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(54) **GOLF BALL COMPRISING RENEWABLE RESOURCE COMPONENT**

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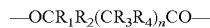
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(57) **ABSTRACT**

The invention is directed to a golf ball comprising a core and a cover, wherein at least one of the core and the cover comprises about 10 wt % or greater of a renewable polymer composition comprising an ultra high molecular weight polyhydroxyalkanoate compound having the formula:



wherein n is an integer, and wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub> and R<sub>4</sub> are selected from the group comprising saturated and unsaturated hydrocarbon radicals, halo- and hydroxy-substituted radicals, hydroxy radicals, halogen radicals; nitrogen-substituted radicals, oxygen-substituted radicals, or hydrogen atoms. In one embodiment, the golf ball also comprises about 90 wt % or less of a non renewable polymer composition. The golf ball may also comprise an intermediate layer disposed about the core and adjacent the cover, wherein at least one of the core, the cover and the intermediate layer comprises the renewable polymer composition. The renewable polymer composition comprises at least one of a flexural modulus of about 50,000 psi or greater and a tensile strength of about 2,000 psi or greater. The at least one of the core and the cover or the intermediate layer may comprise a hardness of from about 50 Shore C to about 90 Shore C.

## GOLF BALL COMPRISING RENEWABLE RESOURCE COMPONENT

### CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of co-pending U.S. patent application Ser. No. 12/762,394, filed Apr. 19, 2010, which is a continuation-in-part of co-pending U.S. patent application Ser. No. 12/752,423, filed Apr. 1, 2010, which is a continuation of co-pending U.S. patent application Ser. No. 12/752,378, filed Apr. 1, 2010.

### FIELD OF THE INVENTION

[0002] The invention relates to a golf ball including a renewable resource component comprising a biodegradable composition in at least one of the golf ball core (having one or more layers), intermediate layer(s) and cover layer(s). The resulting golf ball possesses desirable playing characteristics such as high resiliency, sustained impact durability, and soft feel, meanwhile protecting the environment over an extended period of time by being decomposable.

### BACKGROUND OF THE INVENTION

[0003] Golf balls are generally divided into two classes: solid and wound. Solid golf balls include a solid core of one or more layers, a cover of one or more layers, and optionally one or more intermediate layers. Wound golf balls typically include a solid, hollow, or fluid-filled center, surrounded by tensioned elastomeric material, and a cover. Solid golf balls, as compared with wound balls, are more durable and resilient, providing better distance than wound balls due to their higher initial velocity upon impact with a club face. Meanwhile, the wound construction provides a softer “feel”, lower compression and higher spin rate—characteristics often preferred by accomplished golfers who are able to control the ball’s flight and positioning.

[0004] By altering solid golf ball construction and composition, manufacturers can vary a wide range of playing characteristics such as resilience, durability, spin, and “feel”, optimizing each according to various playing abilities and achieving a solid golf ball possessing feel characteristics more like their wound predecessors. For example, by shifting the density (the weight or mass of the golf ball) toward the center of the ball, the moment of inertia of the golf ball can be reduced, thereby increasing the initial spin rate of the ball as it leaves the golf club head as a result of the higher resistance from the golf ball’s moment of inertia.

[0005] In this regard, core is the “engine” of the golf ball when hit with a club head. That is, it is the spring of the ball and its principal source of resiliency. Meanwhile, the intermediate layers based on ionomers aid in maintaining initial speed, contribute to desired spin rate, and improve playability/impact durability as well as acting as a moisture barrier to protect the cores from the CoR loss. The cover, while originally intended to protect the golf ball from scuffing, may also be modified to target a desired spin rate, feel, and playability, even addressing such issues as “lift” and “drag”.

[0006] Golf ball manufacturers, motivated recently by concerns about the welfare of the environment, have sought to incorporate materials in the core, intermediate layer and/or cover which not only improve performance, but are also at least in part biodegradable, decomposable, and easily disposed of or discarded in an environmentally friendly fashion.

Conventionally, golf ball cores and/or centers are constructed with a polybutadiene-based polymer composition which is obtained from a non-renewable resource such as petroleum, a non biodegradable/non renewable resource which may cause some long term detrimental effects on the environment. The core compositions of this type are constantly being altered in an effort to provide a targeted or desired coefficient of restitution (“COR”) while at the same time resulting in a lower compression which, in turn, can lower the golf ball spin rate, provide better “feel,” or both. This is a difficult task, however, given the physical limitations of currently-available polymers. Accordingly, there is a need for a material that overcomes these limitations, meanwhile being biodegradable.

[0007] Manufacturers likewise struggle in their attempt to improve intermediate and cover layers. For example, the hardness range in golf ball utilizing conventional ionomer blends is still limited and even the softest blends suffer from a “plastic” feel according to some golfers. Recently, polyurethane-based materials have been employed in golf ball layers and, in particular, outer cover layers, due to their softer “feel” characteristics without loss in resiliency and/or durability. However, these polyurethane components are likewise petroleum based, furthering the long term detrimental effect on the environment. Therefore, there remains a similar need for novel and improved golf ball intermediate layer and cover compositions having at least some biodegradable characteristics.

[0008] One attempt to incorporate biodegradable materials in golf balls is seen in U.S. 2006/0205534A1 of Egashira et al., which discloses golf balls including ester group-containing or ester group-free biodegradable compounds. However, Egashira et al., like other attempts, fails to recognize or appreciate that the molecular weight of the renewable resource component in a biodegradable composition, i.e. low, medium high or ultra high is an important consideration and directly impacts golf ball characteristics, playability and melt processability during injection or compression molding of golf ball layers. In this regard, Egashira et al. explicitly instructs that no particular molecular weight limitation should be placed on the biodegradable compounds. See Egashira et al., for example, at [0018].

[0009] Meanwhile, Egashira et al. and other attempts to incorporate biodegradable materials in golf balls do not disclose nor appreciate the benefits of incorporating ultra high molecular weight polyhydroxyalkanoate compounds (UHM-WPHA) in at least one of the core, core layer(s), intermediate layer(s) and cover layer(s) of a golf ball to improve golf ball characteristics. Further, heretofore, the benefits of including functional moieties such as acid, ionic, ester, anhydride or amine in ultra high molecular weight PHA golf ball compositions have also been overlooked.

[0010] Polyhydroxyalkanoates, or PHAs, are produced in nature by bacterial fermentation of sugar or lipids. They are produced by the bacteria to store carbon and energy. The resulting characteristics of a PHA composition can be changed by altering any or all of the bacterial strain being used, the carbon source, and the fermentation conditions. Accordingly, due to this as well as the chemical reactivity nature of PHA’s, several different monomers can be combined within this family to provide materials with a wide range of different properties from very stiff to very soft, each of which may be incorporated to achieve a desired golf ball characteristic. Golf ball properties can also be easily and inexpensively changed by blending, modifying the surface or

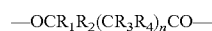
combining PHAs with other polymers, enzymes and inorganic materials, making it possible for a wider range of applications.

**[0011]** Hence, a golf ball designer can simply and inexpensively manufacture golf balls including such biodegradable materials using conventional golf ball manufacturing processes and methods to impart either a low spin from a driver to a high spin golf ball close to the green for better controllability. This is especially true, given that homo and copolymers of PHAs have a wide range of melting points ranging from about 40° C. to about 180° C.

**[0012]** Accordingly, there remains a need for an improved golf ball comprising a renewable polymer composition having a biodegradable ultra high molecular weight polyhydroxyalkanoate component possessing a targeted molecular weight, strategically chosen in order to optimize golf ball characteristics and performance on the green. Further, there is a particular need for an inexpensively manufactured golf ball comprising a renewable polymer composition having both biodegradable features and targeted notched Izod impact strength, polydispersity, flexural modulus strength and/or tensile strength. Such a golf ball would possess desired stiffness and impact durability and result in reduced backspin to the driver, thereby improving distance and control on the green.

#### SUMMARY OF THE INVENTION

**[0013]** This invention is therefore directed to an improved golf ball comprising a renewable polymer composition comprising ultra high molecular weight polyhydroxyalkanoate compounds and their functionalized derivatives and blends. In particular, the golf ball of the invention comprises a core and a cover, wherein at least one of the core and the cover comprises about 10 wt % or greater of a renewable polymer composition comprising a UHMWPHA compound having the formula:



wherein n is an integer, and wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub> and R<sub>4</sub> are selected from the group comprising saturated and unsaturated hydrocarbon radicals, halo- and hydroxy-substituted radicals, hydroxy radicals, halogen radicals; nitrogen-substituted radicals, oxygen-substituted radicals, or hydrogen atoms. Such compositions provide improved resiliency and impact durability during play. The ball travels a longer distance from a driver swing, meanwhile maintaining controllability closer to the green.

**[0014]** In one embodiment, the at least one of the core and the cover further comprises about 90 wt % or less of either a non renewable polymer composition, a different renewable polymer composition, or blend thereof.

**[0015]** In the golf ball of the invention, two particularly synergistic structural arrangements are simultaneously in place within the renewable polymer composition to achieve high resiliency, sustained impact durability, and soft feel. First, the long chain of the UHMWPHA compound, characteristic of its ultra high molecular weight, beneficially serves to transfer load more effectively to the polymer backbone by strengthening intermolecular interactions, resulting in a tougher golf ball material with higher impact strength, etc. This occurs from an increase in chain interactions such as Van der Waals attractions and entanglements that come with increased chain length and tend to fix the individual chains

more strongly in position and resist deformations and matrix breakup, both at higher stresses and higher temperatures.

**[0016]** Meanwhile, the above-enumerated desired golf ball characteristics are further enhanced or achieved where the UHMWPHA compound and the at least one non-renewable polymer composition are associated, coupled and/or bonded via/by at least one of a dipole-dipole interaction, ion-dipole interaction, ion-ion interaction and hydrogen bonding with other golf ball materials. In one embodiment, the UHMWPHA exhibits a bond energy in the range of from about 150 to 250 KJ/mol when bonded with at least one non-renewable polymer composition by dipole-dipole interactions. In another embodiment, the UHMWPHA exhibits a bond energy in the range of from about 450 to 550 KJ/mol when bonded with at least one non-renewable polymer composition by hydrogen bonding. In another embodiment, the UHMWPHA exhibits a bond energy in the range of from about 600 to 950 KJ/mol when bonded with at least one non-renewable polymer composition by ion-dipole or ion-ion interactions. The above bond energy may determined using any technique known in the art, including a calorimetry technique.

**[0017]** By non-limiting example, the UHMWPHA compounds are particularly suitable in golf ball compositions because they are capable of being dipole-dipole coupled, ion-dipole coupled, ion-ion coupled and/or coupled via hydrogen bonding with nonrenewable conventional golf ball compositions. For example, these include, without limit, hard and soft ionomers, acid co-polymers and ter-polymers, polyurethanes, polyester elastomers, polyamide elastomers, polyamides, and polyesters, polyureas, ABS, SAN, PMMA, thermoplastic vulcanized elastomers, maleic anhydride or glycidyl acrylate or methacrylate grafted polymers, polyphenylene oxides, polycarbonates, block copolymers, alternate copolymers, epoxy resins etc. Alternatively, although the UHMWPHA is thermoplastic in nature, a thermoset UHMWPHA composition may be formed by crosslinking it into the composition as fill or by post cross-linking using chemical or radiation cross-linking techniques. In either case, a renewable composition material is produced that has two-ply strength—that is, not only within the renewable polymer composition itself but also as between biodegradable and non renewable materials.

**[0018]** Accordingly, this dual structural synergistic arrangement of the invention within the renewable polymer composition of the golf ball itself and between it and the non-renewable material enables golf ball manufacturers to inexpensively provide a biodegradable golf ball having high resiliency, sustained impact durability, and soft feel.

**[0019]** The golf ball of the invention moreover may include a renewable polymer composition comprising a targeted notched Izod impact strength, polydispersity, flexural modulus and/or tensile strength as disclosed more fully herein. The renewable polymer composition not only provides biodegradable characteristics to the resulting golf ball but also produces a resulting golf ball with desired stiffness, reduced back spin (and therefore increased distance) and impact durability.

