbody>
</table>

[0089] TAIPOL™ BR0150 is the trade name of a rubber produced by Taiwan Synthetic Rubber Corp.

<table>
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<tr>
<th>Table 3 - Inner Cover Layer Material</th>
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<tr>
<td>Resin: C</td>
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<tr>
<td>Neothane 6303D 100</td>
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</tbody>
</table>

[0090] Neothane 6303D is the trade name of a thermoplastic polyurethane produced by Dongsung Highchem Co. LTD.

<table>
<thead>
<tr>
<th>Table 4 - Outer Cover Layer Materials</th>
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<tbody>
<tr>
<td>D</td>
</tr>
<tr>
<td>PTMEG (pbw) 100</td>
</tr>
<tr>
<td>BG (pbw) 15</td>
</tr>
<tr>
<td>TMPME (weight % to total components) 10%</td>
</tr>
<tr>
<td>DCP (weight % to total components) 0.5%</td>
</tr>
<tr>
<td>MDI (pbw) 87.8</td>
</tr>
</tbody>
</table>

[0091] "PTMEG" is polytetramethylene ether glycol, having a number average molecular weight of 2,000, and is commercially available from Invista, under the trade name of Terathane® 2000. "BG" is 1,4-butanediol, commercially available from BASF and other suppliers. "TMPME" is trimethylolpropane monoallylether, commercially available from Perstorp Specialty Chemicals AB. "DCP" is dicumyl peroxide, commercially available from LaPorte Chemicals Ltd. Finally, "MDI" is diphenylmethane diisocyanate, commercially available from Huntsman, under the trade name of Su-
Outer cover material D was formed by mixing PTMEG, BG, TMPME, DCP and MDI in the proportions shown. Specifically, these materials were prepared by mixing the components in a high agitated stir for 1 minute, starting at a temperature of about 70 degrees Celsius, followed by a 10-hour post curing process at a temperature of about 100 degrees Celsius. The post cured polyurethane elastomers are ground into small chips.

From the above materials, golf balls were manufactured as shown in Table 5. Generally, the golf balls were manufactured using conventional compression molding and injection molding processes known in the art of golf ball manufacturing.

<table>
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<tr>
<th>Table 5 - Golf Ball Construction</th>
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<tr>
<td><strong>Inner Core Layer</strong></td>
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<td>Material</td>
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<tr>
<td>Diameter (mm)</td>
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<tr>
<td>Surface Shore D Hardness</td>
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<tr>
<td>Compression Deformation (mm)</td>
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<tr>
<td>COR</td>
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<tr>
<td><strong>Outer Core Layer</strong></td>
</tr>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Thickness (mm)</td>
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<tr>
<td>Surface Shore D Hardness</td>
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<tr>
<td>Compression Deformation (D outer, mm)</td>
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<tr>
<td>COR</td>
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<tr>
<td>Ratio (Dinner)/(D outer)</td>
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<td><strong>Inner Cover Layer</strong></td>
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<td>Material</td>
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<td>Thickness (mm)</td>
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<td>Surface Shore D Hardness</td>
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<td>COR</td>
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<tr>
<td><strong>Outer Cover Layer</strong></td>
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<td>Material</td>
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<tr>
<td>Thickness (mm)</td>
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<td>Surface Shore D Hardness</td>
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<td>Flexural Modulus (psi)</td>
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<td>Ball</td>
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<tr>
<td>COR</td>
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An initial velocity test of driver shot was conducted in the following manner: a Nike SQ Dymo driver (loft: 10.5°; shaft: Diamana by Mitsubishi Rayon; flex: X; grip: golf pride) is fixed to a swing robot manufactured by Miyamae Co., Ltd. and then swung at different head speed from about 80 mph to about 125 mph. The clubface was oriented for a square hit. The forward/backward tee position was adjusted so that the tee was three inches in front of the point in the downswing where the club was vertical. The height of the tee and the toe-heel position of the club relative to the tee were adjusted in order that the center of the impact mark was centered toe to heel across the face. Specifically, the ball was centered relative to the club face both toe-to-heel and top-to-bottom. As used throughout the present specification, the term "initial velocity" refers to a measurement under substantially similar conditions: using a driver, and the golf ball being centered on the club face both toe-to-heel and top-to-bottom.

