

DISPERSANTS AND DISPERSANT VISCOSITY INDEX IMPROVERS
FROM SELECTIVELY HYDROGENATED POLYMERS:
HYDROFORMYLATION/REDUCTIVE AMINATION REACTION PRODUCTS

5 This invention relates to dispersants, dispersants with improved engine performance, dispersants with viscosity index (VI) improving properties, and dispersant VI improvers from functionalized diene polymers, and methods of their use. More particularly, the invention relates to dispersants,
10 dispersants with VI improving properties, and dispersant VI improvers from selectively hydrogenated copolymers prepared using conjugated dienes. The invention is additionally directed to dispersants, dispersants with VI improving properties, and dispersant VI improvers from chemically
15 modified derivatives of the above polymers.

Liquid elastomers are well known and are used in various applications. For example, many functionally terminated polybutadiene liquid elastomers are known. These materials are generally highly unsaturated and frequently form the base
20 polymer for polyurethane formulations. The preparation and application of hydroxy-terminated polybutadiene is detailed by J.C. Brosse et al. in *Hydroxyl-terminated polymers obtained by free radical polymerization - Synthesis, characterization and applications*, Advances in Polymer Science 81, Springer -
25 Verlag, Berlin, Heidelberg, 1987, pp. 167-220.

Also, liquid polymers possessing acrylate, carboxy- or mercapto-terminals are known. In addition to butadiene, it is known to utilize isoprene as the base monomer for the liquid elastomers. The liquid elastomers may contain additional
30 monomers, such as styrene or acrylonitrile, for controlling compatibility in blends with polar materials, such as epoxy resins.

Also known in the prior art are pure hydrocarbon, non-functionalized liquid rubbers. These liquid elastomers
35 contain varying degrees of unsaturation for utilization in vulcanization. Typical of highly unsaturated liquid elastomers is polybutadiene, e.g., that sold under the name

RICON by Ricon Resins, Inc. A liquid polyisoprene which has been hydrogenated to saturate 90% of its original double bonds is marketed as LIR-290 by Kuraray Isoprene Chemical Co. Ltd. Still more highly saturated are liquid butyl rubbers available from Hardman Rubber Co., and Trilene, a liquid ethylene-propylene-diene rubber (EPDM) available from Uniroyal Chemical Co. The more highly saturated liquid elastomers exhibit good oxidation and ozone resistance properties.

Falk, Journal of Polymer Science: PART A-1, 9:2617-23 (1971), discloses a method of hydrogenating 1,4,-polybutadiene in the presence of 1,4-polyisoprene. More particularly, Falk discloses hydrogenation of the 1,4-polybutadiene block segment in the block copolymer of 1,4-polybutadiene - 1,4-polyisoprene - 1,4-polybutadiene and in random copolymers of butadiene and isoprene, with both polymerized monomers having predominantly 1,4-microstructure. Hydrogenation is conducted in the presence of hydrogen and a catalyst made by the reaction of organoaluminum or lithium compounds with transition metal salts of 2-ethylhexanoic acid. Falk, Die Angewandte Chemie, 21(286):17-23 (1972), discloses the hydrogenation of 1,4-polybutadiene segments in a block copolymer of 1,4-polybutadiene-1,4-polyisoprene-1,4-polybutadiene.

Hoxmeier, Published European Patent Application 88202449.0, filed on November 2, 1988, Publication Number 0 315 280, published on May 10, 1989, discloses a method of selectively hydrogenating a polymer made from at least two different conjugated diolefins. One of the two diolefins is more substituted in the 2, 3 and/or 4 carbon atoms than the other diolefin and produces tri- or tetra-substituted double bond after polymerization. The selective hydrogenation is conducted under such conditions as to hydrogenate the ethylenic unsaturation incorporated into the polymer from the lesser substituted conjugated diolefin, while leaving unsaturated at least a portion of the tri- or tetra-substituted unsaturation incorporated into the polymer by the more substituted conjugated diolefin.

Mohajer et al., *Hydrogenated linear block copolymers of butadiene and isoprene: Effects of variation of composition and sequence architecture on properties*, Polymer 23:1523-35 (1982) discloses essentially completely hydrogenated
5 butadiene-isoprene-butadiene(HBIB), HIBI and HBI block copolymers in which butadiene has predominantly 1,4-microstructure.

Kuraray K K, Japanese published patent application Number JP-328 729, filed on December 12, 1987, published on July 4,
10 1989, discloses a resin composition comprising 70-99% wt. of a polyolefin(preferably polyethylene or polypropylene) and 1-30% wt. of a copolymer obtained by hydrogenation of at least 50% of unsaturated bond of isoprene/butadiene copolymer.

Ashless dispersants are additives to lubricant fluids
15 such as fuels and lubricating oils which improve the dispersability of the fluids or improve their viscometric properties. Typically, such dispersants are modified polymers, having an oleophilic polymer backbone to assure good solubility and to maintain particles suspended in the oil, and
20 polar functionality to bind or attach to oxidation products and sludge. Dispersants generally have a solubilizing oleophilic (hydrophobic) tail and a polar (hydrophilic) head, forming micelles when actively bound to sludge.

Common dispersants include polyisobutenes which have been
25 modified by the ene reaction to include functional groups such as succinimides, hydroxyethyl imides, succinate esters/amides, and oxazolines. Other dispersants include Mannich base derivatives of polybutenes, ethylene propylene polymers, and acrylic polymers.

Traditionally, dispersants have been polybutenes
30 functionalized at one site in the molecule via an ene reaction with maleic anhydride followed by imidization with a polyamine. The polybutenes are typically 500-2,000 in molecular weight, and due to the polymerization process
35 employed in their manufacture, have no more than one double bond per polybutene molecule. Accordingly, the number of potential functional groups per chain is limited to one.

Typically, this site is at a terminal portion of the molecule. Moreover, it is generally accepted that, in order to obtain beneficial dispersant properties, a molecule must have at least one functional group per approximately 2,000 molecular weight. Consequently, the molecular weight of traditional polybutene dispersants cannot exceed 2,000 if the desired functionality/hydrocarbon ratio is to be maintained. In addition, traditional dispersants have had molecular structures which have limited the placement of functional groups, generally requiring that such groups be placed at the terminal regions of the molecules.

The polymerization process for the traditional butene polymers has also generated products having an unacceptably wide distribution of molecular weights, i.e., an unacceptably high ratio of weight average molecular weight (M_w) to number average molecular weight (M_n). Typically, such distributions are $M_w/M_n \geq 2.5$, producing compositions whose dispersant properties are not well defined.