**[0020]** Izod impact refers to the kinetic energy that is necessary to initiate material fracturing and continue it to the point of breaking. Typically, a higher material notched Izod impact strength correlates to higher impact durability. Notched Izod Impact is a single point test which measures a material's ability to resist impact from a swinging pendulum. A notched side of the material, having been clamped into a

pendulum impact test fixture, is struck with a pendulum repeatedly until breakage of the material occurs. The specimen is notched in order to prevent the material's deformation upon impact with the pendulum. Sometimes, the material may be tested at a temperature which simulates the actual conditions under which the material will be used. ASTM D256 is one well recognized testing procedure. ASTM impact energy is expressed in J/m or ft-lb/in. The standard L×W×D specimen is 64×12.7×3.2 mm (2.5×0.5× $\frac{1}{8}$  in.). Alternatively, a depth of 6.4 mm or 0.25 in. is sometimes preferred because it is sturdier. The depth just under the notch is 10.2 mm or 0.4 in. Impact strength is calculated by dividing the impact energy, in J or ft/lb, by the thickness of the sample. The test result is often the average of 5 samples.

**[0021]** In the golf ball of the invention, the renewable polymer composition may comprise a notched Izod impact strength of about 0.5 ft-lbs/inch or greater—that is, until no break. In another embodiment, the renewable polymer composition may comprise a notched Izod impact strength of from about 1.0 ft-lbs/inch to about 18.0 ft-lbs/inch. In yet another embodiment, the renewable polymer composition may comprise a notched Izod impact strength of from about 5.0 ft-lbs/inch to about 18.0 ft-lbs/inch.

**[0022]** Alternatively, the renewable polymer composition may comprise an ultra high molecular weight polyhydroxyalkanoate compound having a first notched Izod impact strength  $Iz_1$  and low to medium molecular weight polyhydroxyalkanoate compound having a second notched Izod impact strength  $Iz_2$  wherein the ratio of  $Iz_2$  to  $Iz_1$  is from about 0.03 to about 10.0.

**[0023]** In one non-limiting embodiment of the invention, the renewable polymer composition comprises the notched Izod impact strength at about 23° C. However, the notched Izod impact strength may be measured at a temperature of from about -40° C. to about 40° C.

**[0024]** Polydispersity is a measure of the distribution of molecular mass in a material sample. A polymer composition is polydisperse if its chain lengths vary over a range of molecular masses, thereby producing a broad range of size, shape and mass characteristics. It is the ratio of weight average molecular weight to the number average molecular weight. A composition's polydispersity index will be low, or close to 1, if the composition contains similar sequences and number of monomers with well defined, predictable structure. Polydispersity can be determined by several methods, including for example, Gel permeation chromatography and light scattering measurements.

**[0025]** In the golf ball of the invention, the renewable polymer composition may comprise in one embodiment a polydispersity of from about 1.0 to about 4.0. In another embodiment, the renewable polymer composition may comprise a polydispersity of from about 1.1 to about 3.0. In yet another embodiment, the renewable polymer composition may comprise a polydispersity of from about 1.2 to about 2.5.

**[0026]** Alternatively, the renewable polymer composition may comprise an ultra high molecular weight polyhydroxyalkanoate compound having a first polydispersity  $P_1$  and low to medium molecular weight polyhydroxyalkanoate compound having a second polydispersity  $P_2$  wherein the ratio of  $P_2$  to  $P_1$  is from about 0.25 to about 2.0.

**[0027]** Flexural modulus is a measure of a material's tendency to bend compared with its resistance to bending. It defines the relationship between bending stress and the resulting strain—that is, the ratio of stress to strain. Strain is the

amount a material will deform when a stress is applied. Elastic strain will disappear when the stress is removed. Plastic or yielding strain, on the other hand, results at high levels of stress for a particular material, wherein permanent deformation occurs so that the material will no longer return to its original shape. The units of measure for flexural modulus are pounds per square inch (psi) or Newtons per square meter, or pascals (Pa).

**[0028]** Flexural tests, such as ASTM D 790 are utilized to determine flexural modulus. In three point testing, a sample of specific shape and dimensions is subjected to force at three points. The material is supported on the bottom side near both ends and a force is exerted on the top in the center of the sample. While the test is often conducted at ambient temperature conditions, sometimes the temperature is chosen to simulate actual use conditions. Some materials, like rubber, will deform a great deal before reaching plastic or yielding strain.

**[0029]** In one embodiment of the golf ball of the invention, the renewable polymer composition may comprise a flexural modulus of from about 50,000 psi to about 500,000 psi. In another embodiment, the renewable polymer composition may comprise a flexural modulus of from about 75,000 psi to about 475,000 psi. In yet another embodiment, the renewable polymer composition may comprise a flexural modulus of from about 100,000 psi to about 460,000 psi.

**[0030]** Alternatively, in the golf ball of the invention, the renewable polymer composition may comprise an ultra high molecular weight polyhydroxyalkanoate compound having a first flexural modulus  $FM_1$  and a low to medium molecular weight polyhydroxyalkanoate composition having a second flexural modulus  $FM_2$  wherein the ratio of  $FM_2$  to  $FM_1$  is from about 0.1 to about 1.

**[0031]** The tensile strength of a material is the maximum force that can be applied to a material before it ceases to be "elastic". A material is considered to be elastic as long as it will return to its original shape when the force is terminated. Once a material ceases to be elastic, it reaches its "yield tensile strength", becoming "plastic". That is, the work produced by the force applied is no longer stored in the material as elastic energy but rather is now transformed into heat and energy for deformation. This occurs until the material is deformed to such an extent that it reaches its "ultimate tensile strength". Ultimate tensile strength is the maximum stress a material can withstand before breaking. At this point, the material breaks into two pieces and stored elastic energy within the material is suddenly released as noise, and/or heat and/or cracks. Herein, the term tensile strength shall refer to ultimate tensile strength. Tensile strength is measured in units of force per unit area,  $N/m^2$  (Pa) or pounds per square inch  $lbf/in^2$  (psi).

**[0032]** In one embodiment of the golf ball of the invention, the renewable polymer composition may comprise a tensile strength of from about 2,000 psi to about 6,000 psi.

**[0033]** In another embodiment, the renewable polymer composition may comprise a tensile strength of from about 2,200 psi to about 5,000 psi. In yet another embodiment, the renewable polymer composition may comprise a tensile strength of from about 2,300 psi to about 4,000 psi.

**[0034]** Alternatively, the renewable polymer composition may comprise an ultra high molecular weight polyhydroxyalkanoate compound having a first tensile strength  $TS_1$  and a low to medium molecular weight polyhydroxyalkanoate composition having a second tensile strength  $TS_2$  wherein the ratio of  $TS_2$  to  $TS_1$  is from about 0.3 to about 1.3.

[0035] Knowing or determining any one of the notched Izod, polydispersity, flexural modulus or tensile strength of the renewable polymer composition would not necessarily enable or provide a prediction as to what the value would be for any of these other named properties with respect to the renewable polymer composition.

#### DETAILED DESCRIPTION OF THE INVENTION

[0036] The inventive golf ball including a renewable polymer composition may comprise any type of ball construction known in the art. Such golf ball designs include, for example, single-piece, two-piece, three-piece, four-piece, and five-piece designs so long as at least one layer comprises a renewable component composition prepared in accordance with this invention. The core, intermediate, and/or cover portions of the ball may be single or multi-layered.

[0037] The golf balls of this invention preferably include at least one intermediate layer. As used herein, the term, "intermediate layer" means a layer of the ball disposed between the core and cover. The intermediate layer may be considered an outer core layer or inner cover layer or any other layer disposed between the inner core and outer cover of the ball. The intermediate layer also may be referred to as a casing or mantle layer. The intermediate layer preferably has water vapor barrier properties to prevent moisture from penetrating into the rubber core. The ball may include one or more intermediate layers disposed between the inner core and outer cover.

[0038] The renewable resource component of the golf ball of the invention may be disposed within any or all of the core, core layer(s), intermediate layer(s) and cover layer(s) and associated, coupled and/or bonded with at least one non-renewable polymer composition by one of the following mechanisms: dipole-dipole interaction, ion-dipole interaction, and hydrogen bonding. The UHMWPHA may further comprise at least one ultra high molecular weight polyhydroxyalkanoate compound selected, by non-limiting example, from the group comprising homopolymers of polyhydroxyalkanoate and polyhydroxybutyrate; a copolymer of hydroxybutyric acid and hydroxyvaleric acid; a copolymer of 3-hydroxybutyric acid and 4-hydroxybutyric acid; polyhydroxyoctanoate; a copolymer of 4-hydroxybutyric and 4-hydroxyhexanoic acid; a copolymer of 4-hydroxybutyric acid and 4-hydroxyoctanoic acid; a copolymer of 3-hydroxyoctanoic acid with 3-hydroxybutyric acid; a copolymer of 3-hydroxyhexanoic acid and 3-hydroxybutyric acid; a copolymer containing hydroxyoctanoate groups randomly distributed through the polymer chain and combinations thereof.

[0039] In one embodiment, the ultra high molecular weight polyhydroxyalkanoate compound comprises a molecular weight of about 60,000 grams/mole or greater. In another embodiment, the ultra high molecular weight polyhydroxyalkanoate compound comprises a molecular weight of from about 60,000 grams/mole to about 4,000,000 grams/mole. In yet another embodiment, the ultra high molecular weight polyhydroxyalkanoate compound comprises a molecular weight of from about 100,000 to 2,000,000. In still another embodiment, the ultra high molecular weight polyhydroxyalkanoate compound may comprise a molecular weight of from about 250,000 to about 1,000,000 grams/mole.

[0040] The at least one of the core and the cover of the invention may comprise a hardness of from about 50 Shore C to about 90 Shore C.

[0041] The golf ball may also comprise an intermediate layer disposed about the core and adjacent the cover, wherein at least one of the core, the cover and the intermediate layer comprises the renewable polymer composition. In this embodiment, the at least one of the core, the intermediate layer and the cover may comprise a hardness of from about 50 Shore C to about 90 Shore C.

[0042] In one embodiment of the golf ball of the invention, the at least one of the core and the cover comprises about 5 wt % or greater of the renewable polymer composition. In another embodiment, the renewable polymer composition comprises about 5 wt % or greater of the ultra high molecular weight polyhydroxyalkanoate compound. In yet another embodiment, the at least one of the core and the cover comprises about 5 wt % or greater of the ultra high molecular weight polyhydroxyalkanoate compound. In still another embodiment of the golf ball of the invention, the renewable polymer composition consists of 100 wt % of the ultra high molecular weight polyhydroxyalkanoate compound. Alternatively, the renewable polymer composition may also comprise less than 100 wt % of the ultra high molecular weight polyhydroxyalkanoate compound.

[0043] Furthermore, the mechanics and biocompatibility of UHMWPHA can also be changed by blending, modifying the surface or combining it with other polymers, enzymes and inorganic materials, making it possible for a wider range of golfers to meet their golf ball performance criteria, i.e. higher spin or lower spin on the golf course.

[0044] The ultra high molecular weight polyhydroxyalkanoate compound may further comprise end chain functionalities selected from the group comprising vinyl, carboxylic acid, carboxylic acid ester, anhydride, maleate, malic acid, fumaric acid, acetate, hydroxy, amine, butyrate, propanoate, primary alcohol, secondary alcohol, tertiary alcohol, amide, and polyhydric alcohol to provide improved chemical compatibility with non-PHA renewable and non-renewable polymers as well as to provide a desired golf ball performance.

[0045] The ultra high molecular weight polyhydroxyalkanoate compound may be formed from at least one of monomeric units and oligomeric units selected from the group comprising hydroxybutyrate, hydroxyvalerate, hydroxyhexanoate, hydroxyheptanoate, hydroxyoctanoate, hydroxynonanoate, hydroxydecanoate, hydroxyundecanoate, and hydroxydodecanoate and blends thereof. In addition, the copolymers of PHA of the present invention includes both random, alternate and block polymers.

[0046] In one embodiment,  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  are substantially similar. In another embodiment,  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  are different. In yet another embodiment,  $R_1$  is the same as at least one of  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$ . In still another embodiment,  $R_2$  is the same as at least one of  $R_1$ ,  $R_3$  and  $R_4$ . In still another embodiment,  $R_3$  may be the same as at least one of  $R_1$ ,  $R_2$ , and  $R_4$ . Meanwhile,  $R_4$  may be the same as at least one of  $R_1$ ,  $R_2$ , and  $R_3$ .

[0047] In one embodiment, where  $n$  may be 500 or greater ( $n \geq 500$ ), golf ball layer compositions comprising PHAs have good mechanical properties such as a tensile strength at break, an elongation at break and impact strength so that the golf balls exhibit good impact durability during its usage. Furthermore, when  $n$  is greater than 500, higher flexural modulus results and the golf ball will thereby exhibit a reduced back spin from a driver thereby enhancing its distance. This may be measured according to ASTM D790-03, procedure B, for example.

