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(54) GOLF BALL INCLUDING A LONG-CHAIN BRANCHED NEODYMIUM-CATALYZED POLYBUTADIENE COMPONENT

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(57) ABSTRACT

The invention is directed to a golf ball comprising a long-chain branched neodymium-catalyzed polybutadiene having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s, wherein the overall golf ball comprises a COR of at least about 0.780 and an Atti compression of from about 25 to about 120. The invention is also directed to a golf ball comprising a core, a cover and optionally an intermediate layer disposed between the core and the cover; wherein at least one of said core, cover and intermediate layer comprises a polybutadiene composition comprising a long-chain branched neodymium-catalyzed polybutadiene having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s. In another embodiment, the golf ball comprises a core, a cover and optionally an intermediate layer disposed between the core and the cover; wherein said core comprises a polybutadiene composition comprising a long-chain branched neodymium-catalyzed polybutadiene having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s.

GOLF BALL INCLUDING A LONG-CHAIN BRANCHED NEODYMIUM-CATALYZED POLYBUTADIENE COMPONENT

FIELD OF THE INVENTION

[0001] This invention is directed to golf balls and methods for making golf balls incorporating materials which not only create desirable golf ball playing characteristics such as greater distance due to high COR, but also have broad application in targeting a wide range of compressions meanwhile possessing excellent processability in terms of quality of mix, extrudability, appearance (surface smoothness of extrudate), controlled cold flow, greater green strength, suitable tack and less backrinding, all thereby facilitating and reducing overall golf ball manufacturing costs.

BACKGROUND OF THE INVENTION

[0002] Golf balls are generally classified as either solid or wound. Solid golf balls are typically made with a solid core encased by a cover, both of which can have multiple layers, such as a dual core having a solid center and an outer core layer, or a multi-layer cover having an inner and outer cover layer. Additionally, one or more intermediate layers may be disposed between the core and cover. Golf ball cores and/or centers are conventionally constructed with a thermoset rubber, typically a polybutadiene-based composition, although alternatives such as thermoplastic materials or highly neutral polymers have also been utilized to date. Wound golf balls, precursors to the solid golf ball, typically include a solid, hollow or fluid-filled center, surrounded by tensioned elastomeric material and a cover.

[0003] In this regard, the 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, often 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 COR loss. Golf balls having an overall high COR or coefficient of restitution permit a golfer to achieve desirable travel distance when striking the ball with the club. 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".

[0004] Accordingly, many golfers prefer a ball having an overall high COR. The distance that a golf ball travels upon impact is a function of at least the 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, ranging 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. Accordingly, the higher the golf ball COR, the greater the golf ball travel distance with the same drive energy upon impact with a golf club.

[0005] Meanwhile, many accomplished golfers who are better able to control the ball's flight and positioning on the green also prefer a golf ball having a softer feel, lower compression and higher spin. Early solid golf balls lacked the softer feel, lower compression and higher spin rate of wound golf balls. More recently, however, cores of solid golf balls have been heated and crosslinked to create certain characteristics, such as higher or lower compression, which affects the ball's spin rate off the driver as well as the feel.

[0006] 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. The lower the compression rating, the more the ball will compress or deform upon impact. Atti or PGA compression, a common measure of compression, ranges from about from about 25 to about 120.

[0007] Generally, the more deformable the cover is, the easier it is to impart spin to the balls. This is particularly true for short or wedge shots. This may also be accomplished in a hard cover golf ball, for example, where the core is temporarily deformable when the cover is struck by a club. Meanwhile, altering the composition of an intermediate layer may also help to achieve such desired properties.

[0008] It is desirable to match golf ball compression rating with a player's swing speed in maximizing a golfer's performance on the green. Although the compression of a ball alone does not determine whether a ball flies farther it can certainly influence or contribute to overall distance. Accordingly, golfers with a slower swing or slower club head speed will desire a ball having a lower compression rating (softer ball) in order to prevent losing yardage which would occur if that golfer used a higher compression ball. In turn, golfers with a faster swing or faster club head speed will desire a ball having a higher compression rating.

[0009] Accordingly, manufacturers seek to develop golf balls incorporating versatile materials which provide high overall golf ball COR yet may be modified easily and inexpensively within conventional manufacturing processes to target a wide range golf ball compressions of from about 25 to about 120 according to each golfer's swing speed without compromising controlled processability.

[0010] Controlled processability in golf ball materials remains an important consideration as processing difficulties translate to higher overall golf ball production costs. Here, processing difficulties include both materials handling and manufacturing issues. One handling concern is cold flow, often encountered with bales of uncured rubber during storage and shipment. A solid material X (such as rubber) possesses a property called Cold Flow to the extent that material X permits a second solid material Y to pass through, displace or otherwise permanently change the shape of solid material X over time from the impact of material Y with material X or under pressure applied by material Y toward material X. While temporary deformation or compression of a golf ball as discussed earlier is indeed a desirable golf ball property, cold flow or creep—permanent deformation of golf ball materials under constant compressive load—is not. Accordingly, there is a need for an improved golf ball comprising materials which provide or contribute to a high COR and a wide range of compressions of from about 25 to about 120 and manifesting controlled cold flow.

[0011] Cold flow is not the only processing hurdle faced by golf ball manufacturers in producing golf balls having high COR and varied compression. Low Green strength (the strength of uncured rubber) affects a composition's ability to withstand milling, sheeting and extruding, for example. Golf ball manufacturers desire materials having sufficient green strength to withstand these processes.

[0012] Poor extrudability, roughness of the extrudate, inconsistent quality of mix, insufficient degree of tack and backrinding, are additional processing/handling problems which golf ball manufacturers have faced in manufacturing golf balls with high COR within a wide range of compressions. Regarding tack, a balance must be struck between a material having sufficient tack to adhere to another material, yet not possessing so much tack that it sticks to the mold for example, thereby interfering with molding operations. Meanwhile, backrinding is an artifact of the molding process, for example, when a composition continues to expand during curing and tears away at mold parting lines.

[0013] Previous attempts to incorporate neodymium-catalyzed polybutadiene rubbers in high COR golf balls for a broad range of compressions have met processing difficulties. For example, a high COR golf ball has been disclosed having a core comprising a blend of up to about 50% of a neodymium-catalyzed polybutadiene rubber such as Bayer's CB-22 (highly linear) with a cobalt-catalyzed polybutadiene rubber. However, the processing ability of the blend was found to decline as the amount of the highly linear neodymium-catalyzed polybutadiene in the blend was increased and the amount of the cobalt-catalyzed polybutadiene rubber was correspondingly reduced. See, e.g., U.S. Pat. No. 6,426,387 of Kim, at col 3, lines 59-62.

[0014] Other high COR golf balls are disclosed having cores incorporating a neodymium-catalyzed polybutadiene rubber (such as Bayer's/Lanxess CB-23 and CB-24 (both linear) in an amount of from about 30% by weight to about 45% by weight of the core in a blend with cobalt-catalyzed polybutadiene rubber. There, it was found that processing difficulties were avoided within those neodymium-catalyzed polybutadiene content ranges. See e.g., U.S. Pat. No. 6,315,684 of Binette et al., col. 9. A single neodymium-catalyzed polybutadiene had also been incorporated in a golf ball core in a content range of 55 wt % to 75 wt % of the core where the core compression is below 50 and the overall golf ball compression is 35 to 50 with a high overall golf ball COR of at least 0.780. See U.S. Publ. Nos. 2010/0087274 and 2010/0087277 of O G G et al.