Moreover, functionalization reactions in these polymers have typically yielded substantial quantities of undesirable by-products such as insoluble modified polymers of variant molecular weight. Functionalization reactions can also result in compounds which contain undesirable chemical moieties such as chlorine.

U.S. Patent No. 4,007,121 to Holder et al. describes lubricant additives which include polymers such as ethylene propylene polymers (EPT) having N-hydrocarbylcarboxamide groups. U.S. Patent Nos. 3,868,330 and 4,234,435 to Meinhardt et al. disclose carboxylic acid acylating agents for modification of lubricant additives. Modified polyalkenes are described such as polyisobutene-substituted succinic acylating agents having M_n of 1300-5000 and M_w/M_n of 1.5-4. These processes employ chlorination to provide greater functionality.

Heretofore, the art has failed to produce dispersants and dispersant VI improvers having selective and controllable amounts of polar functionality in their polymeric structure.

Thus, the art has failed to provide any means of developing dispersants and dispersant VI improvers having higher molecular weights and/or higher amounts of functionalization per molecule. The art has also failed to provide dispersant
5 polymers having desirably narrow molecular weight distributions to avoid the presence of by-products which degrade dispersant performance. The art has also failed to provide dispersant and VI improving compositions which exhibit good thermal stability.

10 Accordingly, it is a purpose of this invention to provide dispersants and dispersant VI improvers having polymeric structures which permit highly selective control of the degree of unsaturation and consequent functionalization. Unique materials can also be obtained by chemical modification of the
15 polymers of this invention since the polymers can be selectively modified at controllable sites, such as at random sites or at the terminal ends of the molecules.

It is an additional purpose of this invention to provide a method for the production of dispersants and dispersant VI
20 improvers from polymers having controlled amounts of unsaturation incorporated randomly in an otherwise saturated backbone. In contrast to EPDM-based dispersants, the level of unsaturation can be inexpensively and easily controlled, e.g., from 1% to 50%, to provide a wide variation in
25 functionalizability.

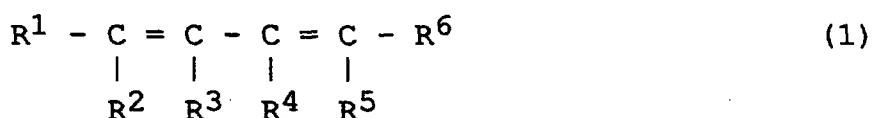
It is a further purpose of the invention to provide dispersant and VI improving polymers having narrow molecular weight distributions and a concomitant lack of undesirable by-products, thereby providing more precisely tailored dispersant
30 and/or VI improving properties.

It is still a further purpose of this invention to provide dispersants having improved engine performance.

The invention provides dispersant and dispersant Viscosity index (VI) improvers which include polymers of
35 conjugated dienes which have been hydrogenated, functionalized, optionally modified, and post treated. The dispersancy and VI improving properties of the compositions of

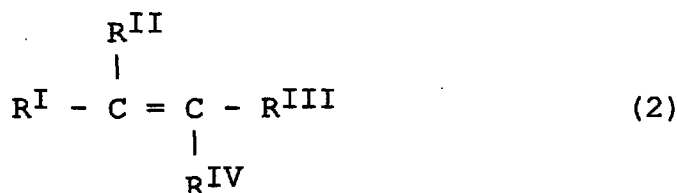
the invention may be controlled by controlling the size of the polymers and the extent and distribution of their functionalization. Accordingly, these substances are termed throughout "dispersant substances".

5 In one embodiment of the invention, there is provided a dispersant substance for modifying the dispersancy or viscometric properties of a lubricant fluid, in which the dispersant substance includes a copolymer of two different conjugated dienes. In this case, the first conjugated diene
10 includes at least one relatively more substituted conjugated diene having at least five carbon atoms and the formula:



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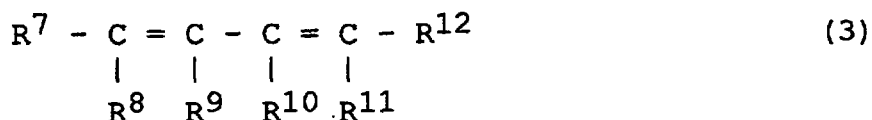
wherein R^1 - R^6 are each hydrogen or a hydrocarbyl group, provided that at least one of R^1 - R^6 is a hydrocarbyl group, and also provided that, after polymerization, the unsaturation
20 of the polymerized conjugated diene of formula (1) has the formula:



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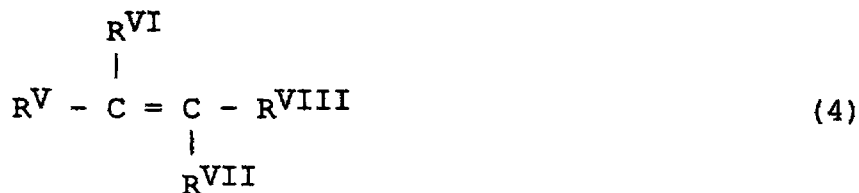
wherein R^I , R^{II} , R^{III} and R^{IV} are each hydrogen or a hydrocarbyl group, provided that either both R^I and R^{II} are
30 hydrocarbyl groups or both R^{III} and R^{IV} are hydrocarbyl groups.

The second conjugated diene in the dispersant substances of this embodiment includes at least one relatively less substituted conjugated diene which is different from the first
35 conjugated diene and has at least four carbon atoms and the formula:



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wherein R^7 - R^{12} are each hydrogen or a hydrocarbyl group, provided that, after polymerization, the unsaturation of the polymerized conjugated diene of formula (3) has the formula:



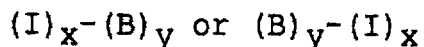
wherein R^V , R^{VI} , R^{VII} and R^{VIII} are each hydrogen or a hydrocarbyl group, provided that one of R^V or R^{VI} is hydrogen, one of R^{VII} or R^{VIII} is hydrogen, and at least one of R^V , R^{VI} , R^{VII} and R^{VIII} is a hydrocarbyl group.

Following polymerization the diene copolymer is selectively hydrogenated and subsequently functionalized to provide a functionalized copolymer having at least one polar functional group.

The functionalized copolymer is optionally modified by reaction with a Lewis base selected from the group consisting of a monoamine, polyamine, polyhydroxy compound, reactive polyether, or a combination thereof.

The copolymer is then post treated with a post-treating agent, for example a boron-containing compound.