**[0048]** Where at least the core comprises the renewable polymer composition with improved resiliency and impact durability, the core may alternatively comprise a surface hardness of from about 50 Shore C to about 90 Shore C, or from about 55 Shore C to about 85 Shore C, or even from about 60 Shore C to about 80 Shore C. Where at least the cover comprises the renewable polymer composition, the cover may alternatively comprise a surface hardness of from about 60 Shore C to about 90 Shore C, or even from about 65 Shore C to about 85 Shore C. Where at least an intermediate layer comprises the renewable polymer composition, the intermediate layer may alternatively comprise a surface hardness of from about 30 about Shore D to about 75 Shore D, or from about 35 Shore D to about 70 Shore D, or even from about 40 Shore D to about 68 Shore D such that a golf ball has a low back spin-rate from a driver but still maintains its controllability for a short game. In another embodiment, the core comprises a first hardness of from about 50 Shore C to about 90 Shore C and the cover comprises a second hardness of from about 60 Shore C to about 95 Shore C wherein the ratio of the second hardness to the first hardness is about 0.6 or greater, regardless as to which of the core or the cover comprise the renewable polymer composition so that a golf ball provides a increased distance and control.

**[0049]** In another embodiment, where at least the core comprises the renewable polymer composition, the core may comprise a hardness of from about 30 Shore D to about 60 Shore D. Where at least the cover comprises the renewable polymer composition, the cover may comprise a hardness of from about 40 Shore D to about 65 Shore D. In an embodiment which includes an intermediate layer, where at least the intermediate layer comprises the renewable polymer composition, the intermediate layer may comprise a hardness of from about 30 Shore D to about 75 Shore D. In another embodiment, the core comprises a first hardness of from about 10 Shore D to about 50 Shore D and the cover comprises a second hardness of from about 30 Shore D to about 70 Shore D wherein the ratio of the second hardness to the first hardness is about 3 or greater, regardless as to which of the core or the cover comprise the renewable polymer composition.

**[0050]** The ultra high molecular weight polyhydroxyalkanoate compound may comprise an acid or ester group content of from about 2.5% by wt to 25% by wt.

**[0051]** The ultra high molecular weight polyhydroxyalkanoate compound may also comprise acid or ester groups wherein about 20 wt % or greater of the acid groups are neutralized by a cation source or about 20 wt % or greater of the ester groups are saponified by an inorganic base so that improved scuff resistant and some resiliency can be achieved in the ball. Alternatively, the ultra high molecular weight polyhydroxyalkanoate compound may comprise acid or ester groups wherein about 70 wt % or greater of the acid groups are neutralized or about 70 wt % or greater of the ester groups are saponified to provide additional boost in resiliency as well as soft and fast characteristics. In another embodiment, the ultra high molecular weight polyhydroxyalkanoate compound may comprise acid or ester groups wherein from about 80 wt % to about 100 wt % of the acid groups are neutralized or from about 80 wt % to about 100 wt % of the ester groups are saponified to improve resiliency and soft and fast characteristics.

**[0052]** The ultra high molecular weight polyhydroxyalkanoate compound may comprise a melt flow modifier

selected from the group comprising animal fats, plants, non-petroleum and petroleum based organic acids and their salts. The ultra high molecular weight polyhydroxyalkanoate compound may comprise the melt flow modifier in an amount of about 10% by weight or greater so that the compositions can provide improved processability such as enhanced melt flow to fill the golf ball layers uniformly without shifting the cores or intermediate layers. Alternatively, the ultra high molecular weight polyhydroxyalkanoate compound may comprise the melt flow modifier in an amount of from about 10% by weight to about 50% by weight. Such compositions also provide improved bio-degradability.

**[0053]** The renewable polymer composition may include a cation selected from the group comprising Li, Na, K, Cs, Mg, Ca, Ba, Mn, Zn, Cs, Zr, Ti, W, and Al such that those compositions provide increased resiliency and scuff resistant due to a strong ionic interaction between the ionic moieties. Preferably, Li, Na, Mg and Zn cations are used in the present invention to provide a balance golf ball performance such as a scuff resistant, resiliency and control due to a cation size and its ionic strength.

**[0054]** In one embodiment, the ultra high molecular weight polyhydroxyalkanoate compound may comprise acid groups wherein about 70 wt % or less of the acid groups are neutralized by, for example, any of the above-disclosed cations. Alternatively, the ultra high molecular weight polyhydroxyalkanoate compound may comprise acid groups wherein about 70 wt % or greater of the acid groups are neutralized by, for example, any of the above-disclosed cations.

**[0055]** In one embodiment, about 10 wt % to about 20 wt % of the renewable polymer composition is crosslinked to provide improved scuff resistance for a short game when the balls were stuck using sharp grooved wedges. The cross-linking can be achieved in one case by reacting functionalized PHAs such as hydroxyl or acid terminated PHAs with glycidyl acrylate or methacrylate or maleic anhydride based homo and copolymers from a non-renewable source like a copolymer of ethylene-glycidyl acrylate or maleic anhydride grafted ethylene-butene or hexene copolymer.

**[0056]** The at least one of the core and the cover further may comprise at least one softening comonomer selected from the group comprising alkyl acrylate, methacrylate, glycidyl acrylate, and glycidyl methacrylate for further controllability of the golf ball on the green. The at least one of the core and the cover may alternatively include a stiffening agent including a density adjusting filler selected from the group comprising zinc oxide, barium sulfate, tungsten, tungsten oxide, tungsten carbide, glass spheres, carbon or glass reinforced polymers or composites, carbon nanotubes, and blends thereof to reduce a back spin-rate from the driver shot to achieve maximum golf ball distance. Furthermore, at least one of the core and the cover may alternatively include at least one nano filler selected from the group comprising nano silicates, nano metallic oxides, nano metal powders, nano zinc oxides, nano carbon tubes, nano fullerenes, polyhedral oligomeric silsesquioxanes and blends thereof.

**[0057]** In one embodiment, the renewable polymer composition further comprises an ester compatibilizer selected from the group comprising a glycidyl ester, a maleic ester and an oligomeric ester. The oligomeric ester may include, for example, poly(1,3-butylene glycol-co-1,2-propylene glycol adipic acid) terminated with 2-ethylhexanol, poly(neopentyl glycol-co-1,4-butylene glycol adipic acid) terminated with 2-ethylhexanol, poly(1,3-butylene glycol adipic acid) unter-

minated, poly(1,3-butylene glycol adipic acid) unterminated, poly(1,2-propylene glycol adipic acid-co-phthalic acid) terminated with 2-ethylhexanol, poly(neopentyl glycol adipic acid) terminated with 2-ethylhexanol, poly(1,2-propylene glycol adipic acid-co-phthalic acid) terminated with 2-ethylhexanol, poly(1,2-propylene glycol-co-1,4-butylene glycol adipic acid) terminated with 2-ethylhexanol, poly(1,3-butylene glycol adipic acid) terminated with mixed fatty acids, poly(1,2-propylene glycol adipic acid) terminated with 2-ethylhexanol, poly(1,2-propylene glycol-co-1,4-butylene glycol adipic acid) terminated with 2-ethylhexanol, poly(1,4-butylene glycol adipic acid), or poly(1,4-butylene glycol-co-ethylene glycol adipic acid).

**[0058]** The golf ball may comprise a blended composition comprising the renewable polymer composition and at least one thermoplastic material selected from the group comprising ethylene based ionomers, highly neutralized polymers, polyester-ether elastomers, polyester-ester elastomers, polyether-amide elastomers, polyester-amide elastomers, polyurethane elastomers, thermoplastic vulcanized materials, EPDM rubber, EPR rubber, SEBS rubber, copolymers of ethylene-alkyl acrylates, copolymers of methacrylates, glycidyl acrylate copolymers, methacrylate copolymers, maleic anhydride grafted homopolymers, maleic anhydride grafted copolymers and polycaprolactone. In one embodiment, the blended composition comprises from about 50 wt % to about 95 wt % of the at least one thermoplastic material.

**[0059]** The renewable polymer composition may further comprise at least one renewable resource selected from the group comprising lignin, crop oils, grains, plant derived glucose, yeast, fungi, vegetable oils, canola oils, corn oils, flax, cellulose, fatty acids, animal fats, tallow oils, fish oils, wood resins, tannis, and polysaccharides to further enhance the bio-degradability and some instances the processability of the UHMWPHA to fill a thin layer of the golf ball to minimize the CoR loss and cost. In another embodiment, the different renewable polymer composition comprises at least one of these renewable resources.

**[0060]** In one embodiment, the renewable polymer composition further comprises at least one renewable resource selected from the group comprising soy protein, starch, polyesters, polylactic acids, triglycerides, homo- and copolymers of polyhydroxyalkanoates. In another embodiment, the different renewable polymer composition comprises at least one of these renewable resources in order to provide improved bio-degradability and melt processability along with desired ball performance.

**[0061]** The golf ball of the present invention may also comprise non renewable polymeric compositions including, for example, a synthetic polymer selected from homo- and copolymers of polyolefin, polyester, polycarbonate, polyamide, polyurethane, polyacrylic, polyimide, epoxy and combinations thereof.

**[0062]** The golf ball of the invention may also comprise an intermediate layer disposed between the core and the cover, wherein at least one of the core, the cover and the intermediate layer comprises the renewable polymer composition. Alternatively, the core may comprise an inner core layer and an outer core layer wherein the outer core layer comprises the renewable polymer composition. In one embodiment of the golf ball of the invention, the cover comprises an inner cover and an outer cover and the inner cover comprises renewable polymer composition. However, these examples are not limiting as to which component/layer of the golf ball may com-

prise the renewable polymer composition or as to the number of golf ball components and/or layers which may comprise the renewable polymer composition.

**[0063]** The cores in the golf balls of this invention may be solid, semi-solid, hollow, fluid-filled, or powder-filled. Typically, the cores are solid and made from rubber compositions containing a base rubber, free-radical initiator agent, cross-linking co-agent, fillers and 5 to 25 wt % of a renewable component of the present invention. The addition of a renewable component provides some biodegradable characteristics along with increased toughness and improved golf ball performance like distance and control. The base rubber may be selected, for example, from polybutadiene rubber, polyisoprene rubber, natural rubber, ethylene-propylene rubber, ethylene-propylene diene rubber, styrene-butadiene rubber, and combinations of two or more thereof. A preferred base rubber is polybutadiene.

**[0064]** Examples of desirable polybutadiene rubbers include BUNA® CB22 and BUNA® CB23, TAKTENE® 1203G1, 220, 221, and PETROFLEX® BRNd-40, commercially available from LANXESS Corporation; BR-1220 available from BST Elastomers Co. LTD; UBEPOL® 360L and UBEPOL® 150L and UBEPOL-BR rubbers, commercially available from UBE Industries, Ltd. of Tokyo, Japan; KINEX® 7245 and KINEX® 7265, commercially available from Goodyear of Akron, Ohio; SE BR-1220, commercially available from Dow Chemical Company; Europrene® NEO-CIS® BR 40 and BR 60, commercially available from Polimeri Europa; and BR 01, BR 730, BR 735, BR 11, and BR 51, commercially available from Japan Synthetic Rubber Co., Ltd; and KARBOCHEM® ND40, ND45, and ND60, commercially available from Karbochem.

**[0065]** Another preferred base rubber is polybutadiene optionally mixed with one or more elastomers such as polyisoprene rubber, natural rubber, ethylene propylene rubber, ethylene propylene diene rubber, styrene-butadiene rubber, polystyrene elastomers, polyethylene elastomers, polyurethane elastomers, polyurea elastomers, acrylate rubbers, polyoctenamers, metallocene-catalyzed elastomers, and plastomers. As discussed further below, highly neutralized acid copolymers (HNPs), as known in the art, also can be used to form the core layer which is blended with 5 to 25 wt % of a renewable component of the present invention. Such compositions will provide increased flexural modulus and toughness thereby improving the golf ball's performance including its impact durability along with some biodegradable characteristics for the environment.