[0015] Accordingly, there is a need for a high COR golf ball which incorporates at least one neodymium-catalyzed polybutadiene component whose structure and properties permit its incorporation in a golf ball in a wide wt % content range to achieve a broad spectrum of desired overall golf ball compressions, meanwhile providing excellent processability. Such versatility in the polybutadiene component would facilitate golf ball manufacture as well as reduce golf ball manufacturing/production costs.

SUMMARY OF THE INVENTION

[0016] High COR golf balls according to the invention incorporating a long-chain branched neodymium-catalyzed polybutadiene component (hereinafter referred to as "LCBNCP") having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s possess excellent golf ball processability and uniformity in product quality across a wide range of overall golf ball compressions. The LCBNCP may comprise at least one of the following: a long-chain branched neodymium-catalyzed polybutadiene; a long-chain branched neodymium-catalyzed polybutadiene composition including a long-chain branched neodymium-catalyzed polybutadiene; and a polybutadiene composition including the long-chain branched neodymium-catalyzed polybutadiene. The LCBNCP may also comprise blends of a long-chain branched neodymium-catalyzed polybutadiene, a long-chain branched neodymium-catalyzed polybutadiene composition and/or a polybutadiene composition.

[0017] The LCBNCP, having long-chain branches and exhibiting a smaller spacial extension in solution, demonstrates a lower solution viscosity than other neodymium-catalyzed polybutadiene compositions at a given molecular weight, Mooney Viscosity and polydispersity. This facilitates coordination between and movement among the various polymeric segments, thereby permitting great and controlled processability as well as particular compatability between the LCBNCP and other golf ball materials. Such processing characteristics include excellent quality of mix, extrudability, extrudate surface smoothness, controlled cold flow, greater green strength, suitable tack and less backrinding. Accordingly, manufacture/production of the golf ball of the invention is easier and less expensive.

[0018] A golf ball of the invention may include a long-chain branched neodymium-catalyzed polybutadiene having a solution viscosity of less than 165 mPa·s in a very wide wt % content range of from at least about 5 wt % of the golf ball to achieve a broad spectrum of desired overall golf ball compressions of from about 25 to about 120 without displaying compromised (uncontrolled or inferior) processability or golf ball product quality. The long-chain branched neodymium-catalyzed polybutadiene may also be incorporated in any or all of the golf ball core, intermediate layer and cover in an amount of at least about 5 wt %.

[0019] In one embodiment, the golf ball comprises at least about 5 wt % of the long-chain branched neodymium-catalyzed polybutadiene. The golf ball may also comprise the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 10 wt % or at least about 15 wt %. Alternatively, the golf ball may also comprise the long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 2 wt % to about 5 wt % or greater.

[0020] The golf ball may also comprise a long-chain branched neodymium-catalyzed polybutadiene composition having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s. This overall golf ball also comprises a COR of at least about 0.780 and a PGA compression of from about 25 to about 120.

[0021] In one embodiment, the golf ball comprises at least about 5 wt % of a long-chain branched neodymium-catalyzed polybutadiene composition. The golf ball may also comprise the long-chain branched neodymium-catalyzed polybutadiene composition in an amount of from about 10 wt % to about 85 wt % or from about 10 wt % to about 75 wt % or from about 5 wt % to about 75 wt % or from about 20 wt % to about 75 wt % or from about 15 wt % to about 85 wt % or even from about 15 wt % to about 65 wt % and even from about 10 wt % to about 95 wt %. Alternatively, the golf ball may also comprise the long-chain branched neodymium-catalyzed polybutadiene composition in an amount of from about 75 wt % to about 95 wt % or from about 75 wt % to about 85 wt % or from about 55 wt % to about 95 wt %. Meanwhile, the golf ball may also comprise the long-chain branched neodymium-catalyzed polybutadiene composition in an amount of from about 5 wt % to about 95 wt % or from about 5 wt % to about 85 wt % or from about 5 wt % to about 55 wt % or from about 5 wt % to about 45 wt % or from about 5 wt % to about 35 wt %. Also, the golf ball may also comprise the long-chain branched neodymium-catalyzed polybutadiene composition in an amount of from about 35 wt % to about 95 wt % or from about 45 wt % to about 95 wt % or from about 65 wt % to about 95 wt %.

[0022] The golf ball of the invention may also comprise a long-chain branched neodymium-catalyzed polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 5 wt % to about 85 wt % or from about 5 wt % to about 75 wt % or from about 5 wt % to about 65 wt % or from about 5 wt % to about 55 wt % or from about 5 wt % to about 45 wt % or from about 5 wt % to about 35 wt % or from about 1 wt % to about 35 wt % or even up to about 100 wt %. Alternatively, the golf ball of the invention may comprise a long-chain branched neodymium-catalyzed polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 55 wt % to about 100 wt % or from about 55 wt % to about 95 wt % or from about 55 wt % to about 85 wt % or from about 55 wt % to about 75 wt %. Meanwhile, the golf ball of the invention may comprise a long-chain branched neodymium-catalyzed polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 25 wt % to about 100 wt % or from about 35 wt % to about 95 wt % or from about 45 wt % to about 95 wt % or from about 75 wt % to about 98 wt %.

[0023] The golf ball of the invention may comprise a long-chain branched neodymium-catalyzed polybutadiene composition consisting essentially of the long-chain branched neodymium-catalyzed polybutadiene. In another embodiment, the golf ball of the invention may comprise a long-chain branched neodymium-catalyzed polybutadiene composition consisting of the long-chain branched neodymium-catalyzed polybutadiene.

[0024] In another embodiment, the golf ball may comprise a polybutadiene composition which comprises at least about 5 wt % of a long-chain branched neodymium-catalyzed polybutadiene. In yet another embodiment, the golf ball may comprise a polybutadiene composition which comprises at least about 10 wt % of a long-chain branched neodymium-catalyzed polybutadiene. In still another embodiment, the golf ball may comprise a polybutadiene composition which comprises at least about 15 wt % of a long-chain branched neodymium-catalyzed polybutadiene. Alternatively, the golf ball may comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 5 wt % to about 100 wt %. In a different embodiment, the golf ball may comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 5 wt % to about 95 wt %. The golf ball of the invention may also comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 5 wt % to about 85 wt % or from about 5 wt % to about 75 wt % or from about 5 wt % to about 65 wt % or from about 5 wt % to about 55 wt % or from about 5 wt % to about 45 wt % or from about 5 wt % to about 35 wt % or from about 1 wt % to about 35 wt % or even up to about 100 wt %. Alternatively, the golf ball of the invention may comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 55 wt % to about 100 wt % or from about 55 wt % to about 95 wt % or from about 55 wt % to about 85 wt % or from about 55 wt % to about 75 wt %. Meanwhile, the golf ball of the invention may comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 25 wt % to about 100 wt % or from about 35 wt % to about 95 wt % or from about 45 wt % to about 95 wt % or from about 75 wt % to about 98 wt %.

[0025] In yet another embodiment, the golf ball of the invention comprises a polybutadiene composition consisting essentially of the long-chain branched neodymium-catalyzed polybutadiene. In still another embodiment, the polybutadiene composition consists of the long-chain branched neodymium-catalyzed polybutadiene.