In a preferred embodiment, the dispersant substance includes a polymer in which the first and second conjugated dienes are polymerized as a block copolymer including at least two alternating blocks:



In this case, the block (I) includes at least one polymerized conjugated diene of formula (1), while the block (B) includes at least one polymerized conjugated diene of formula (3). In addition, x is the number of polymerized monomer units in block (I) and is at least 1, and y is the number of polymerized monomer units in block (B) and is at least 25. It should be understood throughout that x and y are defined relative to blocks in a linear block copolymer or blocks in an

arm or segment of a branched or star-branched copolymer in which the arm or segment has substantially linear structure.

Preferably, in the block copolymers of this embodiment, x is from 1 to 600, and y is from 30 to 4,000, more preferably x is from 1 to 350, and y is from 30 to 2,800. While larger values for x and y are generally related to larger molecular weights, polymers which have multiple blocks and star-branched polymers typically will have molecular weights which are not well represented in the values of x and y for each block.

Alternatively, the dispersant substance includes the first and second conjugated dienes polymerized as a random copolymer. The dispersant substance may include the first and second conjugated dienes polymerized as a branched or star-branched copolymer.

The copolymers useful according to this embodiment typically have a molecular weight of at least 2,000. Preferably, the molecular weight of these polymers is from 2,000 to 1,000,000, more preferably from 5,000 to 500,000.

The molecular weight of a polymer of the invention is generally associated with the physical properties it exhibits when employed as a dispersant or dispersant VI improver. Typically, polymers having lower molecular weights are employed as dispersants, while VI-improving properties and relative thickening power are associated with polymers having higher molecular weights and correspondingly greater viscosity. For purposes of discussion, polymers of the invention having molecular weights in the range of from 2,000 to 20,000 may be classified as dispersants, polymers having molecular weights of from 20,000 to 50,000 may be classified as dispersants with VI-improving properties, and polymers having molecular weights of 50,000 or more may be classified as dispersant VI improvers.

In the dispersant substances of the invention, the copolymer is preferably selectively hydrogenated. It is preferred that the unsaturation of formula (4) be substantially completely hydrogenated, thereby retaining substantially none of the original unsaturation of this type,

while the unsaturation of formula (2) is substantially retained (i.e., the residual unsaturation after hydrogenation), in at least an amount which is sufficient to permit functionalization of the copolymer.

5 After the hydrogenation reaction, the Iodine Number for the residual unsaturation of formula (2) is generally from 50% to 100% of the Iodine Number prior to the hydrogenation reaction. More preferably, after hydrogenation, the Iodine Number for the residual unsaturation of formula (2) is 100% of
10 the Iodine Number prior to the hydrogenation reaction.

After the hydrogenation reaction, the Iodine Number for the residual unsaturation of formula (4) is from 0% to 10% of the Iodine Number prior to the hydrogenation reaction. More preferably, after the hydrogenation reaction, the Iodine
15 Number for the residual unsaturation of formula (4) is from 0% to 0.5% of the Iodine Number prior to the hydrogenation reaction. Most preferably, after the hydrogenation reaction, the Iodine Number for the residual unsaturation of formula (4) is from 0% to 0.2% of the Iodine Number prior to the
20 hydrogenation reaction.

The conjugated diene of formula (1) preferably includes a conjugated diene such as isoprene, 2,3-dimethyl-butadiene, 2-methyl-1,3-pentadiene, myrcene, 3-methyl-1,3-pentadiene, 4-methyl-1,3-pentadiene, 2-phenyl-1,3-butadiene, 2-phenyl-1,3-
25 pentadiene, 3-phenyl-1,3 pentadiene, 2,3-dimethyl-1,3-pentadiene, 2-hexyl-1,3-butadiene, 3-methyl-1,3-hexadiene, 2-benzyl-1,3-butadiene, 2-p-tolyl-1,3-butadiene, or mixtures thereof. More preferably, the conjugated diene of formula (1) includes isoprene, myrcene, 2,3-dimethyl-butadiene or 2-
30 methyl-1,3-pentadiene. Still more preferably, the conjugated diene of formula (1) includes isoprene.

Preferably, the conjugated diene of formula (3) includes 1,3-butadiene, 1,3-pentadiene, 1,3-hexadiene, 1,3-heptadiene, 2,4-heptadiene, 1,3-octadiene, 2,4-octadiene, 3,5-octadiene,
35 1,3-nonadiene, 2,4-nonadiene, 3,5-nonadiene, 1,3-decadiene, 2,4-decadiene, 3,5-decadiene, or mixtures thereof. More preferably, the conjugated diene of formula (3) includes 1,3-

butadiene, 1,3-pentadiene, or 1,3-hexadiene. Still more preferably, the conjugated diene of formula (3) includes 1,3-butadiene.

Generally, when the conjugated diene includes substantial amounts of 1,3-butadiene, the polymerized butadiene includes a mixture of 1,4- and 1,2-units. The preferred structures contain at least 25% of the 1,2-units. More preferably, the structures contain from 30% to 90% of the 1,2-subunits. Most preferably, the structures contain from 45% to 65% of the 1,2-units.

To provide dispersancy, the selectively hydrogenated polymer is chemically modified (functionalized) to provide a polymer having at least one polar functional group, such as, but not limited to, halogen, epoxy, hydroxy, amino, nitrilo, mercapto, imido, carboxy, and sulfonic acid groups of combinations thereof. The functionalized polymers can be further modified to give a more desired type of functionality.

In a preferred case, the selectively hydrogenated polymer is functionalized by a method which includes: reacting the selectively hydrogenated polymer with an unsaturated carboxylic acid (or derivative thereof, such as maleic anhydride) to provide an acylated polymer, and then reacting the acylated polymer with a monoamine, a polyamine, a polyhydroxy compound, a reactive polyether, or a combination thereof.

The modified polymer is contacted with one or more post treating agents.

Any of the dispersant substances of the invention may include a functionalized polymer of the invention distributed in a carrier fluid such as a synthetic or mineral oil, to provide a dispersant concentrate. The dispersant concentrates generally include the polymer in an amount of from 5% wt. to 90% wt., more preferably from 10% wt. to 70% wt., of the dispersant substance, depending upon the molecular weight of the polymer.

The dispersant substances may further include at least one additive selected from the group consisting of

antioxidants, pour point depressants, detergents, dispersants, friction modifiers, anti-wear agents, anti-foam agents, corrosion and rust inhibitors, Viscosity index improvers, and the like.