**[0066]** The base rubber typically is mixed with at least one reactive cross-linking co-agent to enhance the hardness of the rubber composition. Suitable co-agents include, but are not limited to, unsaturated carboxylic acids and unsaturated vinyl compounds. A preferred unsaturated vinyl is trimethylolpropane trimethacrylate. The rubber composition is cured using a conventional curing process. Suitable curing processes include, for example, peroxide curing, sulfur curing, high-energy radiation, and combinations thereof. In one embodiment, the base rubber is peroxide cured. Organic peroxides suitable as free-radical initiators include, for example, dicumyl peroxide; n-butyl-4,4-di(t-butylperoxy) valerate; 1,1-di(t-butylperoxy)3,3,5-trimethylcyclohexane; 2,5-dimethyl-2,5-di(t-butylperoxy)hexane; di-t-butyl peroxide; di-t-amyl peroxide; t-butyl peroxide; t-butyl cumyl peroxide; 2,5-dimethyl-2,5-di(t-butylperoxy)hexyne-3; di(2-t-butylperoxyisopropyl)benzene; dilauroyl peroxide; dibenzoyl

peroxide; t-butyl hydroperoxide; and combinations thereof. Cross-linking agents are used to cross-link at least a portion of the polymer chains in the composition. Suitable cross-linking agents include, for example, metal salts of unsaturated carboxylic acids having from 3 to 8 carbon atoms; unsaturated vinyl compounds and polyfunctional monomers (for example, trimethylolpropane trimethacrylate); phenylene bismaleimide; and combinations thereof. In a particular embodiment, the cross-linking agent is selected from zinc salts of acrylates, diacrylates, methacrylates, and dimethacrylates. In another particular embodiment, the cross-linking agent is zinc diacrylate ("ZDA"). Commercially available zinc diacrylates include those selected from Rockland React-Rite and Sartomer.

**[0067]** The base rubber may also comprise high or medium Mooney viscosity rubber, or blends thereof. The measurement of Mooney viscosity is defined according to ASTM D-1646. The Mooney viscosity range is preferably greater than about 30, more preferably in the range from about 35 to about 75 and more preferably in the range from about 40 to about 60. Polybutadiene rubber with higher Mooney viscosity may also be used, so long as the viscosity of the polybutadiene does not reach a level where the high viscosity polybutadiene clogs or otherwise adversely interferes with the manufacturing machinery. It is contemplated that polybutadiene with viscosity less than about 75 Mooney can be used with the present invention.

**[0068]** In one embodiment of the present invention, golf ball cores made with mid- to high-Mooney viscosity polybutadiene material exhibit increased resiliency (and, therefore, distance) without increasing the hardness of the ball.

**[0069]** Commercial sources of suitable mid- to high-Mooney viscosity polybutadiene include Lanxess Buna CB23 (Nd-catalyzed), which has a Mooney viscosity of around 50 and is a highly linear polybutadiene, and Dow SE BR-1220 (Co-catalyzed). If desired, the polybutadiene can also be mixed with other elastomers known in the art, such as other polybutadiene rubbers, natural rubber, styrene butadiene rubber, and/or isoprene rubber in order to further modify the properties of the core. When a mixture of elastomers is used, the amounts of other constituents in the core composition are typically based on 100 parts by weight of the total elastomer mixture.

**[0070]** Thermoplastic elastomers (TPE) many also be used to modify the properties of the core layers, or the uncured core layer stock by blending with the base thermoset rubber. These TPEs include natural or synthetic balata, or high trans-polyisoprene, high trans-polybutadiene, or any styrenic block copolymer, such as styrene ethylene butadiene styrene, styrene-isoprene-styrene, etc., a metallocene or other single-site catalyzed polyolefin such as ethylene-octene, or ethylene-butene, or thermoplastic polyurethanes (TPU), including copolymers, e.g. with silicone. Other suitable TPEs for blending with the thermoset rubbers of the present invention include PEBAX®, which is believed to comprise polyether amide copolymers, HYTREL®, which is believed to comprise polyether ester copolymers, thermoplastic urethane, and KRATON®, which is believed to comprise styrenic block copolymers elastomers. Any of the TPEs or TPUs above may also contain functionality suitable for grafting, including maleic acid or maleic anhydride. Any of the Thermoplastic Vulcanized Rubbers (TPV) such as Santoprene® or Vibram® or ETPV® can be used along with a present invention. In one embodiment, the TPV has a thermoplastic as a continuous

phase and a cross-linked rubber particulate as a dispersed (or discontinuous) phase. In another embodiment, the TPV has a cross-linked phase as a continuous phase and a thermoplastic as a dispersed (or discontinuous) phase to provide reduced loss in elasticity in order to improve the resiliency of the golf ball.

**[0071]** The rubber compositions also may contain "soft and fast" agents such as a halogenated organosulfur, organic disulfide, or inorganic disulfide compounds. Particularly suitable halogenated organosulfur compounds include, but are not limited to, halogenated thiophenols. Preferred organic sulfur compounds include, but not limited to, pentachlorothiophenol ("PCTP") and a salt of PCTP. A preferred salt of PCTP is ZnPCTP. A suitable PCTP is sold by the Struktol Company (Stow, Ohio) under the tradename, A95. ZnPCTP is commercially available from EchinaChem (San Francisco, Calif.). These compounds also may function as cis-to-trans catalysts to convert some cis-1, 4 bonds in the polybutadiene to trans-1, 4 bonds. Antioxidants also may be added to the rubber compositions to prevent the breakdown of the elastomers. Other ingredients such as accelerators (for example, tetra methylthiuram), processing aids, dyes and pigments, wetting agents, surfactants, plasticizers, as well as other additives known in the art may be added to the rubber composition.

**[0072]** The core may be formed by mixing and forming the rubber composition using conventional techniques. These cores can be used to make finished golf balls by surrounding the core with outer core layer(s), intermediate layer(s), and/or cover materials as discussed further below. In another embodiment, the cores can be formed using highly neutralized polymer (HNP) compositions as disclosed in U.S. Pat. Nos. 6,756,436, 7,030,192, 7,402,629, and 7,517,289. The cores from the highly neutralized polymer compositions can be further cross-linked using any free-radical initiation sources including radiation sources such as gamma or electron beam as well as chemical sources such as peroxides and the like.

**[0073]** The core may contain sections having the same hardness or different hardness levels. That is, there can be uniform hardness throughout the different sections of the core or there can be hardness gradients across the layers. For example, in single cores, there may be a hard-to-soft gradient (a "positive" gradient) from the surface of the core to the geometric center of the core. In other instances, there may be a soft-to-hard gradient (a "negative" gradient) or zero hardness gradient from the core's surface to the core's center. For dual core golf balls, the inner core layer may have a surface hardness that is less than the geometric center hardness to define a first "negative" gradient. As discussed above, an outer core layer may be formed around the inner core layer, and the outer core layer may have an outer surface hardness less than its inner surface hardness to define a second "negative" gradient. In other versions, the hardness gradients from surface to center may be hard-to-soft ("positive"), or soft-to-hard ("negative"), or a combination of both gradients. In still other versions the hardness gradients from surface to center may be "zero" (that is, the hardness values are substantially the same.) Methods for making cores having positive, negative, and zero hardness gradients are known in the art as described in, for example, U.S. Pat. Nos. 7,537,530; 7,537,529; 7,427,242; and 7,410,429, the disclosures of which are hereby incorporated by reference.



**[0074]** Golf balls made in accordance with this invention can be of any size, although the USGA requires that golf balls used in competition have a diameter of at least 1.68 inches and a weight of no greater than 1.62 ounces. For play outside of USGA competition, the golf balls can have smaller diameters and be heavier.

**[0075]** The renewable component composition of this invention can be used to make the outer core, intermediate layer, inner cover, and/or outer cover. In some instances, a traditional thermoplastic or thermosetting composition may be used to make one layer and the renewable component composition may be used to make a different layer of the golf ball depending upon the desired ball construction playing performance properties. If a conventional thermoplastic or thermosetting composition is used in one layer (and the renewable component composition used in a different layer), then a wide variety of thermoplastic or thermosetting materials can be employed. These materials include for example, olefin-based copolymer ionomer resins (for example, Surlyn® ionomer resins and DuPont® HPF 1000 and HPF 2000, commercially available from E. I. du Pont de Nemours and Company; Iotek® ionomers, commercially available from ExxonMobil Chemical Company; Amplify® IO ionomers of ethylene acrylic acid copolymers, commercially available from The Dow Chemical Company; and Clarix® ionomer resins, commercially available from A. Schulman Inc.); polyurethanes; polyureas; copolymers and hybrids of polyurethane and polyurea; polyethylene, including, for example, low density polyethylene, linear low density polyethylene, and high density polyethylene; polypropylene; rubber-toughened olefin polymers; acid copolymers, for example, poly(meth)acrylic acid, which do not become part of an ionic copolymer; plastomers; flexomers; styrene/butadiene/styrene block copolymers; styrene/ethylene-butylene/styrene block copolymers; dynamically vulcanized elastomers; copolymers of ethylene and vinyl acetates; copolymers of ethylene and methyl acrylates; polyvinyl chloride resins; polyamides, poly(amide-ester) elastomers, and graft copolymers of ionomer and polyamide including, for example, Pebax® thermoplastic polyether block amides, commercially available from Arkema Inc; cross-linked trans-polyisoprene and blends thereof; polyester-based thermoplastic elastomers, such as Hytrel®, commercially available from E. I. du Pont de Nemours and Company; polyurethane-based thermoplastic elastomers, such as Elastollan®, commercially available from BASF; synthetic or natural vulcanized rubber; and combinations thereof.

**[0076]** While the inventive golf ball may be formed from a variety of differing and conventional materials for the intermediate layer(s), inner cover layer(s) and/or outer cover layer(s), preferred cover materials include, but are not limited to:

**[0077]** (1) Polyurethanes, such as those prepared from polyols or polyamines and diisocyanates or polyisocyanates and/or their prepolymers, and those disclosed in U.S. Pat. Nos. 5,334,673 and 6,506,851;

**[0078]** (2) Polyureas, such as those disclosed in U.S. Pat. Nos. 5,484,870 and 6,835,794; and

**[0079]** (3) Polyurethane-urea hybrids, blends or copolymers comprising urethane or urea segments.

**[0080]** Suitable polyurethane compositions comprise a reaction product of at least one polyisocyanate and at least one curing agent. The curing agent can include, for example, one or more polyamines, one or more polyols, or a combination thereof. The polyisocyanate can be combined with one or

more polyols to form a prepolymer, which is then combined with the at least one curing agent. Thus, the polyols described herein are suitable for use in one or both components of the polyurethane material, i.e., as part of a prepolymer and in the curing agent. Suitable polyurethanes are described in U.S. Patent Application Publication No. 2005/0176523, which is incorporated by reference in its entirety.

**[0081]** Any polyisocyanate available to one of ordinary skill in the art is suitable for use according to the invention. Exemplary polyisocyanates include, but are not limited to, 4,4'-diphenylmethane diisocyanate (MDI); polymeric MDI; carbodiimide-modified liquid MDI; 4,4'-dicyclohexylmethane diisocyanate (H<sub>12</sub>MDI); p-phenylene diisocyanate (PPDI); m-phenylene diisocyanate (MPDI); toluene diisocyanate (TDI); 3,3'-dimethyl-4,4'-biphenylene diisocyanate; isophoronediiisocyanate; 1,6-hexamethylene diisocyanate (HDI); naphthalene diisocyanate; xylene diisocyanate; p-tetramethylxylene diisocyanate; m-tetramethylxylene diisocyanate; ethylene diisocyanate; propylene-1,2-diisocyanate; tetramethylene-1,4-diisocyanate; cyclohexyl diisocyanate; dodecane-1,12-diisocyanate; cyclobutane-1,3-diisocyanate; cyclohexane-1,3-diisocyanate; cyclohexane-1,4-diisocyanate; 1-isocyanato-3,3,5-trimethyl-5-isocyanatomethylcyclohexane; methyl cyclohexylene diisocyanate; triisocyanate of HDI; triisocyanate of 2,4,4-trimethyl-1,6-hexane diisocyanate; tetracene diisocyanate; naphthalene diisocyanate; anthracene diisocyanate; isocyanurate of toluene diisocyanate; uretdione of hexamethylene diisocyanate; and mixtures thereof. Polyisocyanates are known to those of ordinary skill in the art as having more than one isocyanate group, e.g., di-isocyanate, tri-isocyanate, and tetra-isocyanate. Preferably, the polyisocyanate includes MDI, PPDI, TDI, or a mixture thereof, and more preferably, the polyisocyanate includes MDI. It should be understood that, as used herein, the term MDI includes 4,4'-diphenylmethane diisocyanate, polymeric MDI, carbodiimide-modified liquid MDI, and mixtures thereof and, additionally, that the diisocyanate employed may be "low free monomer," understood by one of ordinary skill in the art to have lower levels of "free" monomer isocyanate groups, typically less than about 0.1% free monomer isocyanate groups. Examples of "low free monomer" diisocyanates include, but are not limited to Low Free Monomer MDI, Low Free Monomer TDI, and Low Free Monomer PPDI.

**[0082]** Any polyol available to one of ordinary skill in the art is suitable for use according to the invention. Exemplary polyols include, but are not limited to, polyether polyols, hydroxy-terminated polybutadiene (including partially/fully hydrogenated derivatives), polyester polyols, polycaprolactone polyols, and polycarbonate polyols. In one preferred embodiment, the polyol includes polyether polyol. Examples include, but are not limited to, polytetramethylene ether glycol (PTMEG), polyethylene propylene glycol, polyoxypropylene glycol, and mixtures thereof. The hydrocarbon chain can have saturated or unsaturated bonds and substituted or unsubstituted aromatic and cyclic groups. Preferably, the polyol of the present invention includes PTMEG.