[0026] The golf ball of the invention may comprise a core, a cover and optionally an intermediate layer disposed between the core and the cover wherein at least one of the core, cover and intermediate layer comprises a long-chain branched neodymium-catalyzed polybutadiene in an amount of at least 5 wt %. In another embodiment, the at least one of the core, cover and intermediate layer comprises a long-chain branched neodymium-catalyzed polybutadiene in an amount of at least 10 wt %. In yet another embodiment, the at least one of the core, cover and intermediate layer comprises a long-chain branched neodymium-catalyzed polybutadiene in an amount of at least 15 wt %.

[0027] The golf ball of the invention may also comprise a core, a cover and optionally an intermediate layer disposed between the core and the cover wherein at least one of the core, cover and intermediate layer comprises a long-chain branched neodymium-catalyzed polybutadiene composition in an amount of at least about 5 wt %. The long-chain branched neodymium-catalyzed polybutadiene composition may meanwhile comprise a long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 5 wt %. And instead, the long-chain branched neodymium-catalyzed polybutadiene composition may either consist essentially of or consist of the long-chain branched neodymium-catalyzed polybutadiene.

[0028] In another embodiment, the at least one of the core, cover and intermediate layer consists essentially of the long-chain branched neodymium-catalyzed polybutadiene composition. In yet another embodiment, the at least one of the core, cover and intermediate layer consists of the long-chain branched neodymium-catalyzed polybutadiene composition.

[0029] Alternatively, a golf ball of the invention may comprise a core, a cover and optionally an intermediate layer disposed between the core and the cover wherein at least one of the core, cover and intermediate layer comprises a polybutadiene composition comprising a long-chain branched neodymium-catalyzed polybutadiene. In this embodiment, the polybutadiene composition may be included in the at least one of the core, intermediate layer and cover in an amount of at least about 5 wt %. In another embodiment, the at least one of the core, cover and intermediate layer consists essentially of the polybutadiene composition. In yet another embodiment, the at least one of the core, cover and intermediate layer consists of the polybutadiene composition.

[0030] The polybutadiene composition may meanwhile include a long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 5 wt %. The polybutadiene composition may even either consist essentially of or consist of the long-chain branched neodymium-catalyzed polybutadiene.

[0031] In still another embodiment, at least one of the cover and intermediate layer comprises the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 2 wt %.

[0032] Alternatively, the cover may comprise the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 2 wt %.

[0033] The golf ball of the invention may comprise a cover and optionally an intermediate layer disposed between the core and the cover wherein at least one of the cover and intermediate layer comprises a long-chain branched neodymium-catalyzed polybutadiene composition. In another embodiment, the at least one of the cover and intermediate layer consists essentially of the long-chain branched neodymium-catalyzed polybutadiene composition. In yet another embodiment, the at least one of the cover and intermediate layer consists of the long-chain branched neodymium-catalyzed polybutadiene composition.

[0034] Alternatively, the cover may comprise the long-chain branched neodymium-catalyzed polybutadiene composition. Or, the cover may consist essentially of the long-chain branched neodymium-catalyzed polybutadiene composition. In another embodiment, the cover may consist of the long-chain branched neodymium-catalyzed polybutadiene composition.

[0035] In still another embodiment, at least one of the cover and intermediate layer comprises the polybutadiene composition. At least one of the cover and intermediate layer may also consist essentially of the polybutadiene composition. Or, the at least one of the cover and intermediate layer may consist of the polybutadiene composition.

[0036] Alternatively, the cover may comprise the polybutadiene composition. Or, the cover may consist essentially of the polybutadiene composition. In another embodiment, the cover may consist of the polybutadiene composition.

[0037] In one embodiment, at least one of the core, cover and intermediate layer comprises at least about 5 wt % of the long-chain branched neodymium-catalyzed polybutadiene. The at least one of the core, cover and intermediate layer may also comprise at least about 2 wt % or at least about 10 wt % or at least about 15 wt % of the long-chain branched neodymium-catalyzed polybutadiene.

[0038] The at least one of the core, cover and intermediate layer may also comprise the long-chain branched neodymium-catalyzed polybutadiene composition in an amount of from about 10 wt % to about 85 wt % or from about 10 wt % to about 75 wt % or from about 5 wt % to about 75 wt % or from about 20 wt % to about 75 wt % or from about 15 wt % to about 85 wt % or even from about 15 wt % to about 65 wt % and even from about 10 wt % to about 95 wt %. Alternatively, the at least one of the core, cover and intermediate layer may also comprise the long-chain branched neodymium-catalyzed polybutadiene composition in an amount of from about 75 wt % to about 95 wt % or from about 75 wt % to about 85 wt % or from about 55 wt % to about 95 wt %. Meanwhile, the at least one of the core, cover and intermediate layer may also comprise the long-chain branched neodymium-catalyzed polybutadiene composition in an amount of from about 5 wt % to about 95 wt % or from about 5 wt % to about 85 wt % or from about 5 wt % to about 55 wt % or from about 5 wt % to about 45 wt % or from about 5 wt % to about 35 wt %. Also, the at least one of the core, cover and intermediate layer may also comprise the long-chain branched neodymium-catalyzed polybutadiene composition in an amount of from about 35 wt % to about 95 wt % or from about 45 wt % to about 95 wt % or from about 65 wt % to about 95 wt %.

[0039] The at least one of the core, cover and intermediate layer may also comprise a long-chain branched neodymium-catalyzed polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 5 wt % to about 85 wt % or from about 5 wt % to about 75 wt % or from about 5 wt % to about 65 wt % or from about 5 wt % to about 55 wt % or from about 5 wt % to about 45 wt % or from about 5 wt % to about 35 wt % or from about 1 wt % to about 35 wt % or even from about 1 wt % to about 95 wt % or even up to about 100 wt %. Alternatively, the golf ball of the invention may comprise a long-chain branched neodymium-catalyzed polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 55 wt % to about 100 wt % or from about 55 wt % to about 95 wt % or from about 55 wt % to about 85 wt % or from about 55 wt % to about 75 wt %. Meanwhile, the golf ball of the invention may comprise a long-chain branched neodymium-catalyzed polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 25 wt % to about 100 wt % or from about 35 wt % to about 95 wt % or from about 45 wt % to about 95 wt % or from about 75 wt % to about 98 wt %.

[0040] In another embodiment, the at least one of the core, cover and intermediate layer may comprise a polybutadiene composition which comprises at least about 5 wt % of a long-chain branched neodymium-catalyzed polybutadiene. In yet another embodiment, the at least one of the core, cover and intermediate layer may comprise a polybutadiene composition which comprises at least about 10 wt % of a long-chain branched neodymium-catalyzed polybutadiene. In still another embodiment, the at least one of the core, cover and intermediate layer may comprise a polybutadiene composition which comprises at least about 15 wt % of a long-chain branched neodymium-catalyzed polybutadiene. Alternatively, the at least one of the core, cover and intermediate layer may comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 5 wt % to about 100 wt %. In a different embodiment, the at least one of the core, cover and intermediate layer may comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 5 wt % to about 95 wt %. The at least one of the core, cover and intermediate layer of the invention may also comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 5 wt % to about 85 wt % or from about 5 wt % to about 75 wt % or from about 5 wt % to about 65 wt % or from about 5 wt % to about 55 wt % or from about 5 wt % to about 45 wt % or from about 5 wt % to about 35 wt % or from about 1 wt % to about 35 wt % or from about 1 wt % to about 95 wt % or even up to about 100 wt %. Alternatively, the at least one of the core, cover and intermediate layer may comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 55 wt % to about 100 wt % or from about 55 wt % to about 95 wt % or from about 55 wt % to about 85 wt % or from about 55 wt % to about 75 wt %. Meanwhile, the at least one of the core, cover and intermediate layer may comprise a polybutadiene composition which comprises a long-chain branched neodymium-catalyzed polybutadiene in amounts of from about 25 wt % to about 100 wt % or from about 35 wt % to about 95 wt % or from about 45 wt % to about 95 wt % or from about 75 wt % to about 98 wt %.