5 The invention further provides a method of modifying the dispersancy or viscometric properties of a fluid such as a lubricant. The method includes admixing with a fluid an amount of a dispersant substance of the invention which is sufficient to provide a dispersant-modified fluid having
10 dispersancy or viscometric properties which are altered from the original fluid. Preferably, the method involves admixing the dispersant substance in an amount of from 0.001% wt. to 20% wt., more preferably from 0.1% wt. to 10% wt., and most preferably from 0.5% wt. to 7% wt., of the dispersant-modified
15 fluid. Typically, the method of the invention is employed to modify lubricating oils and normally liquid fuels; such as motor oils, transmission fluids, hydraulic fluids, gear oils, aviation oils, and the like. In addition, the method may further include admixing with the fluid at least one additive
20 such as antioxidants, pour point depressants, detergents, dispersants, friction modifiers, anti-wear agents, anti-foam agents, corrosion and rust inhibitors, viscosity index improvers, and the like.

 The invention also provides a dispersant-modified fluid,
25 such as a hydrocarbon fluid, having modified dispersancy or viscometric properties. In this embodiment, the dispersant-modified fluid typically includes a mineral or synthetic oil and a dispersant substance of the invention. Preferably, the dispersant-modified fluid of the invention includes a
30 dispersant substance in an amount of from 0.001% wt. to 20% wt., more preferably from 0.1% wt. to 10% wt., and most preferably from 0.5% wt. to 7% wt., of the modified lubricating fluid. The dispersant-modified fluid preferably includes a mineral or synthetic lubricating oil or a normally
35 liquid fuel; such as motor oils, transmission fluids, hydraulic fluids, gear oils, aviation oils, and the like. These dispersant-modified fluids may further include at least

one additive such as antioxidants, pour point depressants, detergents, dispersants, friction modifiers, anti-wear agents, anti-foam agents, corrosion and rust inhibitors, viscosity index improvers, and the like.

5 The polymers are prepared under anionic polymerization conditions. Following polymerization, the polymers of the invention are selectively hydrogenated to provide a controlled amount and extent of residual unsaturation. After the selective hydrogenation reaction, the hydrogenation catalyst
10 is removed from the polymer and the polymer is chemically modified or functionalized to impart desirable characteristics for the dispersant substances of the invention.

Accordingly, as a result of the invention, there are now provided dispersants, dispersants with VI-improving
15 properties, and dispersant VI improvers prepared by polymerization of conjugated dienes, followed by selective hydrogenation and functionalization. These dispersant substances of the invention possess numerous advantages, including improved engine performance, controlled molecular
20 weight, controlled molecular weight distribution, controlled polymer structure, variable and controlled amounts and distribution of functionality, superior thermal stability, potentially permitting reduced treat levels and yielding benefits such as improved viscometric properties.

25 These and other advantages of the present invention will be appreciated from the detailed description and examples which are set forth herein. The detailed description and examples enhance the understanding of the invention, but are not intended to limit the scope of the invention.

30 The polymeric dispersants of the invention, typically having lower molecular weights, can be employed in any lubricant or fuel composition that requires a dispersant to control the deposition of sludge particles on, for example, engine parts. Other polymeric substances of the invention,
35 typically those having higher molecular weights, may be employed for their VI-improving properties in any lubricant fluid which may benefit from a modification of its viscometric

properties. These compounds may also find a variety of uses in addition to lubricant additives, such as adhesives, sealants and impact modifiers.

As noted above, traditional dispersants have been
5 polybutenes functionalized via an ene reaction with maleic anhydride followed by imidization with a polyamine. The polybutenes are typically 500-2,000 in molecular weight. With one olefin per polybutene molecule, the number of potential functional groups per chain is limited to one. Consequently,
10 the molecular weight of polybutene may not exceed 2,000 if the desired functionality/hydrocarbon ratio is to be maintained.

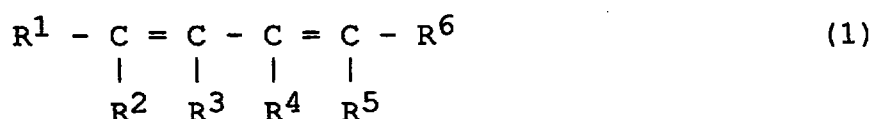
By contrast, with this invention, the amount of residual unsaturation can be controllably varied. As a result, the amount of functionality one wishes to incorporate is quite
15 flexible. In addition, the molecular weight of the polymer backbone is not limited to 2,000. Higher molecular weight polymers can be prepared and functionalized such that the same functionality/hydrocarbon ratio that is found in the traditional dispersant is maintained if so desired. Moreover,
20 with this invention, the position of the functionality is not limited to the end of the polymer chain as it is with polybutenes. Instead, a variety of options are now available, including, for example, randomly along the backbone, at one end, at both ends, or in the center, of the polymer chain.

25 If a polymer according to the invention is of sufficiently high molecular weight (e.g., 20,000-50,000), it will exhibit increased thickening power and viscosity index-improving (VI-improving) properties, as well as sludge dispersing ability. Hence, the use of these materials may
30 permit reduction in use of both traditional dispersants and VI. If materials are prepared with backbones that are 50,000 in molecular weight, the functionalized versions can be classified as dispersant VI improvers or VI improvers with dispersant properties. Their dispersant capabilities are
35 outstanding for dispersant VI improvers.

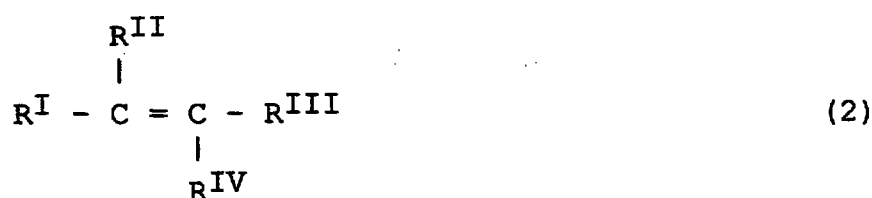
In one embodiment, the present invention provides polymers including at least two different conjugated dienes,

wherein one of the dienes is more substituted in the 2, 3, and/or 4 carbon positions than the other diene. The more substituted diene produces vinylidene, tri-, or tetra-substituted double bonds after polymerization. Hydrogenation of the material is done selectively so as to saturate the lesser substituted olefins, which primarily arise from the lesser substituted diene, while leaving a portion of the more substituted conjugated olefins behind for functionalizing.