**[0083]** In another embodiment, polyester polyols are included in the polyurethane material. Suitable polyester polyols include, but are not limited to, polyethylene adipate glycol; polybutylene adipate glycol; polyethylene propylene adipate glycol; o-phthalate-1,6-hexanediol; poly(hexamethylene adipate) glycol; and mixtures thereof. The hydrocarbon

chain can have saturated or unsaturated bonds, or substituted or unsubstituted aromatic and cyclic groups.

**[0084]** In another embodiment, polycaprolactone polyols are included in the materials of the invention. Suitable polycaprolactone polyols include, but are not limited to, 1,6-hexanediol-initiated polycaprolactone, diethylene glycol initiated polycaprolactone, trimethylol propane initiated polycaprolactone, neopentyl glycol initiated polycaprolactone, 1,4-butanediol-initiated polycaprolactone, and mixtures thereof. The hydrocarbon chain can have saturated or unsaturated bonds, or substituted or unsubstituted aromatic and cyclic groups.

**[0085]** In yet another embodiment, polycarbonate polyols are included in the polyurethane material of the invention. Suitable polycarbonates include, but are not limited to, polyphthalate carbonate and poly(hexamethylene carbonate) glycol. The hydrocarbon chain can have saturated or unsaturated bonds, or substituted or unsubstituted aromatic and cyclic groups. In one embodiment, the molecular weight of the polyol is from about 200 to about 4000.

**[0086]** Polyamine curatives are also suitable for use in the polyurethane composition of the invention and have been found to improve cut, shear, and impact resistance of the resultant balls. Preferred polyamine curatives include, but are not limited to, 3,5-dimethylthio-2,4-toluenediamine and isomers thereof; 3,5-diethyltoluene-2,4-diamine and isomers thereof, such as 3,5-diethyltoluene-2,6-diamine; 4,4'-bis-(sec-butylamino)-diphenylmethane; 1,4-bis-(sec-butylamino)-benzene, 4,4'-methylene-bis-(2-chloroaniline); 4,4'-methylene-bis-(3-chloro-2,6-diethylaniline); polytetramethyleneoxide-di-p-aminobenzoate; N,N'-dialkyl-diamino diphenyl methane; p,p'-methylene dianiline; m-phenylenediamine; 4,4'-methylene-bis-(2-chloroaniline); 4,4'-methylene-bis-(2,6-diethylaniline); 4,4'-methylene-bis-(2,3-dichloroaniline); 4,4'-diamino-3,3'-diethyl-5,5'-dimethyl diphenylmethane; 2,2', 3,3'-tetrachloro diamino diphenylmethane; trimethylene glycol di-p-aminobenzoate; and mixtures thereof. Preferably, the curing agent of the present invention includes 3,5-dimethylthio-2,4-toluenediamine and isomers thereof, such as ETHACURE® 300, commercially available from Albermarle Corporation of Baton Rouge, La. Suitable polyamine curatives, which include both primary and secondary amines, preferably have molecular weights ranging from about 64 to about 2000.

**[0087]** At least one of a diol, triol, tetraol, or hydroxy-terminated curatives may be added to the aforementioned polyurethane composition. Suitable diol, triol, and tetraol groups include ethylene glycol; diethylene glycol; polyethylene glycol; propylene glycol; polypropylene glycol; lower molecular weight polytetramethylene ether glycol; 1,3-bis(2-hydroxyethoxy)benzene; 1,3-bis-[2-(2-hydroxyethoxy)ethoxy]benzene; 1,3-bis-[2-[2-(2-hydroxyethoxy)ethoxy]ethoxy]benzene; 1,4-butanediol; 1,5-pentanediol; 1,6-hexanediol; resorcinol-di-β(3-hydroxyethyl)ether; hydroquinone-di-(β-hydroxyethyl)ether; and mixtures thereof. Preferred hydroxy-terminated curatives include 1,3-bis(2-hydroxyethoxy)benzene; 1,3-bis-[2-(2-hydroxyethoxy)ethoxy]benzene; 1,3-bis-[2-[2-(2-hydroxyethoxy)ethoxy]ethoxy]benzene; 1,4-butanediol, and mixtures thereof. Preferably, the hydroxy-terminated curatives have molecular weights ranging from about 48 to 2000. It should be understood that molecular weight, as used herein, is the absolute weight average molecular weight and would be understood as such by one of ordinary skill in the art.

**[0088]** Both the hydroxy-terminated and amine curatives can include one or more saturated, unsaturated, aromatic, and cyclic groups. Additionally, the hydroxy-terminated and amine curatives can include one or more halogen groups. The polyurethane composition can be formed with a blend or mixture of curing agents. If desired, however, the polyurethane composition may be formed with a single curing agent.

**[0089]** In a preferred embodiment of the present invention, saturated polyurethanes are used to form one or more of the cover layers, preferably the outer cover layer, and may be selected from among both castable thermoset and thermoplastic polyurethanes.

**[0090]** Thermosetting polyurethanes or polyureas are suitable for the outer cover layers of the golf balls of the invention.

**[0091]** Additionally, polyurethane can be replaced with or blended with a polyurea material. Polyureas are distinctly different from polyurethane compositions, but also result in desirable aerodynamic and aesthetic characteristics when used in golf ball components. The polyurea-based compositions are preferably saturated in nature.

**[0092]** The polyether amine may be blended with additional polyols to formulate copolymers that are reacted with excess isocyanate to form the polyurea prepolymer. In one embodiment, less than about 30 percent polyol by weight of the copolymer is blended with the saturated polyether amine. In another embodiment, less than about 20 percent polyol by weight of the copolymer, preferably less than about 15 percent by weight of the copolymer, is blended with the polyether amine. The polyols listed above with respect to the polyurethane prepolymer, e.g., polyether polyols, polycaprolactone polyols, polyester polyols, polycarbonate polyols, hydrocarbon polyols, other polyols, and mixtures thereof, are also suitable for blending with the polyether amine. The molecular weight of these polymers may be from about 200 to about 4000, but also may be from about 1000 to about 3000, and more preferably are from about 1500 to about 2500.

**[0093]** The polyurea composition can be formed by crosslinking a polyurea prepolymer with a single curing agent or a blend of curing agents. The curing agent of the invention is preferably an amine-terminated curing agent, more preferably a secondary diamine curing agent so that the composition contains only urea linkages. In one embodiment, the amine-terminated curing agent may have a molecular weight of about 64 or greater. In another embodiment, the molecular weight of the amine-curing agent is about 2000 or less. As discussed above, certain amine-terminated curing agents may be modified with a compatible amine-terminated freezing point depressing agent or mixture of compatible freezing point depressing agents.

**[0094]** Suitable amine-terminated curing agents include, but are not limited to, ethylene diamine; hexamethylene diamine; 1-methyl-2,6-cyclohexyl diamine; tetrahydropropylene ethylene diamine; 2,2,4- and 2,4,4-trimethyl-1,6-hexanediamine; 4,4'-bis-(sec-butylamino)-dicyclohexylmethane; 1,4-bis-(sec-butylamino)-cyclohexane; 1,2-bis-(sec-butylamino)-cyclohexane; derivatives of 4,4'-bis-(sec-butylamino)-dicyclohexylmethane; 4,4'-dicyclohexylmethane diamine; 1,4-cyclohexane-bis-(methylamine); 1,3-cyclohexane-bis-(methylamine); diethylene glycol di-(aminopropyl) ether; 2-methylpentamethylene-diamine; diaminocyclohexane; diethylene triamine; triethylene tetramine; tetraethylene pentamine; propylene diamine; 1,3-diaminopropane; dimethylamino propylamine;

diethylamino propylamine; dipropylene triamine; imido-bis-propylamine; monoethanolamine, diethanolamine; triethanolamine; monoisopropanolamine, diisopropanolamine; isophoronediamine; 4,4'-methylenebis-(2-chloroaniline); 3,5-dimethylthio-2,4-toluenediamine; 3,5-dimethylthio-2,6-toluenediamine; 3,5-diethylthio-2,4-toluenediamine; 3,5-diethylthio-2,6-toluenediamine; 4,4'-bis-(sec-butylamino)-diphenylmethane and derivatives thereof; 1,4-bis-(sec-butylamino)-benzene; 1,2-bis-(sec-butylamino)-benzene; N,N'-dialkylamino-diphenylmethane; N,N,N',N'-tetrakis(2-hydroxypropyl)ethylene diamine; trimethyleneglycol-di-p-aminobenzoate; polytetramethyleneoxide-di-p-aminobenzoate; 4,4'-methylenebis-(3-chloro-2,6-diethylaniline); 4,4'-methylenebis-(2,6-diethylaniline); meta-phenylenediamine; paraphenylenediamine; and mixtures thereof. In one embodiment, the amine-terminated curing agent is 4,4'-bis-(sec-butylamino)-dicyclohexylmethane.

**[0095]** Suitable saturated amine-terminated curing agents include, but are not limited to, ethylene diamine; hexamethylene diamine; 1-methyl-2,6-cyclohexyl diamine; tetrahydropropylene ethylene diamine; 2,2,4- and 2,4,4-trimethyl-1,6-hexanediamine; 4,4'-bis-(sec-butylamino)-dicyclohexylmethane; 1,4-bis-(sec-butylamino)-cyclohexane; 1,2-bis-(sec-butylamino)-cyclohexane; derivatives of 4,4'-bis-(sec-butylamino)-dicyclohexylmethane; 4,4'-dicyclohexylmethane diamine; 4,4'-methylenebis-(2,6-diethylaminocyclohexane); 1,4-cyclohexane-bis-(methylamine); 1,3-cyclohexane-bis-(methylamine); diethylene glycol di-(aminopropyl)ether; 2-methylpentamethylene-diamine; diaminocyclohexane; diethylene triamine; triethylene tetramine; tetraethylene pentamine; propylene diamine; 1,3-diaminopropane; dimethylamino propylamine; diethylamino propylamine; imido-bis-propylamine; monoethanolamine, diethanolamine; triethanolamine; monoisopropanolamine, diisopropanolamine; isophoronediamine; triisopropanolamine; and mixtures thereof. In addition, any of the polyether amines listed above may be used as curing agents to react with the polyurea prepolymer.

**[0096]** Alternatively, other suitable polymers include partially or fully neutralized ionomer, metallocene, or other single-site catalyzed polymer, polyester, polyamide, non-ionic thermoplastic elastomer, copolyether-esters, copolyether-amides, polycarbonate, polybutadiene, polyisoprene, polystyrene block copolymers (such as styrene-butadiene-styrene), styrene-ethylene-propylene-styrene, styrene-ethylene-butylene-styrene, and the like, and blends thereof.

**[0097]** Cover layers of the inventive golf ball may also be formed from ionic polymers, preferably highly-neutralized ionomers (HNP). In a preferred embodiment, at least one intermediate layer of the golf ball is formed from an HNP material or a blend of HNP materials. The acid moieties of the HNP's, typically ethylene-based ionomers, are preferably neutralized greater than about 70%, more preferably greater than about 90%, and most preferably at least about 100%. The HNP's can be also be blended with a second polymer component, which, if containing an acid group, may be neutralized in a conventional manner, by the organic fatty acids of the present invention, or both. The second polymer component, which may be partially or fully neutralized, preferably comprises ionic copolymers and terpolymers, ionomer precursors, thermoplastics, polyamides, polycarbonates, polyesters, polyurethanes, polyureas, thermoplastic elastomers, polybutadiene rubber, balata, metallocene-catalyzed polymers (grafted and non-grafted), single-site polymers, high-

crystalline acid polymers, cationic ionomers, and the like. HNP polymers typically have a material 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.

**[0098]** In one embodiment of the present invention the HNP's are ionomers and/or their acid precursors that are preferably neutralized, either fully or partially, with organic acid copolymers or the salts thereof. The acid copolymers are preferably  $\alpha$ -olefin, such as ethylene,  $C_{3-8}$   $\alpha,\beta$ -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.

**[0099]** The acid copolymers can be described as E/X/Y copolymers where E is ethylene, X is an  $\alpha,\beta$ -ethylenically unsaturated carboxylic acid, and Y is a softening comonomer. In a preferred embodiment, X is acrylic or methacrylic acid and Y is a  $C_{1-8}$  alkyl acrylate or methacrylate ester. X is preferably present in an amount from about 1 to about 35 weight percent of the polymer, more preferably from about 5 to about 30 weight percent of the polymer, and most preferably from about 10 to about 20 weight percent of the polymer. Y is preferably present in an amount from about 0 to about 50 weight percent of the polymer, more preferably from about 5 to about 25 weight percent of the polymer, and most preferably from about 10 to about 20 weight percent of the polymer.