Furthermore, each of the tests shown in Tables 6-9 (including, but not limited to, the initial velocity tests) were...
conducted relative to a standard known golf ball, the Nike "One Tour D." The "One Tour D" is a tour-level golf ball made and sold by Nike Inc. that is widely commercially available. Namely, any test that measures a golf ball in accordance with this disclosure should first be calibrated to achieve the values as shown below for the One Tour D under the conditions as noted. In this way, the testing procedure can be standardized relative to a known golf ball. The margin of error within any test is +/- 1 mph, +/- 1 degree angle, and +/- 150 rpm. Any value that is described as being "about" or "substantially" a certain value may vary by these margin of errors.

Initial velocity tests were done at 125 mph, 110 mph, 95 mph, and 80 mph. The results are shown in Tables 6-9 below.

The example was constructed in accordance with Table 5, above. The comparative examples C1-C4 are commercially available golf balls. Specifically, the "Pro V1" is a tour-level golf ball made and sold by Titleist, the "Tour (i)s" is a tour-level golf ball made and sold by Callaway Golf, and the "One Tour" and "One Tour D" are both tour-level golf balls made and sold by Nike Inc. For each example and comparative example, six instances of each golf ball were tested with the golf ball being aligned on the seam, and six instances were tested with the golf ball being aligned on the pole. These twelve data points were then averaged for each type of golf ball to arrive at the data shown in Tables 6-9.

The golf balls as shown in the second column of Table 6 are the same example and comparative examples E1 and C1-C4 throughout all tests. The weights and compressions shown in Table 6 are the same through all of the tests, and are omitted from Tables 7-9 only for convenience.

The following tests for driver shots show how exemplary golf ball in accordance with this disclosure achieve a better initial velocity performance when the head speed is very high.

### Table 6 - Golf ball Testing Data - Head Speed = 125 mph

<table>
<thead>
<tr>
<th>#</th>
<th>Golf Ball</th>
<th>Weight (mph)</th>
<th>Compression (mph)</th>
<th>Ball IV (rpm)</th>
<th>Back spin (rpm)</th>
<th>Launch angle °</th>
<th>Carry (yards)</th>
<th>Total Distance (yards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>Example 1</td>
<td>45.72</td>
<td>2.55</td>
<td>174</td>
<td>2561</td>
<td>12.3</td>
<td>294</td>
<td>313</td>
</tr>
<tr>
<td>C1</td>
<td>One Tour D</td>
<td>45.57</td>
<td>2.86</td>
<td>171</td>
<td>2905</td>
<td>13.2</td>
<td>286</td>
<td>299</td>
</tr>
<tr>
<td>C2</td>
<td>Pro V1</td>
<td>45.83</td>
<td>2.66</td>
<td>173</td>
<td>3065</td>
<td>12.5</td>
<td>288</td>
<td>300</td>
</tr>
<tr>
<td>C3</td>
<td>Tour (i)s</td>
<td>45.94</td>
<td>2.58</td>
<td>171</td>
<td>3103</td>
<td>12.9</td>
<td>285</td>
<td>297</td>
</tr>
<tr>
<td>C4</td>
<td>One Tour</td>
<td>45.62</td>
<td>2.6</td>
<td>171</td>
<td>3375</td>
<td>12.3</td>
<td>283</td>
<td>292</td>
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</tbody>
</table>

### Table 7 - Golf ball Testing Data - Head Speed = 110 mph

<table>
<thead>
<tr>
<th>Test #</th>
<th>Ball Initial Velocity (mph)</th>
<th>Back spin (rpm)</th>
<th>Launch angle °</th>
<th>Carry (yards)</th>
<th>Total Distance (yards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>160</td>
<td>2745</td>
<td>12.3</td>
<td>264</td>
<td>284</td>
</tr>
<tr>
<td>C1</td>
<td>159</td>
<td>2748</td>
<td>12.7</td>
<td>263</td>
<td>283</td>
</tr>
<tr>
<td>C2</td>
<td>159</td>
<td>2829</td>
<td>12.6</td>
<td>263</td>
<td>283</td>
</tr>
<tr>
<td>C3</td>
<td>157</td>
<td>2801</td>
<td>12.7</td>
<td>260</td>
<td>279</td>
</tr>
<tr>
<td>C4</td>
<td>160</td>
<td>3223</td>
<td>12.5</td>
<td>263</td>
<td>276</td>
</tr>
</tbody>
</table>