In this embodiment, the more substituted conjugated diene will have at least five (5) carbon atoms and the following formula:

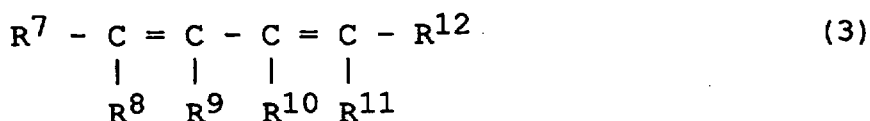


wherein R^1 - R^6 are each hydrogen (H) or a hydrocarbyl group, provided that at least one of R^1 - R^6 is a hydrocarbyl group. After polymerization, the unsaturation in the polymerized conjugated diene of formula (1) has the following formula:

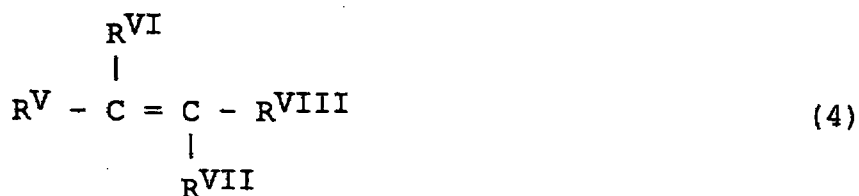


wherein R^I , R^{II} , R^{III} and R^{IV} are each hydrogen or a hydrocarbyl group, provided that either both R^I and R^{II} are hydrocarbyl groups or both R^{III} and R^{IV} are hydrocarbyl groups. Examples of conjugated dienes of formula 1 include isoprene, 2,3-dimethylbutadiene, 2-methyl-1,3-pentadiene, myrcene, and the like. Isoprene is highly preferred.

The lesser substituted conjugated diene in this embodiment differs from the other diene in that it has at least four (4) carbon atoms and the following formula:



wherein R^7 - R^{12} are each hydrogen or a hydrocarbyl group. After polymerization, the unsaturation in the polymerized conjugated diene of formula (3) has the following formula:



wherein R^V , R^{VI} , R^{VII} and R^{VIII} are each hydrogen (H) or a hydrocarbyl group, provided that one of R^V or R^{VI} is hydrogen, one of R^{VII} or R^{VIII} is hydrogen, and at least one of R^V , R^{VI} , R^{VII} and R^{VIII} is a hydrocarbyl group. Examples of the conjugated diene of formula (3) include 1,3-butadiene, 1,3-pentadiene, 2,4-hexadiene, and the like. A highly preferred conjugated diene of formula 3 is 1,3-butadiene.

An exception to this scheme would be when a tetra-substituted diene, e.g., 2,3-dimethylbutadiene, is used for the more substituted component. When this occurs, a tri-substituted olefin, e.g. isoprene, may be used for the lesser substituted component, such that one or both of R^V and R^{VI} are hydrogen and both R^{VII} and R^{VIII} are hydrocarbyl.

It will be apparent to those skilled in the art that in the original unsaturation of formula (2), R^I , R^{II} , R^{III} and R^{IV} may all be hydrocarbyl groups, whereas in the original unsaturation of formula (4) at least one of R^V , R^{VI} , R^{VII} and R^{VIII} must be a hydrogen.

The hydrocarbyl group or groups in the formula (1) to (4) are the same or different and they are substituted or unsubstituted alkyl, alkenyl, cycloalkyl, cycloalkenyl, aryl, alkaryl, or aralkyl groups, or any isomers thereof.

The copolymers of this embodiment are prepared by anionically polymerizing a diene of formula (1) at a level of from 0.5% wt. to 25% wt., and a diene of formula (3) at a level of from 75% wt. to 99.5% wt., in a hydrocarbon solvent using an alkyllithium catalyst. The two monomers can be polymerized in block, tapered block, or random fashion. Since

the polymerization is anionic, the molecular weight distribution of these copolymers is typically very narrow, generally ranging from 1.01 to 1.20, and the molecular weight is determined by the ratio of monomer to initiator and/or by the presence of coupling agents.

The monomers (1) and (3) may be polymerized either simultaneously or in stepwise fashion depending on the desired position of the remaining unsaturation after hydrogenation. If random positioning of the unsaturation is desired, both monomers are reacted together to give a random copolymer. If it is desirable to have the functionality on only one end, then the monomers are reacted in stepwise fashion, the order being determined as desired, to provide a diblock copolymer. If functionality is needed on both ends, then a conjugated diene of formula (1) is polymerized first, followed by a diene of formula (3). To the living anion, a coupling agent, e.g., phenyl benzoate or methyl benzoate, is then added to yield a desired triblock copolymer. Alternatively, a diene of formula (1) may be added to the living diblock to give the triblock.

A fourth approach would allow the functionality to be positioned in the center of the polymer chain. In this case, a diene of formula (3) is polymerized first, followed by a diene of formula (1). Then a triblock is formed by addition of a coupling agent or by addition of more diene of formula (3). In addition, combinations of the above approaches may be employed.

The invention can include polymers of differing microstructures. The presence of polar modifier increases the activity of the catalyst and, therefore, increase the level of 1,2-microstructure over 1,4-microstructure in polybutadiene, for example. The percentage of vinyl obtained is directly proportional to the concentration of the modifier employed. Since the reaction temperature also plays a role in determining the microstructure of polybutadiene, the level of modifier must be chosen taking into account the combined effects. Antkowiak et al., *Temperature and Concentration Effects on Polar-modified Alkyl Lithium Polymerizations and*

Copolymerizations, Journal of Polymer Science: Part A-1, 10:1319-34 (1972), have presented a way for quickly determining the proper conditions for preparation of any 1,2-microstructure content within a range of from 10% to 80%. Use
5 of this method or any others to achieve the desired microstructure will be known to those skilled in the art.

The dispersants and dispersant VI improvers of the invention can include different polymer macrostructures. Polymers may be prepared and utilized having linear and/or
10 nonlinear, e.g., star-branched, macrostructures. The star-branched polymers can be prepared by addition of divinylbenzene or the like to the living polymer anion. Lower levels of branching can be obtained through the use of tri-functional or tetra-functional coupling agents, such as
15 tetrachlorosilane.

In all embodiments of this invention, whenever a reference is made to the "original double bond" or the "original unsaturation" of the block or random polymer (or copolymer), it is understood to mean the double bond(s) in the
20 polymer prior to the hydrogenation reaction. By contrast, the terms "residual double bond(s)" and "residual unsaturation", as used herein, refer to the unsaturated group(s), typically excluding aromatic unsaturation, present in the copolymer after the selective hydrogenation reaction.