**[0100]** 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/n-butyl methacrylate, ethylene/acrylic acid/methyl methacrylate, ethylene/acrylic acid/methyl acrylate, ethylene/methacrylic acid/methyl acrylate, ethylene/methacrylic acid/methyl methacrylate, and ethylene/acrylic acid/n-butyl methacrylate. Preferred acid-containing ethylene copolymers include, ethylene/methacrylic acid/n-butyl acrylate, ethylene/acrylic acid/n-butyl acrylate, ethylene/methacrylic acid/methyl acrylate, ethylene/acrylic acid/ethyl acrylate, ethylene/methacrylic acid/ethyl acrylate, and ethylene/acrylic acid/methyl acrylate copolymers. The most preferred acid-containing ethylene copolymers are, ethylene/(meth) acrylic acid/n-butyl acrylate, ethylene/(meth) acrylic acid/ethyl acrylate, and ethylene/(meth) acrylic acid/methyl acrylate copolymers.

**[0101]** Ionomers are typically neutralized with a metal cation, such as Li, Na, Mg, K, Ca, or Zn. It has been found that by adding sufficient organic acid or salt of organic acid, along with a suitable base, to the acid copolymer or ionomer, however, the ionomer can be neutralized, without losing processability, to a level much greater than for a metal cation. Preferably, the acid moieties are neutralized greater than about 80%, preferably from 90-100%, most preferably 100% without losing processability. This accomplished by melt-blending an ethylene  $\alpha,\beta$ -ethylenically unsaturated carboxylic acid copolymer, for example, with an organic acid or a salt of organic acid, and adding a sufficient amount of a cation source to increase the level of neutralization of all the acid moieties (including those in the acid copolymer and in the organic acid) to greater than 90%, (preferably greater than 100%).

**[0102]** The organic acids of the present invention are aliphatic, mono- or multi-functional (saturated, unsaturated, or multi-unsaturated) organic acids. Salts of these organic acids may also be employed. The salts of organic acids of the

present invention include the salts of barium, lithium, sodium, zinc, bismuth, chromium, cobalt, copper, potassium, strontium, titanium, tungsten, magnesium, cesium, iron, nickel, silver, aluminum, tin, or calcium, salts of fatty acids, particularly stearic, behenic, erucic, oleic, linoleic or dimerized derivatives thereof. It is preferred that the organic acids and salts of the present invention be relatively non-migratory (they do not bloom to the surface of the polymer under ambient temperatures) and non-volatile (they do not volatilize at temperatures required for melt-blending).

**[0103]** The ionomers of the invention may also be more conventional ionomers, i.e., partially-neutralized with metal cations. The acid moiety in the acid copolymer is neutralized about 1 to about 90%, preferably at least about 20 to about 75%, and more preferably at least about 40 to about 70%, to form an ionomer, by a cation such as lithium, sodium, potassium, magnesium, calcium, barium, lead, tin, zinc, aluminum, or a mixture thereof.

**[0104]** A moisture vapor barrier layer, such as disclosed in U.S. Pat. Nos. 6,632,147; 6,932,720; 7,004,854; and 7,182,702, all of which are incorporated by reference herein in their entirety, are optionally employed between the cover layer and the core. The moisture barrier layer may be disposed between the outer core layer and the cover layer. The moisture vapor barrier protects the inner and outer cores from degradation due to exposure to moisture, for example water, and extends the usable life of the golf ball. In one embodiment, the moisture barrier layer comprises a UHMWPHA as defined and described herein. The moisture vapor transmission rate of the moisture barrier layer is selected to be less than the moisture vapor transmission rate of the cover layer. The moisture barrier layer has a specific gravity of from about 1.1 to about 1.2 and a thickness of less than about 0.03 inches. Other suitable materials for the moisture barrier layer include a combination of a styrene block copolymer and a flaked metal, for example aluminum flake.

**[0105]** The UHMWPHAs of the inventive composition may also be foamed using any foaming technique known in the art to provide a softer feel for playability.

**[0106]** The renewable component composition constituting the layer(s) of the golf ball may contain additives, ingredients, and other materials in amounts that do not detract from the properties of the final composition. These additive materials include, but are not limited to, activators such as calcium or magnesium oxide; fatty acids such as stearic acid and salts thereof; fillers and reinforcing agents such as organic or inorganic particles, for example, clays, talc, calcium, magnesium carbonate, silica, aluminum silicates zeolites, powdered metals, and organic or inorganic fibers, plasticizers such as dialkyl esters of dicarboxylic acids; surfactants; softeners; tackifiers; waxes; ultraviolet (UV) light absorbers and stabilizers; antioxidants; optical brighteners; whitening agents such as titanium dioxide and zinc oxide; dyes and pigments; processing aids; release agents; and wetting agents. These compositions provide improved melt processability, a balance of ball performance.

**[0107]** The renewable component of this invention may be blended with non-ionomeric and olefin-based ionomeric polymers to form the composition that will be used to make the golf ball layer. Examples of non-ionomeric polymers include vinyl resins, polyolefins including those produced using a single-site catalyst or a metallocene catalyst, polyure-

thanes, polyureas, polyamides, polyphenylenes, polycarbonates, polyesters, polyacrylates, engineering thermoplastics, and the like.

**[0108]** Olefin-based ionomers, such as ethylene-based copolymers, normally include an unsaturated carboxylic acid, such as methacrylic acid, acrylic acid, or maleic acid. Other possible carboxylic acid groups include, for example, crotonic, maleic, fumaric, and itaconic acid. "Low acid" and "high acid" olefin-based ionomers, as well as blends of such ionomers, may be used. In general, low acid ionomers are considered to be those containing 16 wt. % or less of carboxylic acid, whereas high acid ionomers are considered to be those containing greater than 16 wt. % of carboxylic acid. The acidic group in the olefin-based ionic copolymer is partially or totally neutralized with metal ions such as zinc, sodium, lithium, magnesium, potassium, calcium, manganese, nickel, chromium, copper, or a combination thereof. For example, ionomeric resins having carboxylic acid groups that are neutralized from about 10 percent to about 100 percent may be used. In one embodiment, the acid groups are partially neutralized. That is, the neutralization level is from 10 to 80%, more preferably 20 to 70%, and most preferably 30 to 50%. In another embodiment, the acid groups are highly or fully neutralized. Or, the neutralization level may be from about 80 to 100%, more preferably 90 to 100%, and most preferably 95 to 100%. The blend may contain about 5 to about 30% by weight of the renewable component composition and about 95 to about 70% by weight of a partially, highly, or fully-neutralized olefin-based ionomeric copolymer. The above-mentioned blends may contain one or more suitable compatibilizers such as glycidyl acrylate or glycidyl methacrylate or maleic anhydride containing-polymers.

**[0109]** In the present invention, the surface hardness of a core is obtained from the average of a number of measurements taken from opposing hemispheres of a core, taking care to avoid making measurements on the parting line of the core or on surface defects, such as holes or protrusions. Hardness measurements are made pursuant to ASTM D-2240 "Indentation Hardness of Rubber and Plastic by Means of a Durometer." Because of the curved surface of a core, care must be taken to insure that the core is centered under the durometer indenter before a surface hardness reading is obtained. A calibrated, digital durometer, capable of reading to 0.1 hardness units is used for all hardness measurements and is set to take hardness readings at 1 second after the maximum reading is obtained. The digital durometer must be attached to, and its foot made parallel to, the base of an automatic stand, such that the weight on the durometer and attack rate conform to ASTM D-2240.

**[0110]** To prepare a core for hardness gradient measurements, the core is gently pressed into a hemispherical holder having an internal diameter approximately slightly smaller than the diameter of the core, such that the core is held in place in the hemispherical portion of the holder while concurrently leaving the geometric central plane of the core exposed. The core is secured in the holder by friction, such that it will not move during the cutting and grinding steps, but the friction is not so excessive that distortion of the natural shape of the core would result. The core is secured such that the parting line of the core is roughly parallel to the top of the holder. The diameter of the core is measured 90 degrees to this orientation prior to securing. A measurement is also made from the bottom of the holder to the top of the core to provide a reference point for future calculations. A rough cut, made

slightly above the exposed geometric center of the core using a band saw or other appropriate cutting tool, making sure that the core does not move in the holder during this step. The remainder of the core, still in the holder, is secured to the base plate of a surface grinding machine. The exposed 'rough' core surface is ground to a smooth, flat surface, revealing the geometric center of the core, which can be verified by measuring the height of the bottom of the holder to the exposed surface of the core, making sure that exactly half of the original height of the core, as measured above, has been removed to within  $\pm 0.004$  inches.

**[0111]** Leaving the core in the holder, the center of the core is found with a center square and carefully marked and the hardness is measured at the center mark. Hardness measurements at any distance from the center of the core may be measured by drawing a line radially outward from the center mark, and measuring and marking the distance from the center, typically in 2-mm increments. All hardness measurements performed on the plane passing through the geometric center are performed while the core is still in the holder and without having disturbed its orientation, such that the test surface is constantly parallel to the bottom of the holder. The hardness difference from any predetermined location on the core (e.g., first outer surface, second outer surface, etc.) is calculated as the average hardness at the predetermined location minus the hardness at a chosen reference point at or closer to the geometric center than the predetermined location. For example, if the predetermined location is the second outer surface and is softer than its reference point, the inner surface, a negative hardness gradient results between the two points. Conversely, if inner surface is harder than the second outer surface, a positive hardness gradient results.

**[0112]** Hardness with respect to intermediate and cover layers may refer to surface hardness.

**[0113]** Golf ball compression remains an important factor to consider in maximizing playing performance. It affects the ball's spin rate off the driver as well as the feel. Initially, compression was referred to as the tightness of the windings around a golf ball. Today, compression refers to how much a ball will deform under a compressive force when a driver hits the ball. A ball actually tends to flatten out when a driver meets the ball; it deforms out of its round shape and then returns to its round shape, all in a second or two. Compression ratings of from about 70 to about 120 are common. The lower the compression rating, the more the ball will compress or deform upon impact.

**[0114]** People with a slower swing or slower club head speed will desire a ball having a lower compression rating. While the compression of a ball alone does not determine whether a ball flies farther—the club head speed actually determines that—compression can nevertheless influence or contribute to overall distance. For example, a golfer with a slower club head speed who uses a high compression ball will indeed lose yardage that would otherwise be achieved if that golfer used a low compression (or softer) ball. Accordingly, it is desirable to match golf ball compression rating with a player's swing speed in maximizing a golfer's performance on the green.

**[0115]** Several different methods can be used to measure compression, including Atti compression, Riehle compression, load/deflection measurements at a variety of fixed loads and offsets, and effective modulus. See, e.g., *Compression by Any Other Name, Science and Golf IV, Proceedings of the World Scientific Congress of Golf* (Eric Thain ed., Routledge,

2002) ("J. Dalton") The term compression, as used herein, refers to Atti compression and is measured using an Atti compression test device. A piston compresses a ball against a spring and the piston remains fixed while deflection of the spring is measured at 1.25 mm (0.05 inches). Where a core has a very low stiffness, the compression measurement will be zero at 1.25 mm. In order to measure the compression of a core using an Atti compression tester, the core must be shimmed to a diameter of 1.680 inches because these testers are designed to measure objects having that diameter. Atti compression units can be converted to Riehle (cores), Riehle (balls), 100 kg deflection, 130-10 kg deflection or effective modulus using the formulas set forth in J. Dalton.

**[0116]** According to one aspect of the present invention, the golf ball is formulated to have a compression of from about 50 to about 120. In one embodiment, the compression of the core is greater than about 50. In another embodiment, the compression of the core is greater than about 70. In yet another embodiment, the compression of the core is from about 80 to about 100.

**[0117]** The distance that a golf ball would travel upon impact is a function of the coefficient of restitution (COR) and the aerodynamic characteristics of the ball. For golf balls, COR has been approximated as a ratio of the velocity of the golf ball after impact to the velocity of the golf ball prior to impact. The COR varies from 0 to 1.0. A COR value of 1.0 is equivalent to a perfectly elastic collision, that is, all the energy is transferred in the collision. A COR value of 0.0 is equivalent to a perfectly inelastic collision—that is, all of the energy is lost in the collision.