### Table 8 - Golf ball Testing Data - Head Speed = 95 mph

<table>
<thead>
<tr>
<th>Test #</th>
<th>Ball Initial Velocity (mph)</th>
<th>Back spin (rpm)</th>
<th>Launch angle °</th>
<th>Carry (yards)</th>
<th>Total Distance (yards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>116</td>
<td>2664</td>
<td>11.1</td>
<td>157</td>
<td>191</td>
</tr>
<tr>
<td>C1</td>
<td>117</td>
<td>2512</td>
<td>11.5</td>
<td>158</td>
<td>194</td>
</tr>
<tr>
<td>C2</td>
<td>116</td>
<td>2783</td>
<td>11.3</td>
<td>158</td>
<td>191</td>
</tr>
<tr>
<td>C3</td>
<td>117</td>
<td>2659</td>
<td>11.1</td>
<td>156</td>
<td>191</td>
</tr>
<tr>
<td>C4</td>
<td>116</td>
<td>2980</td>
<td>10.9</td>
<td>156</td>
<td>188</td>
</tr>
</tbody>
</table>
Table 10 shows how an exemplary ball in accordance with this disclosure has a large difference between the initial velocity under a high club head speed and the initial velocity under a low club head speed. In particular, the difference between 125 mph and 80 mph is larger than any comparative example. Accordingly, the slope of the function "initial velocity = function (club head speed)" is steep.

Therefore, a golf ball in accordance with this disclosure may perform well at lower swing speeds (such as those achieved by amateur golfers) by achieving an initial velocity that is substantially similar to various comparative examples. Further, a golf ball in accordance with this disclosure may also perform better than a variety of comparative examples at higher swing speeds (such as those achieved by professional golfers) by achieving an increased initial velocity. Therefore, a golf ball in accordance with this disclosure may be versatile enough to be easily used by golfers having a wide range of abilities.

While various embodiments of the invention have been described, the description is intended to be exemplary, rather than limiting and it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible that are within the scope of the invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents. Also, various modifications and changes may be made within the scope of the attached claims.

Further embodiments include:

1. A golf ball (300) comprising:

   an inner core (310), the inner core (310) being formed primarily of at least one thermoplastic highly neutralized polymer;
   an outer core layer (320), the outer core layer (320) substantially surrounding the inner core (310) and comprising a thermoset rubber; and
   at least one cover layer (330, 340);

   wherein the inner core (310) has a compression deformation of from about 3.5 mm to about 4.1 mm, the outer core layer (320) has a compression deformation of from about 2.7 mm to about 3.3 mm, and a ratio of the compression deformation of the inner core (310) to the compression deformation of the outer core layer (320) is from about 1.1 to about 1.3; and

   the golf ball (300) has an initial velocity measured at a club head speed of about 125 mph of at least about 174 mph, and the golf ball (100) has a COR of at most about 0.80, wherein
the inner core (310) has a diameter of from about 20 mm to about 26 mm;
the inner core (310) is made primarily of a thermoset rubber, and the outer core layer (320) has a thickness of
from about 5 mm to about 9 mm;
the golf ball (300) comprises as the at least one cover layer (330, 340) an inner cover layer (330), the inner
cover layer (330) substantially surrounding the outer core layer (320); and an outer cover layer (340), the outer
cover layer (340) substantially surrounding the inner cover layer (330); and
the inner core (310) has a first COR,
the outer core (320) layer has a second COR,
the second COR being greater than the first COR, the second COR having a value of at least 0.80,
wherein the cover layer (330, 340) comprises a crosslinked thermoplastic polyurethane that is the reaction
product of unsaturated bonds located in hard segments of the polyurethane polymer prepared using trimethy-
lolpropane monoallyl ether, as catalyzed by a free radical initiator.

2. The golf ball (300) according to embodiment 1, wherein the golf ball (300) has a initial velocity measured at a
club head speed of about 80 mph of at least 88 mph, and the difference between the initial velocity at a club head
speed of about 125 mph and the initial velocity at the club head speed of about 80 mph is at least about 86 mph.

3. The golf ball (300) according to embodiment 1, wherein the outer core layer (320) has a surface Shore D hardness
of at least about 55.

4. The golf ball (300) according to embodiment 1, wherein the inner core (310) consists essentially of a mixture of
two highly neutralized polymers.