25 The molecular structure of the original or residual double bonds can be determined in any conventional manner, as is known to those skilled in the art, e.g., by infrared (IR) or nuclear magnetic resonance (NMR) analysis. In addition, the total original or residual unsaturation of the polymer can
30 be quantified in any conventional manner, e.g., by reference to the Iodine Number of the polymer.

In any polymers of any of the embodiments of this invention, the microstructure of the polymerized conjugated diene of formula (3) must be such that the polymer is not
35 excessively crystalline after the selective hydrogenation reaction. That is, after the selective hydrogenation reaction the polymer must retain its elastomeric properties, e.g., the

polymer should contain not more than 10% of polyethylene crystallinity. Generally, problems of crystallinity occur only when the polymer includes polymerized 1,3-butadiene. Limiting polymeric crystallinity may be accomplished in various ways. For example, this is accomplished by introducing side branches into the polymerized conjugated dienes of formula (1) and/or (3), e.g., by controlling the microstructure of 1,3-butadiene if it is the predominant monomer in the diene of formula (3); by using a mixture of dienes of formula (3) containing less than predominant amounts of 1,3-butadiene; or by using a single diene of formula (3), other than 1,3-butadiene. More particularly, if the conjugated diene(s) of formula (3) is predominantly (at least 50% by mole) 1,3-butadiene, the side branches are introduced into the polymer by insuring that the polymerized diene of formula (3) contains a sufficient amount of the 1,2-units to prevent the selectively hydrogenated polymer from being excessively crystalline. Thus, if the conjugated diene of formula (3) is predominantly (at least 50% by mole, e.g., 100% by mole) 1,3-butadiene, the polymerized diene of formula (3), prior to the selective hydrogenation reaction, must contain not more than 75% wt., preferably from 10% wt. to 70% wt., and most preferably from 35% wt. to 55% wt. of the 1,4-units, and at least 25% wt., preferably from 30% wt. to 90% wt., and most preferably from 45% wt. to 65% wt. of the 1,2-units. If the polymerized diene(s) of formula (3) contains less than 50% by mole of 1,3-butadiene, e.g., 1,3-pentadiene is used as the only diene of formula (3), the microstructure of the polymerized diene of formula (3) prior to the selective hydrogenation reaction is not critical since, after hydrogenation, the resulting polymer will contain substantially no crystallinity.

In all embodiments of the invention, mixtures of dienes of formula (1) or (3) may be used to prepare block copolymers (I)_x-(B)_y or any of the random copolymers or star-branched block and random polymers of the invention. Similarly, mixtures of aryl-substituted olefins may also be used to

prepare block, random, or star-branched copolymers of this invention. Accordingly, whenever a reference is made herein to a diene of formula (1) or (3), or to an aryl-substituted olefin, it may encompass more than one diene of formula (1) or (3), respectively, and more than one aryl-substituted olefin.

The block copolymers of this invention comprise two or more alternating blocks, identified above. Linear block copolymers having two blocks and block copolymers having three or more blocks are contemplated herein.

The block polymers useful according to the invention typically include at least one block which is substantially completely saturated, while also including at least one block containing controlled levels of unsaturation providing a hydrocarbon elastomer with selectively positioned unsaturation for subsequent functionalization. For the copolymers prepared from two different conjugated dienes, it has been found that the two dienes in the copolymers hydrogenate at different rates, permitting selective control of the placement of residual unsaturation.

The many variations in composition, molecular weight, molecular weight distribution, relative block lengths, microstructure, branching, and T_g (glass transition temperature) attainable with the use of anionic techniques employed in the preparation of our polymers will be obvious to those skilled in the art.

While not wishing to limit the molecular weight range of liquid elastomers prepared according to our invention, the minimum molecular weight for these liquid polymers is at least 2,000, preferably 2,000 to 100,000, and most preferably 5,000 to 35,000. The star-branched block and random copolymers of this invention may have substantially higher molecular weights and still retain liquid properties. The minimum weight for solid polymers of this invention is at least 50,000 to 1,000,000. The block copolymers of this invention are functionalizable. Without wishing to be bound by any theory of operability, it is believed that they can be functionalized in a controlled manner through the unsaturated groups on the

terminal or the interior blocks to provide dispersants and dispersant VI improvers having almost uniform distribution of molecular weights. The star-branched and linear versions of the random copolymers and homopolymers of this invention are also functionalizable.

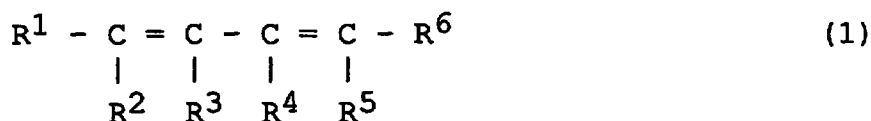
All numerical values of molecular weight given in this specification and the drawings are of number average molecular weight (M_n).

The invention will be described hereinafter in terms of the embodiments thereof summarized above. However, it will be apparent to those skilled in the art that the invention is not limited to these particular embodiments, but, rather, it covers all the embodiments encompassed by the broadest scope of the description of the invention.

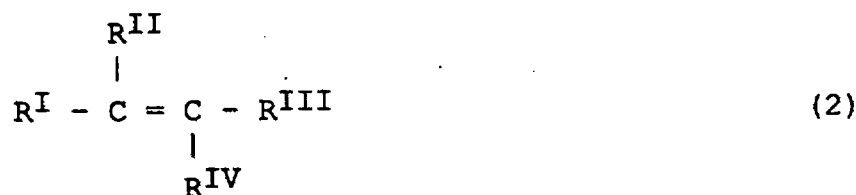
Copolymers From at Least Two Dissimilar Conjugated Dienes

In this embodiment of the invention, there are provided copolymers of two dissimilar conjugated dienes, preferably isoprene and 1,3-butadiene. The two monomers can be polymerized by anionic polymerization process in either a block, tapered block, or random fashion.