[0041] In one embodiment, the long-chain branched neodymium-catalyzed polybutadiene has a solution viscosity of less than 155 mPa·s. In another embodiment, the long-chain branched neodymium-catalyzed polybutadiene has a solution viscosity of less than 145 mPa·s. In yet another embodiment, the long-chain branched neodymium-catalyzed polybutadiene has a solution viscosity of less than 135 mPa·s. In still another embodiment, the long-chain branched neodymium-catalyzed polybutadiene has a solution viscosity of less than 125 mPa·s. Alternatively, the long-chain branched neodymium-catalyzed polybutadiene has a solution viscosity of less than 115 mPa·s. In a different embodiment, the long-chain branched neodymium-catalyzed polybutadiene has a solution viscosity of less than 105 mPa·s. In still a different embodiment, the long-chain branched neodymium-catalyzed polybutadiene may have a solution viscosity of less than 95 mPa·s. The long-chain branched neodymium-catalyzed polybutadiene may also have a solution viscosity of less than 80 mPa·s or even 70 mPa·s.

[0042] In one embodiment, the long-chain branched neodymium-catalyzed polybutadiene composition has a solution viscosity of less than 155 mPa·s. In another embodiment, the long-chain branched neodymium-catalyzed polybutadiene composition has a solution viscosity of less than 145 mPa·s. In yet another embodiment, the long-chain branched neodymium-catalyzed polybutadiene composition has a solution viscosity of less than 135 mPa·s. In still another embodiment, the long-chain branched neodymium-catalyzed polybutadiene composition has a solution viscosity of less than 125 mPa·s. Alternatively, the long-chain branched neodymium-catalyzed polybutadiene composition has a solution viscosity of less than 115 mPa·s. In a different embodiment, the long-chain branched neodymium-catalyzed polybutadiene composition has a solution viscosity of less than 105 mPa·s. In still a different embodiment, the long-chain branched neodymium-catalyzed polybutadiene composition may have a solution viscosity of less than 95 mPa·s. The long-chain branched neodymium-catalyzed polybutadiene composition may also have a solution viscosity of less than 80 mPa·s or even 70 mPa·s.

[0043] In one embodiment, the polybutadiene composition has a solution viscosity of less than 155 mPa·s. In another embodiment, the polybutadiene composition has a solution viscosity of less than 145 mPa·s. In yet another embodiment, the polybutadiene composition has a solution viscosity of less than 135 mPa·s. In still another embodiment, the polybutadiene composition has a solution viscosity of less than 125 mPa·s. Alternatively, the polybutadiene composition has a solution viscosity of less than 115 mPa·s. In a different embodiment, the polybutadiene composition has a solution viscosity of less than 105 mPa·s. In still a different embodiment, the polybutadiene composition may have a solution viscosity of less than 95 mPa·s. The polybutadiene composition may also have a solution viscosity of less than 80 mPa·s or even 70 mPa·s.

[0044] In one embodiment, in any golf ball of the invention incorporating an LCBNCP having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s, the appearance (surface smoothness of extrudate incorporating same), may be improved by up to about 75% over the appearance of extrudate including neodymium-catalyzed polybutadiene components having a solution viscosity of 165 mPa·s or greater.

[0045] In another embodiment, in any golf ball of the invention incorporating an LCBNCP having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s, the cold flow may be reduced by up to about 40% over the cold flow of neodymium-catalyzed polybutadiene containing golf ball components having a solution viscosity of 165 mPa·s or greater.

[0046] In yet another embodiment, in any golf ball of the invention incorporating an LCBNCP having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s, the green strength may be improved by up to about 50% over that of golf balls including neodymium-catalyzed polybutadiene containing golf ball components having a solution viscosity of 165 mPa·s or greater.

[0047] In still another embodiment, in any golf ball of the invention incorporating an LCBNCP having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s, the tack may be up to 65% more suitable than that of neodymium-catalyzed polybutadiene containing golf ball components having a solution viscosity of 165 mPa·s or greater.

[0048] Meanwhile, in any golf ball of the invention incorporating an LCBNCP having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s, backrinding may be reduced by up to about 50% over neodymium-catalyzed polybutadiene containing golf ball components having a solution viscosity of 165 mPa·s or greater.

[0049] In one embodiment, the overall golf ball has a compression of from about 25 to about 110. In another embodiment, the overall golf ball has a compression of from about 35 to about 100. In yet another embodiment, the overall golf ball has a compression of from about 45 to about 95. In still another embodiment, the compression may be from about 55 to about 85, or from about 65 to about 75. Meanwhile, the compression may also be from about 50 to about 110, or from about 60 to about 100, or from about 70 to about 90, or even from about 80 to about 110

[0050] Generally, in golf balls of the invention, the overall golf ball COR is at least about 0.780. In another embodiment, the overall golf ball COR is at least about 0.788. In yet another embodiment, the overall golf ball COR is at least about 0.791. In still another embodiment, the overall golf ball COR is at least about 0.794. Also, the overall golf ball COR may be at least about 0.797. The overall golf ball COR may even be at least about 0.800, or at least about 0.803, or at least about 0.812.

[0051] Another aspect of the invention relates to a method of making a golf ball having a COR of at least about 0.780 comprising the steps of: selecting a long-chain branched neodymium-catalyzed polybutadiene having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s; and providing a core, a cover and optionally an intermediate layer disposed between the core and the cover wherein at least one of said core, cover and intermediate layer is formed from the long-chain branched neodymium-catalyzed polybutadiene. In another embodiment, at least one of said cover and intermediate layer is formed from the long-chain branched neodymium-catalyzed polybutadiene. In yet another embodiment, said cover is formed from the long-chain branched neodymium-catalyzed polybutadiene.

[0052] In each embodiment, the long-chain branched neodymium-catalyzed polybutadiene may be selected and/or provided in any or all of the core, cover and intermediate layer in any amount as discussed herein. For example, the long-chain branched neodymium-catalyzed polybutadiene may be selected and/or provided in an amount of at least about 2 wt % of any or all of the core, cover and intermediate layer.

[0053] Alternatively, the invention relates to a method of making a golf ball having a COR of at least about 0.780 comprising the steps of: selecting a long-chain branched neodymium-catalyzed polybutadiene composition having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s; and providing a core, a cover and optionally an intermediate layer disposed between the core and the cover wherein at least one of said core, cover and intermediate layer is formed from the long-chain branched neodymium-catalyzed polybutadiene composition. In another embodiment, at least one of said cover and intermediate layer is formed from the long-chain branched neodymium-catalyzed polybutadiene composition. In yet another embodiment, said cover is formed from the long-chain branched neodymium-catalyzed polybutadiene composition.

[0054] In each embodiment, the long-chain branched neodymium-catalyzed polybutadiene composition may be selected and/or provided in any or all of the core, cover and intermediate layer in any amount as discussed herein. For example, the long-chain branched neodymium-catalyzed polybutadiene composition may be selected and/or provided in an amount of at least about 5 wt % of any or all of the core, cover and intermediate layer. In another embodiment, the long-chain branched neodymium-catalyzed polybutadiene composition may comprise a long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 5 wt % of the composition. Any or all of the core, intermediate layer and cover may comprise, consist essentially of or consist of the long-chain branched neodymium-catalyzed polybutadiene composition.