**[0118]** COR, as used herein, is determined by firing a golf ball or golf ball subassembly (e.g., a golf ball core) from an air cannon at two given velocities and calculating the COR at a velocity of 125 ft/s. Ball velocity is calculated as a ball approaches ballistic light screens which are located between the air cannon and a steel plate at a fixed distance. As the ball travels toward the steel plate, each light screen is activated, and the time at each light screen is measured. This provides an incoming transit time period inversely proportional to the ball's incoming velocity. The ball impacts the steel plate and rebounds through the light screens, which again measure the time period required to transit between the light screens. This provides an outgoing transit time period inversely proportional to the ball's outgoing velocity. COR is then calculated as the ratio of the outgoing transit time period to the incoming transit time period,  $COR = V_{out}/V_{in} = T_{in}/T_{out}$ . Preferably, a golf ball according to the present invention has a COR of at least about 0.78, more preferably, at least about 0.80.

**[0119]** The spin rate of a golf ball also remains an important golf ball characteristic. High spin rate allows skilled players more flexibility in stopping the ball on the green if they are able to control a high spin ball. On the other hand, recreational players often prefer a low spin ball since they do not have the ability to intentionally control the ball, and lower spin balls tend to drift less off the green.

**[0120]** Golf ball spin is dependent on variables including, for example, distribution of the density or specific gravity within a golf ball. For example, when the density or specific gravity is located in the golf ball center, a lower moment of inertia results which increases spin rate. Alternatively, when the density or specific gravity is concentrated in the outer regions of the golf ball, a higher moment of inertia results with a lower spin rate. The moment of inertia for a one piece ball that is 1.62 ounces and 1.68 inches in diameter is approximately 0.4572 oz-in<sup>2</sup>, which is the baseline moment of inertia value.

**[0121]** Accordingly, by varying the materials and the hardness of the regions of each core layer, different moments of inertia may be achieved for the golf ball of the present invention. In one embodiment, the resulting golf ball has a moment of inertia of from about 0.440 to about 0.455 oz-in<sup>2</sup>. In another embodiment, the golf balls of the present invention have a moment of inertia of from about 0.456 oz-in<sup>2</sup> to about 0.470 oz-in<sup>2</sup>. In yet another embodiment, the golf ball has a moment of inertia of from about 0.450 oz-in<sup>2</sup> to about 0.460 oz-in<sup>2</sup>.

**[0122]** In one embodiment, the UHMWPHA composition of the present invention has a moisture vapor transmission rate ("MVTR") of 10 gmil/100 in<sup>2</sup>/day or less, preferably 8 or less, more preferably 2 or less. As used herein, MVTR is given in gmil/100 in<sup>2</sup>/day, and is measured at 20.degree. C., according to ASTM F1249-99.

**[0123]** By way of non-limiting prophetic example, a golf ball according to the invention may be made as follows:

The Core:

**[0124]** A golf ball core of the present invention can be made using the ingredients as shown in Table I below. As used herein, the term "phr" represents parts per hundred parts by weight of rubber.

TABLE I

Core Compositions for 1.550" diameter Core				
Ingredients (phr)	Comparative Example 1	Example 1	Example 2	Example 3
Polybutadiene rubber, Taktene ® 220	100	100	100	100
Peroxide initiator, Perkadox BC-FF*	0.8	0.8	0.8	0.8
Co-agent, SR-526**	30	30	30	30
ZnO	5	5	5	5
Density adjusting filler, BaSO <sub>4</sub>	20	20	20	20
UHMWPHA having a melt index of 5.0 at 210° C./2.16 Kg and a Vicat softening temperature of 180° F.	0	5	10	15

Perkadox BC-FF\*: Dicumyl peroxide (99 to 100% active) available from Akzo Nobel  
SR-526\*\*: Zinc diacrylate available from Sartomer

**[0125]** Referring to Table I, the composition of the core in comparative example 1 is identical to that of the cores in Examples 1, 2 and 3 except that the comparative example 1 core comprises no UHMWPHA. In contrast, the cores of Examples 1, 2 and 3 in Table I comprise varying amounts of UHMWPHA as indicated in addition to the co-agent. A core as reflected in Examples 1, 2 and 3 would possess higher compression and improved flight characteristics over the core of Comparative Example 1.

**[0126]** Although the co-agent provides stiffening similar to the UHMWPHA, and would provide resilience and impact durability, the UHMWPHA also possesses biodegradable characteristics as a renewable resource, whereas the co-agent does not. Moreover, while Comparative Example 1 and Examples 1, 2 and 3 of Table I each include 30 phr co-agent,

a further inventive core is envisioned which includes less co-agent than does Comparative Example 1 (for example 25 phr) and meanwhile includes an UHMWPHA in an amount which would nevertheless retain or increase resilience and compression as compared with the core of Comparative Example 1 having 30 phr co-agent.

**[0127]** Additionally, where a core comprises the ingredients represented in Table I, these ingredients may be included in amounts within the following ranges (phr):

**[0128]** Polybutadiene rubber, Taktene® 220: 100

**[0129]** Peroxide initiator, Perkadox BC-FF: from about 0.4 to about 2.0, preferably from about 0.5 to about 1.4, most preferably from about 0.6 to about 1.2

**[0130]** Co-agent, SR-526: from about 20 to about 45, preferably from about 24 to about 40, most preferably from about 28 to about 36

**[0131]** ZnO: from about 2 to about 20

**[0132]** Density adjusting filler, BaSO<sub>4</sub>: from about 5 to about 50, or from about 10 to about 40 and most preferably from about 15 to about 30

**[0133]** UHMWPHA: from about 5 to about 50, preferably from about 5 to about 40 and most preferably from about 5 to about 30

**[0134]** When the Vicat softening temperature of the UHMWPHA is below 150° F., conventional rubber mixing equipment such as a roll mill/internal mixer/extruder may be used to make golf cores. However, when the Vicat softening temperature of the UHMWPHA is above 150° F., then it is preferable to blend a diene rubber and the UHMWPHA together using a single or twin-screw compounding machine to produce a homogeneous polymer blend at a mixing temperature of up to about 450° F. in order to prevent any degradation of the diene rubber during the mixing process. To this blend, the remaining ingredients as disclosed in Table 1 may be added and mixed uniformly on a roll mill or other rubber processing equipment at a temperature not exceeding about 200° F. to prevent any cross-linking prior to core molding. In one embodiment, the core molding may be performed at 350° F. for 11 minutes when a dicumyl peroxide initiator is used by any compression molding procedure known in the golf ball art. Furthermore, other core molding techniques including a one step or a multi-step curing can be employed to provide desirable golf ball core performance including increased CoR at lower compression. Optionally, the core formulations may include an antioxidant such as Vanox® MBPC to provide a negative or zero gradient in hardness properties (as disclosed for example in U.S. Pat. No. 7,678,312).

Inner Cover and/or Intermediate Layer:

**[0135]** A golf ball inner cover or intermediate layer of the invention can be made using the ingredients as shown in Table II. As used in Table II, the term "phr" represents parts per hundred parts by weight of resin.

TABLE II

Inner Cover Compositions				
Ingredients (phr)	Comparative Example 2	Example 4	Example 5	Example 6
Surlyn ® 9910***	100	100	100	100
UHMWPHA having a melt index of 5.0 at 210° C./2.16 Kg	0	5	10	15

\*\*\*Surlyn ® 9910 is a Zinc ionomer from Du Pont.

[0136] Referring to Table II, these ingredients may be combined as a physical mixture (salt and pepper like) for an injection molding process directly or can be compounded using a single or twin-screw compounding machine. The compounded composition may be injection molded as an inner cover layer having a thickness in the range of from about 0.010 inches to about 0.050 inches, preferably from about 0.020 inches to about 0.040 inches and most preferably from about 0.025 inches to 0.030 inches either by making half shells followed by compression molding or by using a retractable pin injection molding (RPIM) process known in the golf ball art. An inner cover/intermediate layer as reflected in Examples 4, 5 and 6 would possess higher stiffness and reduced backspin from the driver as well as provide biodegradability as compared with that of Comparative Example 2. Alternatively, the inner cover or intermediate layer may include an UHMWPHA in an amount within the same ranges as disclosed above with respect to the core composition.

Outer Cover:

[0137] A golf ball outer cover of the present invention can be made using the ingredients as shown in Table III:

TABLE III

Outer Cover Compositions				
Ingredients (phr)	Comparative Example 3	Example 7	Example 8	Example 9
Thermoplastic Urethane Estane ® 58134****	100	100	100	100
UHMWPHA having a melt index of 5.0 at 210° C./2.16 Kg	0	5	10	15

\*\*\*\*Estane ® 58134 is a thermoplastic urethane from Lubrizol Corporation

[0138] Referring to Table III, these ingredients may be combined as a physical mixture (salt and pepper like) for an injection molding process directly or can be compounded using a single or twin-screw compounding machine. The compounded composition is injection molded as a golf ball outer cover layer either by making half shells followed by compression molding or by RPIM process known in the golf ball art. Furthermore, other techniques such as a co-injection molding method can be employed to produce a very soft outer skin and a very thin hard middle layer based on the UHMWPHA compositions. The covers in Examples 7, 8 and 9 of Table III would possess higher stiffness and reduced backspin from the driver as well as provide biodegradability as compared with that of Comparative Example 3 of Table III. The outer cover may alternatively include an UHMWPHA in an amount within the same ranges disclosed hereinabove with respect to the core composition, inner cover and intermediate layers.

[0139] Golf balls may also be made according to the invention pursuant to the prophetic non-limiting examples below. In examples 10-33 of Tables IV-VII below, at least one of a core layer, intermediate layer/inner cover layer and outer cover layer includes both a renewable polymer composition (RPC) comprising an UHMWPHA renewable polymer and a masterbatch non-renewable composition. These golf balls may be manufactured according to any method or process

known in the art including for example but limited to compression molding, injection molding, injection compression, casting, RIM, RPIM.

[0140] Table IV below demonstrates in examples 10-12 that the durability of a golf ball of the invention improves/increases as the Notched Izod Impact Strength of a layer comprising 10 phr of a RPC comprising UHMWPHA is raised from 1 ft.lb./in. to 10 ft.lbs./in. to 18 ft.lbs./in. The trend is the same in examples 13-15 at 20 phr RPC.

TABLE IV

Effect of Renewable Polymer Composition (RPC) Notched Izod On Golf Ball Properties						
Ingredients (phr)	Ex. 10	Ex. 11	Ex. 12	Ex. 13	Ex. 14	Ex. 15
Masterbatch* RPC	100	100	100	100	100	100
Notched Izod of 1 ft.lbs./in. at 23° C.				20		
RPC		10			20	
Notched Izod of 10 ft.lbs./in. at 23° C.				10		20
RPC						
Notched Izod of 18 ft.lbs./in. at 23° C.						
Golf Ball Impact Durability	Durable	More Durable	Even More Durable	Durable	More Durable	Even More Durable

\*The Master Batch, in Examples 10-33 of Tables IV-VII herein shall refer to and include a composition comprising one of the following:  
 (1) Where the Core comprises the RPC, the masterbatch composition comprises of 100 phr polybutadiene rubber, 0.6 phr of Perkadox BC-FF peroxide initiator, 30 phr of SR-526 Zinc diacrylate coagent, 5 phr of ZnO filler and 20 phr of BaSO4 density adjusting filler;  
 (2) Where the Inner cover or intermediate layer comprises the RPC, the masterbatch composition comprises 100 phr of Surllyn 9910; and  
 (3) Where the Outercover comprises the RPC, the masterbatch composition comprises 100 phr of Estane 58881 (TPU).

[0141] Table V below demonstrates in examples 16-18 that the durability of a golf ball of the invention improves/increases as the Polydispersity of a layer comprising 10 phr of a RPC comprising UHMWPHA is raised from 1 to 2 to 2.5. The trend is the same in examples 19-21 at 20 phr RPC.

TABLE V

Effect of RPC Polydispersity On Golf Ball Properties						
Ingredients (phr)	Ex. 16	Ex. 17	Ex. 18	Ex. 19	Ex. 20	Ex. 21
Masterbatch* RPC	100	100	100	100	100	100
Polydispersity of 1				20		
RPC		10			20	
Polydispersity of 2				10		20
RPC						
Polydispersity of 2.5						
Golf Ball Impact Durability	Durable	More Durable	Even More Durable	Durable	More Durable	Even More Durable

[0142] Table VI below demonstrates in examples 22-24 that golf ball stiffness increases and back spin decreases according to the invention as the Flexural modulus of a layer comprising 10 phr of a RPC comprising UHMWPHA is raised from 50,000 psi to 150,00 psi to 250,000 psi. The trend is the same in examples 25-27 at 20 phr RPC.