5. The golf ball (300) according to embodiment 1, wherein
the first COR being greater than the golf ball COR.

6. The golf ball (300) according to embodiment 1, wherein the cover layer (330, 340) comprises a crosslinked
thermoplastic polyurethane that is the reaction product of unsaturated bonds located in hard segments of the poly-
urethane polymer, as catalyzed by a free radical initiator; the unsaturated bonds being present in an unsaturated
diol of formula (1):

$$\text{HO-}\left(\text{H}_2\text{C}ight)_x\text{C-}\left(\text{CH}_2\right)_y\text{OH}$$

in which $R^1$ is a substituted or unsubstituted alkyl group, substituted or unsubstituted aryl group, substituted or
unsubstituted alkyl-aryl group, substituted or unsubstituted ether group, substituted or unsubstituted ester group,
any combination of these groups, or H, optionally including an unsaturated bond in any main chain or side chain of
any group; $R^2$ is a substituted or unsubstituted alkyl group, substituted or unsubstituted aryl group, substituted or
unsubstituted alkyl-aryl group, substituted or unsubstituted ether group, substituted or unsubstituted ester group,
or a continuation of the single bond, and $R^2$ includes an allyl group; and $x$ and $y$ are integers independently having
any value from 1 to 10.

7. The golf ball (300) of embodiment 1, wherein the golf ball (300) has an initial velocity measured at a club head
speed of about 80 mph of at least about 88 mph.

8. The golf ball (300) of embodiment 1, wherein
the inner cover layer (330) is formed primarily of a thermoplastic material, has a surface Shore D hardness of at
least 60, and has a thickness of less than 1 mm; and
the outer cover layer (340) comprises a thermoplastic material, has a surface Shore D hardness of from 50 to 60,
and has a thickness that is greater than the thickness of the inner cover layer (330).
Claims

1. A golf ball (300) comprising:
   - an inner core (310), the inner core (310) consisting essentially of at least one highly neutralized polymer;
   - an outer core layer (320), the outer core layer (320) substantially surrounding the inner core (310) and being made primarily of a thermoset rubber;
   - an inner cover layer (330), the inner cover layer (330) substantially surrounding the outer core layer (320); and
   - an outer cover layer (340), the outer cover layer (340) substantially surrounding the inner cover layer (330);
   wherein the golf ball (300) has an initial velocity measured at a club head speed of about 125 mph of at least about 174 mph, wherein
   - the inner core (310) has a surface Shore D hardness of at least about 60;
   - the outer core layer (320) has a surface Shore D hardness of from about 50 to about 60;
   - the inner cover layer (330) has a surface Shore D hardness of at least 60; and the outer cover layer (340) has a surface Shore D hardness of from about 50 to about 60.

2. The golf ball (300) of claim 1, wherein the golf ball (300) has an initial velocity measured at a club head speed of about 129 km/h (80 mph) of at least 142 km/h (88 mph), and the difference between the initial velocity at a club head speed of about 201 km/h (125 mph) and the initial velocity at the club head speed of about 129 km/h (80 mph) is at least about 138 km/h (86 mph).

3. The golf ball (300) of claim 1, wherein the inner core (310) consists essentially of a mixture of two highly neutralized polymers.

4. The golf ball (300) of claim 1, wherein
   - the inner core (310) has a diameter of from about 20 mm to about 26 mm;
   - the outer core layer (320) has a thickness of from about 5 mm to about 9 mm; the inner cover layer (330) has a thickness of less than 1 mm; and
   - the outer cover layer (340) has a thickness that is greater than the thickness of the inner cover layer (330).

5. The golf ball (300) of claim 19, wherein
   - the inner core (310) has a first COR;
   - the outer core layer (320) has a second COR;
   - the second COR being greater than the first COR, the second COR being 0.80 or more; and the first COR being greater than the golf ball COR.

6. The golf ball (300) of claim 1, wherein the golf ball (300) has a COR of about 0.80 or less.
# Documents Considered to Be Relevant

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>Classification of the application (IPC)</th>
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The present search report has been drawn up for all claims.

Examiner: Jekabsons, Armands

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<td>Munich</td>
<td>19 April 2016</td>
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- **T**: theory or principle underlying the invention
- **E**: earlier patent document, but published on, or after the filing date
- **D**: document cited in the application
- **L**: document cited for other reasons
- **A**: member of the same patent family, corresponding document

**CATEGORY OF CITED DOCUMENTS**

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19-04-2016

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For more details about this annex: see Official Journal of the European Patent Office, No. 12/82
REFERENCES CITED IN THE DESCRIPTION

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