[0055] The invention also relates to a method of making a golf ball having a COR of at least about 0.780 and a compression of from about 25 to about 120. In one embodiment, the method is for controlling the processability of the golf ball as defined herein. In particular, the method of making the golf ball comprises the steps of: selecting a polybutadiene composition comprising a long-chain branched neodymium-catalyzed polybutadiene having a cis-1,4 content of at least about 96% by weight and a solution viscosity of less than 165 mPa·s; and providing a core, a cover and optionally an intermediate layer disposed between the core and the cover wherein at least one of said core, cover and intermediate layer is formed from the polybutadiene composition. In another embodiment, at least one of the intermediate layer and cover comprise the polybutadiene composition. In still another embodiment, the cover comprises the polybutadiene composition.

[0056] In each embodiment, the polybutadiene composition may be selected and/or provided in any or all of the core, cover and intermediate layer in any amount as discussed herein. For example, the polybutadiene composition may be selected and/or provided in an amount of at least about 5 wt % of any or all of the core, cover and intermediate layer. In another embodiment, the long-chain branched neodymium-catalyzed polybutadiene may be present in the polybutadiene composition in an amount of at least about 5 wt %. Any or all of the core, intermediate layer and cover may comprise, consist essentially of or consist of the polybutadiene composition.

[0057] The LCBNCP may also comprise combinations/blends of a long-chain branched neodymium-catalyzed polybutadiene, a long-chain branched neodymium-catalyzed polybutadiene composition and/or a polybutadiene composition. In a non-limiting example, each is present in the LCBNCP in a ratio of 1:1:1, respectively. In another embodiment, each is present in the LCBNCP in a ratio of 2:1:1, respectively. In yet another embodiment, each may be present in the LCBNCP in a ratio of 4:1:1. In still another embodiment, each may be present in the LCBNCP in a ratio of 4:2:1. Or, for example, the LCBNCP may include a long-chain branched neodymium-catalyzed polybutadiene composition and a polybutadiene composition in a 1:3 ratio. These combinations/ratios are intended as examples of some of the many other possible combinations/blends/ratios of an inventive golf ball incorporating an LCBNCP including the long-chain branched neodymium-catalyzed polybutadiene, long-chain branched neodymium-catalyzed polybutadiene composition and/or polybutadiene composition.

DETAILED DESCRIPTION OF THE INVENTION

[0058] 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 at least a base rubber, free-radical initiator agent, cross-linking co-agent, and fillers. In the golf ball of the invention, the base rubber may be the LCBNCP of either: at least about 5 wt % of a polybutadiene composition comprising, consisting essentially of or consisting of a long-chain branched neodymium-catalyzed polybutadiene; or a long-chain branched neodymium-catalyzed polybutadiene composition comprising at least 5 wt % of a long-chain branched neodymium-catalyzed polybutadiene. The addition of an LCBNCP in the golf ball provides a golf ball having a high COR and wide range of possible compressions with excellent processability relating to both golf ball materials handling and golf ball manufacture.

[0059] One example of a suitable base rubber LCBNCP for the golf ball of the invention and method of making same is LANXESS BUNA CB 25 ("CB25"). LANXESS' CB 25 is a long-chain branched neodymium-catalyzed polybutadiene having a solution viscosity of 145, much lower than the solution viscosities of other LANXESS neodymium-catalyzed polybutadienes such as CB 22, CB 23, and CB 24. Two neodymium-catalyzed polybutadienes may have identical Mooney viscosities yet have very different solution viscosities. For example, while CB 24 and CB 25 both have Mooney's of 44, CB 24's solution viscosity is at least 20 mPa·s greater than that of CB 25. The golf ball of the invention possesses superior processability and performance due to the lower solution viscosity of the long chain branched neodymium-catalyzed polybutadiene at a given molecular weight, Mooney viscosity and polydispersity.

[0060] Examples of polybutadiene rubbers for blending with the base rubber may include BUNA® CB22, BUNA® CB23 and BUNA® CB24, 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® NEOCIS® 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.

[0061] The base rubber may further include polyisoprene rubber, natural rubber, ethylene-propylene rubber, ethylene-propylene diene rubber, styrene-butadiene rubber, and combinations of two or more thereof. 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 as part of the blend. Such compositions will provide increased flexural modulus and toughness thereby improving the golf ball's performance including its impact durability.

[0062] 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 compound 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-butyl-peroxyisopropyl)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.

[0063] The LCBNCP may also comprise low, medium or high 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, as long as the solution viscosity of the LCBNCP is less than 165 mPa·s or as otherwise disclosed herein in alternative embodiments.

[0064] 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.

[0065] If desired, the LCBNCP 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.

[0066] Thermoplastic elastomers (TPE) may 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.

[0067] 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.

[0068] 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.

[0069] 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.

[0070] The outer core, intermediate layer, inner cover, and/or outer cover may also comprise, consist essentially of or consist of the LCBNCP. In some instances, a traditional thermoplastic or thermosetting composition may be used to make one layer and the LCBNCP 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 LCBNCP 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® 10 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 ionomeric 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.

[0071] 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:

[0072] (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;

[0073] (2) Polyureas, such as those disclosed in U.S. Pat. Nos. 5,484,870 and 6,835,794; and

[0074] (3) Polyurethane-urea hybrids, blends or copolymers comprising urethane or urea segments.

[0075] 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.

[0076] 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_{12}MDI); p-phenylene diisocyanate (PPDI); m-phenylene diisocyanate (MPDI); toluene diisocyanate (TDI); 3,3'-dimethyl-4,4'-biphenylene diisocyanate; isophoronediisocyanate; 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; napthalene 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. Additionally, the prepolymers synthesized from these diisocyanates may be "low free monomer," understood by one of ordinary skill in the art to have lower levels of "free" isocyanate monomers, typically less than about 0.1% free isocyanate. Examples of "low free monomer" prepolymers include, but are not limited to Low Free Monomer MDI prepolymers, Low Free Monomer TDI prepolymers, and Low Free Monomer PPDI prepolymers.

[0077] 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.

[0078] 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.

[0079] 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.

[0080] 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.

[0081] 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'-dialkyldiamino 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.

[0082] 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-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.

[0083] 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.

[0084] 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

[0085] Thermosetting polyurethanes or polyureas are suitable for the outer cover layers of the golf balls of the invention.

[0086] Additionally, polyurethane can be replaced with or blended with a polyurea material. Polyureas are distinctly different from polyurethane compositions, giving better shear resistance. The polyurea-based compositions are preferably saturated in nature.

[0087] 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.

[0088] 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

[0089] Suitable amine-terminated curing agents include, but are not limited to, ethylene diamine; hexamethylene diamine; 1-methyl-2,6-cyclohexyl diamine; tetrahydroxypropylene 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; 3,5-diethyltoluene-2,4-diamine; 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-diethyleneaniline); 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.

[0090] Suitable saturated amine-terminated curing agents include, but are not limited to, ethylene diamine; hexamethylene diamine; 1-methyl-2,6-cyclohexyl diamine; tetrahydroxypropylene 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 prepolymers.

[0091] Alternatively, other suitable polymers include partially or fully neutralized ionomer, metallocene, or other single-site catalyzed polymer, polyester, polyamide, non-ionomeric thermoplastic elastomer, copolyether-esters, copolyether-amides, polycarbonate, polybutadiene, polyisoprene, polystryrene block copolymers (such as styrene-butadiene-styrene), styrene-ethylene-propylene-styrene, styrene-ethylene-butylene-styrene, and the like, and blends thereof.