TABLE VI

Effect of RPC Flexural Modulus On Golf Ball Properties						
Ingredients (phr)	Ex. 22	Ex. 23	Ex. 24	Ex. 25	Ex. 26	Ex. 27
Masterbatch*	100	100	100	100	100	100
RPC	10			20		
Flex modulus of 50 kpsi at 23° C.						
RPC		10			20	
Flex modulus of 150 kpsi at 23° C.						
RPC			10			20
Flex modulus of 250 kpsi at 23° C.						
Layer stiffness and back spin from driver	Stiff and low back spin	More stiff and reduced back spin	Even more stiff and further reduced back spin	Stiff and low back spin	More stiff and reduced back spin	Even more stiff and further reduced back spin

**[0143]** Table VII below demonstrates in examples 28-30 that both stiffness and durability increase in a golf ball according to the invention as the Tensile Strength of a layer comprising 10 phr of a RPC comprising UHMWPHA is raised from 2,000 psi to 4,000 psi to 5,500 psi. The trend is the same in examples 31-33 at 20 phr RPC.

composition comprising one or more of the following non-UHMWPHA renewable polymers:

**[0147]** Mirel® bio-polymers based on PHA's from Metabolix-Telles such as

**[0148]** Mirel® P1000 and Mirel® P 4000 series like Mirel® P1003 and Mirel® P 4001;

TABLE VII

Effect of RPC Tensile Strength at Break on Golf Ball Properties						
Ingredients (phr)	Ex. 28	Ex. 29	Ex. 30	Ex. 31	Ex. 32	Ex. 33
Masterbatch*	100	100	100	100	100	100
RPC	10			20		
Tensile strength at break of 2,000 psi at 23° C.						
RPC		10			20	
Tensile strength at break of 4,000 psi at 23° C.						
RPC			10			20
Tensile strength at break of 5,500 psi at 23° C.						
Layer stiffness and Golf ball durability from impact	Stiff and Durable	More Stiff and More Durable	Even More Stiff and Even More Durable	Stiff and Durable	More Stiff and More Durable	Even More Stiff and Even More Durable

**[0144]** Accordingly, as is shown in the prophetic examples above, a golf ball according to the invention comprising in at least one of its core, intermediate layer, inner cover layer or outer cover layer a renewable polymer composition comprising a UHMWPHA improves golf ball characteristics including, for example the characteristics identified above within the notched Izod, polydispersity, flexural modulus and tensile ranges disclosed the specification. Moreover, other desired characteristics, including for example resiliency and playability in general may be improved within these disclosed ranges.

**[0145]** The masterbatch disclosed in examples 10-33 above represents only one of many possible formulations for the non-renewable composition component and may be modified or replaced with any formulation known in the art for forming cores, core layers, intermediate layers, inner cover layers, and outer covers.

**[0146]** A golf ball according to the invention may also comprise in at least one of the core, cover, intermediate layer, inner cover layer and outer cover layer a renewable polymer

**[0149]** NatureWorks® bio-polymers based on PLA's from NatureWorks such as Ingeo® 2000, 3000, 4000, 6000, 7000 and 8000 series like Ingeo® 2002D, 3001D, 3051D, 3051D, 4032D, 4042D, 4050D, 4060D, 6201D, 6202D, 6204D, 6251D, 6302D, 6350D, 6400D, 6751D, 7000D, 7032D, 8251D and 8302D;

**[0150]** Pearlthane® bio-polymers based on Polyurethane's from Merquinsa such as Pearlthane® ECO D12T85, D12T90, D12T95, D12T60D, D20N88, D20N50D and D<sub>20</sub>N55D;

**[0151]** Pebax®Rnew bio-polymers based on Polyamide-ether or ester elastomers from Arkema such as Pebax®Rnew 35R53SA01 or SP01, 40R53SA01 or SP01, 55 R53SA01, 63 R53SA01 or SP01, 70R53SA01 or SP01 and 72 R53SA01;

**[0152]** Hytrel® RS bio-polymers containing at least 50% renewably sourced ingredients based on Polyester-ether or ester elastomers from Du Pont such as Hytrel® RS40F3 NC010 and RS40F5 NC010;



[0153] Biomax® PTT 1002 and 1100 resins based on a renewably sourced polyester resin made from propanediol and terephthalic acid from Du Pont;

[0154] Biomax® Biomax® Strong 100 and 120 based on partially renewable petroleum based polymer modifiers from Du Pont; and

[0155] Zytel® RS LC1600 BK385 based on a renewable sourced Polyamide 1010 containing a minimum amount of 60% renewably sourced ingredient from Du Pont.

[0156] Unless otherwise expressly specified, all of the numerical ranges, amounts, values and percentages such as those for amounts of materials, and others in the specification may be read as if prefaced by the word “about” even though the term “about” may not expressly appear with the value, amount or range. Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

[0157] Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. Furthermore, when numerical ranges of varying scope are set forth herein, it is contemplated that any combination of these values inclusive of the recited values may be used.

[0158] While it is apparent that the illustrative embodiments of the invention disclosed herein fulfill the preferred embodiments of the present invention, it is appreciated that numerous modifications and other embodiments may be devised by those skilled in the art. Examples of such modifications include reasonable variations of the numerical values and/or materials and/or components discussed above. Hence, the numerical values stated above and claimed below specifically include those values and the values that are approximate to those stated and claimed values. Therefore, it will be understood that the appended claims are intended to cover all such modifications and embodiments, which would come within the spirit and scope of the present invention.

[0159] The invention described and claimed herein is not to be limited in scope by the specific embodiments herein disclosed, since these embodiments are intended as illustrations of several aspects of the invention. Any equivalent embodiments are intended to be within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. For example, the compositions of the present invention may be used in a variety of equipment. Such modifications are also intended to fall within the scope of the appended claims.

[0160] While any of the embodiments herein may have any known dimple number and pattern, a preferred number of dimples is 252 to 456, and more preferably is 330 to 392. The dimples may comprise any width, depth, and edge angle disclosed in the prior art and the patterns may comprise multitudes of dimples having different widths, depths and edge angles. The parting line configuration of said pattern

may be either a straight line or a staggered wave parting line (SWPL). Most preferably the dimple number is 330, 332, or 392 and comprises 5 to 7 dimples sizes and the parting line is a SWPL.

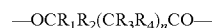
[0161] In any of these embodiments the single-layer core may be replaced with a two or more layer core wherein at least one core layer has a negative hardness gradient. Other than in the operating examples, or unless otherwise expressly specified, all of the numerical ranges, amounts, values and percentages such as those for amounts of materials and others in the specification may be read as if prefaced by the word “about” even though the term “about” may not expressly appear with the value, amount or range.

[0162] Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

[0163] While it is apparent that the illustrative embodiments of the invention disclosed herein fulfill the objective stated above, it is appreciated that numerous modifications and other embodiments may be devised by those skilled in the art. Therefore, it will be understood that the appended claims are intended to cover all such modifications and embodiments, which would come within the spirit and scope of the present invention.

What is claimed is:

1. A golf ball comprising a core and a cover, wherein at least one of the core and the cover comprises about 10 wt % or greater of a renewable polymer composition comprising an ultra high molecular weight polyhydroxyalkanoate compound having the formula:



wherein n is an integer, and wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub> and R<sub>4</sub> are selected from the group comprising saturated and unsaturated hydrocarbon radicals, halo- and hydroxy-substituted radicals, hydroxy radicals, halogen radicals; nitrogen-substituted radicals, oxygen-substituted radicals, or hydrogen atoms; and

wherein the renewable polymer composition comprises a flexural modulus of about 50,000 psi or greater.

2. The golf ball of claim 1, wherein the renewable polymer composition comprises an ultra high molecular weight polyhydroxyalkanoate compound having a first flexural modulus FM<sub>1</sub> and a low to medium molecular weight polyhydroxyalkanoate composition having a second flexural modulus FM<sub>2</sub> wherein the ratio of FM<sub>2</sub> to FM<sub>1</sub> is from about 0.1 to about 1.

3. The golf ball of claim 1, wherein the renewable polymer composition consists of 100 wt % of the ultra high molecular weight polyhydroxyalkanoate compound.

4. The golf ball of claim 1, wherein the renewable polymer composition comprises less than 100 wt % of the ultra high molecular weight polyhydroxyalkanoate compound.

5. The golf ball of claim 1, wherein the at least one of the core and the cover further comprises about 90% or less of a non renewable polymer composition.

6. The golf ball of claim 1, wherein the at least one of the core and the cover comprises about 5 wt % or greater of the ultra high molecular weight polyhydroxyalkanoate compound.

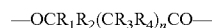
7. The golf ball of claim 1, wherein the at least one of the core and the cover comprises about 5 wt % or greater of the renewable polymer composition.

8. The golf ball of claim 1, wherein the renewable polymer composition comprises about 5 wt % or greater of the ultra high molecular weight polyhydroxyalkanoate compound.

9. The golf ball of claim 1, wherein the renewable polymer composition comprises a flexural modulus of about 100,000 psi or greater.

10. A golf ball comprising a core, a cover, and an intermediate layer disposed about the core and adjacent the cover, wherein at least one of the core, the cover and the intermediate layer comprises:

about 10 wt % or greater of a renewable polymer composition comprising an ultra high molecular weight polyhydroxyalkanoate compound having the formula:



wherein n is an integer, and wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub> and R<sub>4</sub> are selected from the group comprising saturated and unsaturated hydrocarbon radicals, halo- and hydroxy-substituted radicals, hydroxy radicals, halogen radicals; nitrogen-substituted radicals, oxygen-substituted radicals, or hydrogen atoms;

about 90% or less of a non renewable polymer composition;

wherein the renewable polymer composition comprises a tensile strength of about 2,000 psi or greater; and

wherein the at least one of the core, the cover and the intermediate layer comprises a hardness of from about 50 Shore C to about 90 Shore C.

11. The golf ball of claim 10, wherein the renewable polymer composition comprises an ultra high molecular weight polyhydroxyalkanoate compound having a first tensile strength TS<sub>1</sub> and a low to medium molecular weight polyhydroxyalkanoate composition having a second tensile strength TS<sub>2</sub> wherein the ratio of TS<sub>2</sub> to TS<sub>1</sub> is from about 0.3 to about 1.3.

12. The golf ball of claim 10, wherein the renewable polymer composition consists of 100 wt % of the ultra high molecular weight polyhydroxyalkanoate compound.

13. The golf ball of claim 10, wherein the renewable polymer composition comprises less than 100 wt % of the ultra high molecular weight polyhydroxyalkanoate compound.

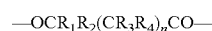
14. The golf ball of claim 10, wherein the core comprises a first hardness of from about 10 Shore D to about 50 Shore D

and the cover comprises a second hardness of from about 30 Shore D to about 70 Shore D wherein the ratio of the second hardness to the first hardness is about 3 or greater.

15. The golf ball of claim 10, wherein the renewable polymer composition further comprises an ester compatibilizer selected from the group comprising a glycidyl ester, a maleic ester and an oligomeric ester.

16. A golf ball comprising a core, a cover, and an intermediate layer disposed about the core and adjacent the cover, wherein at least one of the core, the cover and the intermediate layer comprises:

about 10 wt % or greater of a renewable polymer composition comprising an ultra high molecular weight polyhydroxyalkanoate compound having the formula:



wherein n is an integer, and wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub> and R<sub>4</sub> are selected from the group comprising saturated and unsaturated hydrocarbon radicals, halo- and hydroxy-substituted radicals, hydroxy radicals, halogen radicals; nitrogen-substituted radicals, oxygen-substituted radicals, or hydrogen atoms;

about 90% or less of a non renewable polymer composition; and

wherein the renewable polymer composition comprises a tensile strength of about 2,000 psi or greater.

17. The golf ball of claim 16, wherein the renewable polymer composition comprises an ultra high molecular weight polyhydroxyalkanoate compound having a first tensile strength TS<sub>1</sub> and a low to medium molecular weight polyhydroxyalkanoate composition having a second tensile strength TS<sub>2</sub> wherein the ratio of TS<sub>2</sub> to TS<sub>1</sub> is from about 0.3 to about 1.3.

18. The golf ball of claim 16, wherein the renewable polymer composition consists of 100 wt % of the ultra high molecular weight polyhydroxyalkanoate compound.

19. The golf ball of claim 16, wherein the renewable polymer composition comprises less than 100 wt % of the ultra high molecular weight polyhydroxyalkanoate compound.

20. The golf ball of claim 16, wherein the core comprises a first hardness of from about 10 Shore D to about 50 Shore D and the cover comprises a second hardness of from about 30 Shore D to about 70 Shore D wherein the ratio of the second hardness to the first hardness is about 3 or greater.

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