The copolymers of this embodiment include a first conjugated diene having at least five (5) carbon atoms and the following formula:

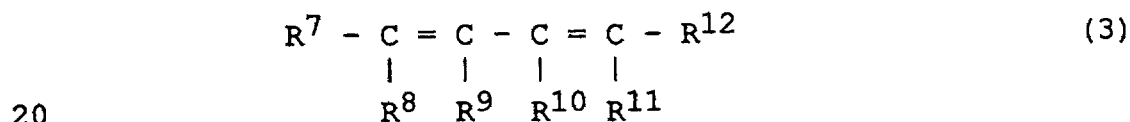


wherein R^1 - R^6 are each hydrogen or a hydrocarbyl group, provided that at least one of R^1 - R^6 is a hydrocarbyl group, and further provided that, when polymerized, the structure of the double bond in the polymerized conjugated diene of formula (1) has the following formula:

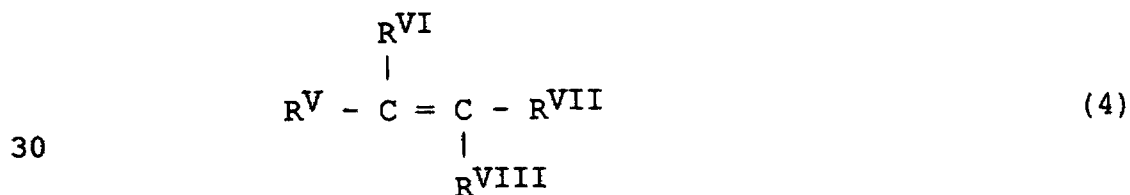


wherein R^{I} , R^{II} , R^{III} and R^{IV} are each hydrogen or a hydrocarbyl group, provided that either both R^{I} and R^{II} are hydrocarbyl groups or both R^{III} and R^{IV} are hydrocarbyl groups. In the double bond of the polymerized conjugated diene of formula (2), R^{I} , R^{II} , R^{III} and R^{IV} may all be hydrocarbyl groups.

The polymers of this embodiment also include a second conjugated diene, different from the first conjugated diene, having at least four (4) carbon atoms and the following formula:



wherein R^7 - R^{12} are each hydrogen or a hydrocarbyl group, provided that the structure of the double bond in the polymerized conjugated diene of formula (3) has the following formula:



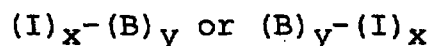
wherein R^{V} , R^{VI} , R^{VII} and R^{VIII} are each hydrogen (H) or a hydrocarbyl group, provided that one of R^{V} or R^{VI} is hydrogen, one of R^{VII} or R^{VIII} is hydrogen, and at least one of R^{V} , R^{VI} , R^{VII} and R^{VIII} is a hydrocarbyl group.

Following polymerization the diene copolymer of this embodiment is preferably functionalized by a method which includes selectively hydrogenating the copolymer to provide a

selectively hydrogenated copolymer, followed by functionalizing the selectively hydrogenated copolymer to provide a functionalized copolymer having at least one polar functional group.

5 The polymers of this embodiment include a first conjugated diene of formula (1) in an amount of from 0.5% wt. to 30% wt., and a second conjugated diene in an amount of from 70% wt. to 99.5% wt. Preferably, a first conjugated diene is included in an amount of from 1% wt. to 25% wt., and a second
10 conjugated diene in an amount of from 75% to 99% wt. More preferably, a first conjugated diene is included in an amount of from 5% wt. to 20% wt., and a second conjugated diene is included in an amount of from 80% to 95% wt.

15 The polymers of this embodiment include block copolymers having at least two alternating blocks:



20 In this case, the polymer includes at least one block (I). The block (I) is a block of at least one polymerized conjugated diene of formula (1) as described above. These block copolymers also include at least one polymerized block (B). The block (B) is a block of at least one polymerized conjugated diene of formula (3) described above.

25 In the block copolymers of this embodiment, x is at least 1, preferably from 1 to 600, and most preferably from 1 to 350. The above definition of x means that each of the (I) blocks is polymerized from at least 1, preferably 1-600, and more preferably 1-350, monomer units.

30 In the block copolymers of this embodiment, y is at least 25, preferably from 30 to 4,000, more preferably from 30 to 2,800. The above definition of y means that each of the (B) blocks is polymerized from at least 25, preferably 30-4,000, and more preferably 30-2,800, monomer units.

35 The block copolymer comprises 0.5 to 25%, preferably 1 to 20% by wt. of the (I) blocks, and 80 to 99.5%, preferably 80 to 99% by wt. of the (B) blocks.

In any of the copolymers of this embodiment, the structures of the double bonds defined by formula (2) and (4) are necessary to produce copolymers which can be selectively hydrogenated in the manner described herein, to produce the selectively hydrogenated block and random copolymers of this invention.

The hydrocarbyl group or groups in the formula (1) and (2) are the same or different and they are substituted or unsubstituted alkyl, alkenyl, cycloalkyl, cycloalkenyl, aryl, alkaryl, or aralkyl groups, or any isomers thereof. Suitable hydrocarbyl groups are alkyls of 1-20 carbon atoms, alkenyls of 1-20 carbon atoms, cycloalkyls of 5-20 carbon atoms, aryls of 6-12 carbon atoms, alkaryl groups of 7-20 carbon atoms or aralkyls of 7-20 carbon atoms. Examples of suitable alkyl groups are methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, decyl, methyl-decyl or dimethyl-decyl. Examples of suitable alkenyl groups are ethenyl, propenyl, butenyl, pentenyl or hexenyl. Examples of suitable cycloalkyl groups are cyclohexyl or methylcyclohexyl. Examples of suitable cycloalkenyl groups are 1-, 2-, or 3-cyclohexenyl or 4-methyl-2-cyclohexenyl. Examples of suitable aryl groups are phenyl or diphenyl. Examples of suitable alkaryl groups are 4-methyl-phenyl (p-tolyl) or p-ethyl-phenyl. Examples of suitable aralkyl groups are benzyl or phenethyl. Suitable conjugated dienes of formula (1) used to polymerize the (I) block are isoprene, 2,3-dimethyl-butadiene, 2-methyl-1,3-pentadiene, myrcene, 3-methyl-1,3-pentadiene, 4-methyl-1,3-pentadiene, 2-phenyl-1,3-butadiene, 2-phenyl-1,3-pentadiene, 3-phenyl-1,3-pentadiene, 2,3-dimethyl-1,3-pentadiene, 2-hexyl-1,3-butadiene, 3-methyl-1,3-hexadiene, 2-benzyl-1,3-butadiene, 2-p-tolyl-1,3-butadiene, or mixtures thereof, preferably isoprene, myrcene, 2,3-dimethyl-butadiene, or 2-methyl-1,3-pentadiene, and most preferably isoprene.