[0092] Cover layers of the inventive golf ball may also be formed from ionomeric 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 ionomeric 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.

[0093] 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 α-olefin, such as ethylene, C_{3-8} α,β-ethylenically unsaturated carboxylic acid, such as acrylic and methacrylic acid, copolymers. They may optionally contain a softening monomer, such as alkyl acrylate and alkyl methacrylate, wherein the alkyl groups have from 1 to 8 carbon atoms.

[0094] The acid copolymers can be described as E/X/Y copolymers where E is ethylene, X is an α,β-ethylenically unsaturated carboxylic acid, andY 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.

[0095] 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.

[0096] 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, 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 is accomplished by melt-blending an ethylene α,β-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%).

[0097] 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, linoelic 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).

[0098] 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.

[0099] 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 and extends the usable life of the golf ball. In one embodiment, the moisture barrier layer comprises a LCBNCP 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.

[0100] The LCBNCP constituting the layer(s) of the inventive 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, and a balance of ball performance.

[0101] Blowing/foaming agents may also be particularly compatible with the LCBNCP incorporated golf ball of the invention, including, for example those disclosed in U.S. Pat. No. 7,708,654. Typical physical foaming/blowing agents include volatile liquids such as freons (CFCs), other halogenated hydrocarbons, water, aliphatic hydrocarbons, gases, and solid blowing agents, i.e., compounds that liberate gas as a result of desorption of gas. Preferably, the blowing agent includes an adsorbent. Typical adsorbents include, for example, activated carbon, calcium carbonate, diatomaceous earth, and silicates saturated with carbon dioxide.

[0102] Chemical foaming/blowing agents are more preferred, particularly when the core includes thermoplastics such as ionomers, highly neutralized polymers, and polyolefins. Chemical blowing agents may be inorganic, such as ammonium carbonate and carbonates of alkalai metals, or may be organic, such as azo and diazo compounds, such as nitrogen-based azo compounds. Suitable azo compounds include, but are not limited to, 2,2'-azobis(2-cyanobutane), 2,2'-azobis(methylbutyronitrile), azodicarbonamide, p,p'-oxybis(benzene sulfonyl hydrazide), p-toluene sulfonyl semicarbazide, p-toluene sulfonyl hydrazide. Other blowing agents include any of the Celogens® sold by Crompton Chemical Corporation, and nitroso compounds, sulfonylhydrazides, azides of organic acids and their analogs, triazines, tri- and tetrazole derivatives, sulfonyl semicarbazides, urea derivatives, guanidine derivatives, and esters such as alkoxyboroxines. Other possible blowing agents include agents that liberate gasses as a result of chemical interaction between components such as mixtures of acids and metals, mixtures of organic acids and inorganic carbonates, mixtures of nitriles and ammonium salts, and the hydrolytic decomposition of urea.

[0103] Alternatively, low specific gravity can be achieved by incorporating low density fillers or agents such as hollow fillers or microspheres in the polymeric matrix, where the cured composition has the preferred specific gravity. Moreover, the polymeric matrix can be foamed to decrease its specific gravity, microballoons, or other low density fillers as described in U.S. Pat. No. 6,692,380 ("'380 patent"). The '380 patent is incorporated by reference in its entirety.

[0104] The LCBNCP in the golf ball 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, polyurethanes, polyureas, polyamides, polyphenylenes, polycarbonates, polyesters, polyacrylates, engineering thermoplastics, and the like. Also, in one embodiment of the invention, processability of the golf ball of the invention may even be enhanced by incorporating in the core a metallocene-catalyzed polybutadiene.

[0105] 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 LCBNCP 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.

[0106] 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.

[0107] A golf ball according to the invention may therefore incorporate the LCBNCP in a core to achieve various hardness gradients therein. For example, the LCBNCP may be incorporated in a single-core constituting a solid core having a "positive" hardness gradient (that is, the outer surface of the core is harder than its geometric center.) In a second embodiment, the LCBNCP may be incorporated in a dual-core comprising an inner core and a surrounding outer core layer. The inner core has a "positive" hardness gradient and the outer core layer has a "negative" hardness gradient (that is, the outer surface of the outer core layer is softer than the inner surface of the outer core layer.) Other embodiments of golf balls having various combinations of positive, negative, and zero hardness gradients may be made in accordance with this invention. For example, the inner core may have a positive hardness gradient and the outer core layer also may have a positive hardness gradient. In another example, the inner core may have a positive hardness gradient and the outer core layer may have a "zero" hardness gradient. (That is, the hardness values of the outer surface of the outer core layer and the inner surface of the outer core layer are substantially the same.) Particularly, the term, "zero hardness gradient" as used herein, means a surface to center Shore C hardness gradient of less than 8, preferably less than 5 and most preferably less than 3 and may have a value of zero or negative 1 to negative 25. The term, "negative hardness gradient" as used herein, means a surface to center Shore C hardness gradient of less than zero. The terms, zero hardness gradient and negative hardness gradient, may be used herein interchangeably to refer to hardness gradients of negative 1 to negative 25. The term, "positive hardness gradient" as used herein, means a surface to center Shore C hardness gradient of 8 or greater, preferably 10 or greater, and most preferably 20 or greater. By the term, "steep positive hardness gradient" as used herein, it is meant surface to center Shore C hardness gradient of 20 or greater, more preferably 25 or greater, and most preferably 30 or greater. For example, the LCBNCP containing core may have a step positive hardness gradient of 35, 40, or 45 Shore C or greater. Methods for measuring the hardness of the inner core and surrounding layers and determining the hardness gradients are discussed in further detail below.

[0108] The center hardness of a core is obtained according to the following procedure. 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 is 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' surface is ground to a smooth, flat surface, revealing the geometric center of the core, which can be verified by measuring the height from 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 0.004 inches. 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 according to ASTM D-2240. Additional hardness measurements at any distance from the center of the core can then be made by drawing a line radially outward from the center mark, and

[0109] measuring the hardness at any given distance along the line, typically in 2 mm increments from the center. The hardness at a particular distance from the center should be measured along at least two, preferably four, radial arms located 180° apart, or 90° apart, respectively, and then averaged. All hardness measurements performed on a 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, and thus also parallel to the properly aligned foot of the durometer.

[0110] The outer surface hardness of a golf ball layer is measured on the actual outer surface of the layer and is obtained from the average of a number of measurements taken from opposing hemispheres, 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, care must be taken to ensure that the golf ball or golf ball subassembly is centered under the durometer indentor before a surface hardness reading is obtained. A calibrated, digital durometer, capable of reading to 0.1 hardness units is used for the hardness measurements. The digital durometer must be attached to, and its foot made parallel to, the base of an automatic stand. The weight on the durometer and attack rate conform to ASTM D-2240. In certain embodiments, a point or plurality of points measured along the "positive" or "negative" gradients may be above or below a line fit through the gradient and its outermost and innermost hardness values. In an alternative preferred embodiment, the hardest point along a particular steep "positive" or "negative" gradient may be higher than the value at the innermost portion of the inner core (the geometric center) or outer core layer (the inner surface)—as long as the outermost point (i.e., the outer surface of the inner core) is greater than (for "positive") or lower than (for "negative") the innermost point (i.e., the geometric center of the inner core or the inner surface of the outer core layer), such that the "positive" and "negative" gradients remain intact.

[0111] As discussed above, the direction of the hardness gradient of a golf ball layer is defined by the difference in hardness measurements taken at the outer and inner surfaces of a particular layer. The center hardness of an inner core and hardness of the outer surface of an inner core in a single-core ball or outer core layer are readily determined according to the test procedures provided above. The outer surface of the inner core layer (or other optional intermediate core layers) in a dual-core ball are also readily determined according to the procedures given herein for measuring the outer surface hardness of a golf ball layer, if the measurement is made prior to surrounding the layer with an additional core layer. Once an additional core layer surrounds a layer of interest, the hardness of the inner and outer surfaces of any inner or intermediate layers can be difficult to determine. Therefore, for purposes of the present invention, when the hardness of the inner or outer surface of a core layer is needed after the inner layer has been surrounded with another core layer, the test procedure described above for measuring a point located 1 mm from an interface is used.

[0112] Also, it should be understood that there is a fundamental difference between "material hardness" and "hardness as measured directly on a golf ball." For purposes of the present invention, material hardness is measured according to ASTM D2240 and generally involves measuring the hardness of a flat "slab" or "button" formed of the material. Surface hardness as measured directly on a golf ball (or other spherical surface) typically results in a different hardness value. The difference in "surface hardness" and "material hardness" values is due to several factors including, but not limited to, ball construction (that is, core type, number of cores and/or cover layers, and the like); ball (or sphere) diameter; and the material composition of adjacent layers. It also should be understood that the two measurement techniques are not linearly related and, therefore, one hardness value cannot easily be correlated to the other. Shore C hardness was measured according to the test methods D-2240.

[0113] 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 or PGA 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. The approximate relationship that exists between Atti or PGA compression and Riehle compression can be expressed as: (Atti or PGA compression)=(160−Riehle Compression). Thus, a Riehle compression of 100 would be the same as an Atti compression of 60.

[0114] 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.

[0115] 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.

[0116] 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 center has a higher density or specific gravity than the outer layers, 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^2, which is the baseline moment of inertia value.

[0117] 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 to 0.440 to about 0.455 oz-in^2. In another embodiment, the golf balls of the present invention have a moment of inertia of from about 0.456 oz-in^2 to about 0.470 oz-in^2. In yet another embodiment, the golf ball has a moment of inertia of from about 0.450 oz-in^2 to about 0.460 oz-in^2.

[0118] In one embodiment, the LCBNCP composition of the golf ball of the present invention has a moisture vapor transmission rate ("MVTR") of 10 g/m^2/day or less, preferably 8 or less, more preferably 2 or less. As used herein, MVTR is given in g/m^2/day, and is measured at 20° C., according to ASTM F1249-99.

[0119] By way of non-limiting prophetic example, the novelty of the invention may be demonstrated as follows. Table I below reveals the superior processability of four core material formulations for incorporation in the inventive golf ball over three comparative core material formulations under the same conditions. All of the core materials would be formulated to be incorporated in a golf ball having high COR and a broad range of compressions as arranged in Table I. In table I, each of the core materials for incorporation in an inventive golf ball would include a polybutadiene composition incorporating 15 wt % of a long-chain branched neodymium-catalyzed polybutadiene. The solution viscosities of the long-chain branched neodymium-catalyzed polybutadienes in each of the inventive golf ball core materials would be less than 165 mPa·s as indicated in Table I. Meanwhile, each of the comparative golf ball core materials would have the same formulation as that of the inventive golf ball core material except that the long-chain branched neodymium-catalyzed polybutadiene of the inventive golf ball core material would be replaced with a neodymium-catalyzed polybutadiene having a solution viscosity of 165 mPa·s or greater. Specifically, Ex1-Ex4 might be LCBNCP's having SV's of 145 (LANXESS BUNA CB 25), 130, 100, and 85, respectively. The comparative examples 1, 2 and 3 would incorporate the following neodymium-catalyzed polybutadienes, respectively: LANXESS BUNA CB 22 (SV 400); LANXESS BUNA CB 23 (SV 300); and LANXESS BUNA CB 24 (SV 165).

[0120] The processability of each golf ball core composition/material would be evaluated. In particular, for each of the four inventive golf ball core formulations as well as the three comparative golf ball core formulations, the following would be measured: quality of mix, extrudability, appearance (surface smoothness of extrudate), cold flow, green strength, tack, and backrinding.

[0121] Quality of mix, extrudability, surface smoothness, tack, and backrinding may be observed visually for each material prior to molding or by any other method known in the art. Cold flow may be examined by the following method or any other method known in the art. Each neodymium-catalyzed raw polybutadiene or compounded golf ball core stock, having the dimensions 120 mm (length) by 115 mm (width) and 100 mm (depth) would be placed/fit into one end of a steel box having the dimensions 120 mm length by 200 mm width and 100 mm depth. A 6 kg steel block is placed and fit on top of the slug having dimensions 120 mm by 115 mm width and X mm depth. The change (increase) in the slug's width is monitored/marked on the box at discrete intervals over 10,000 minutes. Green strength may be evaluated using any method known in the art for testing the tensile strength and/or tensile modulus of the uncured rubber.

[0122] In Table I, the core materials of an inventive golf ball having a targeted overall golf ball ("GB") COR of 0.788 and a variety of compressions are assigned a rating of "great" since each of these core materials displays excellent processability in the 7 processing categories identified above. The core materials in comparative example 3 are assigned a rating of "worse" because their processability is inferior to that of each of the inventive cores under the same conditions. In turn, the core materials in comparative example 2 are assigned a rating of "even worse" because these comparative cores display even worse processability at a given condition than the core materials of comparative example 2. Finally, the core materials of comparative example 1 are assigned a rating of "worst" since these core materials display the worst processability of any of the other core materials under the same conditions.

[0123] And this assessment could be repeated for different weight % contents of LCBNCP in the inventive golf ball core materials, intermediate layer materials and/or cover materials, such as 50 wt % or 90 wt %, for example.

[0124] Accordingly, an inventive golf ball including a polybutadiene composition incorporating 15 wt % or even 50 wt % or even 90 wt % of a long-chain branched neodymium-catalyzed polybutadiene having a solution viscosity less than 165 mPa·s would possess and display superior processability over the comparative golf balls including neodymium-catalyzed polybutadienes having solution viscosities of 165 mPa·s or greater.

TABLE I

Processability of Golf Ball Materials* including Polybutadiene Composition incorporating 15 wt % of LCBNCP having Solution viscosity of less than 165 mPa · s

Processability of GB core material at targeted GB COR & compression	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Ex 1	Ex 2	Ex 3	Ex 4
0.788 & 25	Worst	Even Worse	Worse	Great	Great	Great	Great
0.791 & 35	Worst	Even Worse	Worse	Great	Great	Great	Great
0.794 & 45	Worst	Even Worse	Worse	Great	Great	Great	Great
0.797 & 55	Worst	Even Worse	Worse	Great	Great	Great	Great
0.800 & 65	Worst	Even Worse	Worse	Great	Great	Great	Great
0.803 & 75	Worst	Even Worse	Worse	Great	Great	Great	Great
0.806 & 85	Worst	Even Worse	Worse	Great	Great	Great	Great
0.809 & 95	Worst	Even Worse	Worse	Great	Great	Great	Great

TABLE I-continued

Processability of Golf Ball Materials* including Polybutadiene Composition incorporating 15 wt % of LCBNCP having Solution viscosity of less than 165 mPa · s

Processability of GB core material at targeted GB COR & compression	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Ex 1	Ex 2	Ex 3	Ex 4
0.812 & 105	Worst	Even Worse	Worse	Great	Great	Great	Great
0.815 & 115	Worst	Even Worse	Worse	Great	Great	Great	Great

*In Table I, the balance of golf ball components may include, for example, a "masterbatch" composition comprising one of the following:
(1) Where the golf ball material is a core formulation comprising the polybutadiene composition incorporating LCBNCP, the masterbatch composition may comprise, for example, 100 phr polybutadiene rubber, 0.6 phr of Perkadox BC-FF peroxide initiator, 20-40 phr of SR-526 Zinc diacrylate coagent (amount varies according to desired compression), 5 phr of ZnO filler and BaSO4 density adjusting filler (amount varies according to desired specific gravity);
(2) Where the golf ball material is an inner cover or intermediate layer formulation comprising the polybutadiene composition incorporating LCBNCP, the masterbatch composition may comprise, for example, 100 phr of Surlyn 9910; and
(3) Where the golf ball material is an outer cover formulation comprising the polybutadiene composition incorporating LCBNCP, the masterbatch composition may comprise, for example, 100 phr of Estane 58881 (TPU).

[0125] Accordingly, a golf ball according to the invention comprising in at least one of its core, intermediate layer, inner cover layer or outer cover layer an LCBNCP as described herein improves golf ball processability/processing characteristics including, for example excellent quality of mix, extrudability, extrudate surface smoothness, controlled cold flow, greater green strength, suitable tack, less backrinding, and improved compatability with other golf ball materials including for example foaming agents.

[0126] The LCBNCP's disclosed in the examples of Table I above represent only several of many possible formulations for the LCBNCP which may be modified or replaced with any formulation consistent with the disclosure herein, including combinations and blends of several LCBNCP's or at least one LCBNCP with at least one linear neodymium-catalyzed polybutadiene.

[0127] 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.

[0128] 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.

[0129] 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.

[0130] 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.

[0131] 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 comprises 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.

[0132] 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.

[0133] 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.

What is claimed is:

1. A golf ball comprising a long-chain branched neodymium-catalyzed polybutadiene having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s,

wherein the overall golf ball comprises a COR of at least about 0.780 and an Atti compression of from about 25 to about 120.

2. The golf ball of claim **1**, comprising the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 5 wt %.

3. The golf ball of claim **1**, comprising the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 10 wt %.

4. The golf ball of claim **1**, comprising the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 15 wt %.

5. The golf ball of claim **1**, comprising the long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 2 wt % to about 5 wt % or greater.

6. The golf ball of claim **1**, wherein the COR is at least about 0.791.

7. The golf ball of claim **1**, wherein the COR is at least about 0.797.

8. The golf ball of claim **1**, wherein the COR is at least about 0.803.

9. The golf ball of claim **1**, wherein the solution viscosity of the long-chain branched neodymium-catalyzed polybutadiene is less than 155 mPa·s.

10. The golf ball of claim **1**, wherein the solution viscosity of the long-chain branched neodymium-catalyzed polybutadiene is less than 145 mPa·s.

11. The golf ball of claim **1**, wherein the solution viscosity of the long-chain branched neodymium-catalyzed polybutadiene is less than 115 mPa·s.

12. A golf ball comprising:

a core, a cover and optionally an intermediate layer disposed between the core and the cover;

wherein at least one of said core, cover and intermediate layer comprises a polybutadiene composition comprising a long-chain branched neodymium-catalyzed polybutadiene having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s.

13. The golf ball of claim **12**, the at least one of said core, cover and intermediate layer comprising the polybutadiene composition in an amount of at least about 5 wt %.

14. The golf ball of claim **12**, the polybutadiene composition comprising the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 5 wt %.

15. The golf ball of claim **12**, wherein the at least one of said core, cover and intermediate layer comprises the polybutadiene composition in an amount of at least about 5 wt % and wherein the polybutadiene composition comprises the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 5 wt %.

16. The golf ball of claim **12**, wherein the at least one of the core, cover and intermediate layer comprises the polybutadiene composition in an amount of from about 5 wt % to about 95 wt %.

17. The golf ball of claim **12**, wherein the at least one of the core, cover and intermediate layer comprises the polybutadiene composition in an amount of from about 10 wt % to about 85 wt %.

18. The golf ball of claim **12**, wherein the at least one of the core, cover and intermediate layer comprises the polybutadiene composition in an amount of up to about 100 wt %.

19. The golf ball of claim **12**, wherein the polybutadiene composition of the at least one of the core, intermediate layer and cover comprises the long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 5 wt % to about 95 wt %.

20. The golf ball of claim **12**, wherein the polybutadiene composition of the at least one of the core, intermediate layer and cover comprises the long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 10 wt % to about 85 wt %.

21. The golf ball of claim **12**, wherein the polybutadiene composition of the at least one of the core, intermediate layer and cover comprises the long-chain branched neodymium-catalyzed polybutadiene in an amount of up to about 100 wt %.

22. The golf ball of claim **12**, wherein the COR is at least about 0.791.

23. The golf ball of claim **12**, wherein the COR is at least about 0.797.

24. The golf ball of claim **12**, wherein the COR is at least about 0.803.

25. The golf ball of claim **12**, wherein the solution viscosity of the polybutadiene composition is less than 155 mPa·s.

26. The golf ball of claim **12**, wherein the solution viscosity of the polybutadiene composition is less than 145 mPa·s.

27. The golf ball of claim **12**, wherein the solution viscosity of the polybutadiene composition is less than 115 mPa·s.

28. A golf ball comprising:

a core, a cover and optionally an intermediate layer disposed between the core and the cover;

wherein said core comprises a polybutadiene composition comprising a long-chain branched neodymium-catalyzed polybutadiene having a cis-1,4 content of at least about 96% and a solution viscosity of less than 165 mPa·s.

29. The golf ball of claim **28**, said core, cover and intermediate layer comprising the polybutadiene composition in an amount of at least about 5 wt %.

30. The golf ball of claim **28**, the polybutadiene composition comprising the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 5 wt %.

31. The golf ball of claim **28**, wherein said core comprises the polybutadiene composition in an amount of at least about 5 wt % and wherein the polybutadiene composition comprises the long-chain branched neodymium-catalyzed polybutadiene in an amount of at least about 5 wt %.

32. The golf ball of claim **28**, wherein the core comprises the polybutadiene composition in an amount of from about 5 wt % to about 95 wt %.

33. The golf ball of claim **28**, wherein the core comprises the polybutadiene composition in an amount of from about 10 wt % to about 85 wt %.

34. The golf ball of claim **28**, wherein the core comprises the polybutadiene composition in an amount of up to about 100 wt %.

35. The golf ball of claim **28**, wherein the polybutadiene composition of the core comprises the long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 5 wt % to about 95 wt %.

36. The golf ball of claim **28**, wherein the polybutadiene composition of the core comprises the long-chain branched neodymium-catalyzed polybutadiene in an amount of from about 10 wt % to about 85 wt %.

37. The golf ball of claim **28**, wherein the COR is at least about 0.791.

38. The golf ball of claim **28**, wherein the COR is at least about 0.797.

39. The golf ball of claim **28**, wherein the COR is at least about 0.803.

40. The golf ball of claim **28**, wherein the solution viscosity of the polybutadiene composition is less than 155 mPa·s.

41. The golf ball of claim **28**, wherein the solution viscosity of the polybutadiene composition is less than 145 mPa·s.

42. The golf ball of claim **28**, wherein the solution viscosity of the polybutadiene composition is less than 115 mPa·s.

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