The hydrocarbyl group or groups in the formula (3) may or may not be the same as those in formula (4). These hydrocarbyl groups are the same as those described above in conjunction with the discussion of the hydrocarbyl groups of

formula (1) and (2). Suitable monomers for the (B) block are 1,3-butadiene, 1,3-pentadiene, 2,4-hexadiene, 1,3-hexadiene, 1,3-heptadiene, 2,4-heptadiene, 1,3-octadiene, 2,4-octadiene, 3,5-octadiene, 1,3-nonadiene, 2,4-nonadiene, 3,5-nonadiene, 1,3-decadiene, 2,4-decadiene, 3,5-decadiene, or mixtures thereof, preferably 1,3-butadiene, 1,3-pentadiene, 2,4-hexadiene, or 1,3-hexadiene, and most preferably it is 1,3-butadiene. It is generally preferred that each of the (B) blocks is polymerized from a single monomer.

The scope of this embodiment, and of any other embodiments of the invention wherein the block (B) is used, also encompasses polymers wherein the block (B) may comprise copolymers of one or more conjugated diene of formula (3) and controlled amounts (0.3 to 30 mole %) of an aryl-substituted olefin, e.g., styrene or other suitable monomers (such as alkylated styrene, vinyl naphthalene, or alkylated vinyl naphthalene) incorporated for control of glass transition temperature (T_g), density, solubility parameters and refractive index. Similarly, the scope of this embodiment also encompasses polymers wherein the block (B) may be comprised of copolymers of one or more conjugated diene of formula (3) and any other anionically polymerizable monomer capable of polymerizing with the conjugated diene of formula (3). Similar considerations also apply in the case of the (I) block(s), which can include similar styrene/diene copolymers.

The copolymer is polymerized by anionic polymerization, discussed in detail below. As will be apparent to those skilled in the art, the block copolymer of this embodiment contains at least two alternating blocks, (I)-(B) or (B)-(I), referred to herein as diblocks. The block copolymer of this embodiment may contain three alternating blocks, e.g., (I)-(B)-(I), referred to herein as triblocks or triblock units, but it may contain an unlimited number of blocks. The functionalization of any of these copolymers is conducted in a conventional manner and is described below.

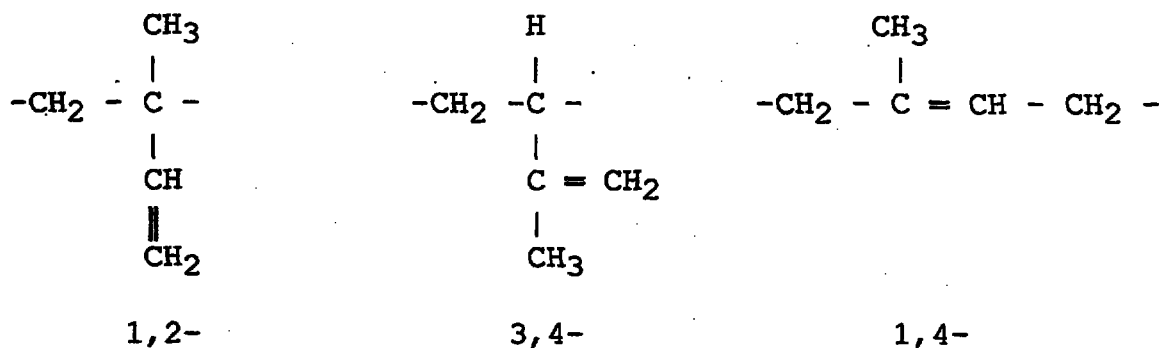
After the (I)-(B) copolymer is polymerized, it is subjected to a selective hydrogenation reaction during which

the polymerized conjugated dienes of formula (3) of the copolymer are selectively hydrogenated to such an extent that they contain substantially none of the original unsaturation, while the polymerized conjugated dienes of formula (1) of the copolymer retain a sufficient amount of their original unsaturation to permit functionalization.

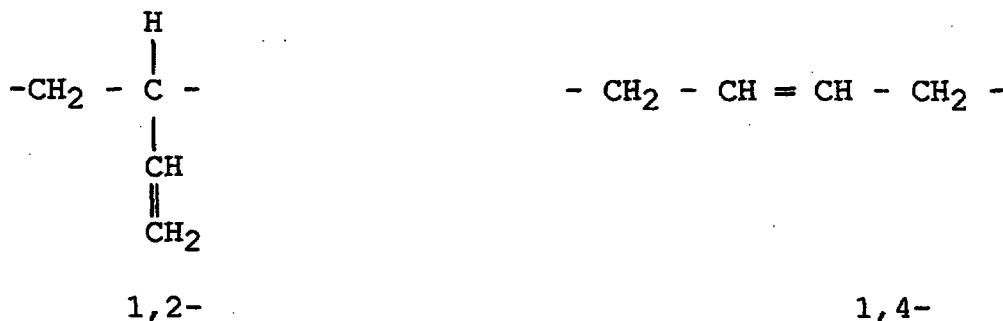
Generally, for a copolymer wherein the conjugated dienes of formula (1) and (3) are polymerized to provide unsaturation of formula (2) and (4), respectively, as discussed above, the Iodine Number for the unsaturation of formula (2) after the selective hydrogenation reaction is from 20% to 100%, preferably from 50% to 100%, and most preferably 100%, of the Iodine Number prior to the selective hydrogenation reaction; and for the unsaturation of formula (4) it is from 0% to 10%, preferably from 0% to 0.5%, and most preferably from 0% to 0.2%, of the Iodine Number prior to the selective hydrogenation reaction. The Iodine Number, as is known to those skilled in the art, is defined as the theoretical number of grams of iodine which will add to the unsaturation in 100 grams of olefin and is a quantitative measure of unsaturation.

In this embodiment of the invention, although the microstructure of the (I) blocks is not critical and may consist of 1,2-, 3,4- and/or 1,4-units, schematically represented below for the polyisoprene blocks, when a polar compound is used during the polymerization of the (I) block, the (I) blocks comprise primarily (at least 50% wt.) 3,4-units, the rest being primarily (less than 50% wt.) 1,4-units; when the polar compound is not used during the polymerization of the (I) block, the (I) blocks comprise primarily (80% wt.) 1,4-units, the rest being primarily 1,2- and 3,4- units.

26



The microstructure of the (B) blocks, when the predominant monomer used to polymerize the (B) blocks is 1,3-butadiene, should be a mixture of 1,4- and 1,2- units schematically shown below for the polybutadiene blocks:



since the hydrogenation of the predominantly 1,4- microstructure produces a crystalline polyethylene segment. The microstructure of the (I) and (B) blocks (as well as of the polymerized conjugated dienes of formula (1) or (3) in any polymers of this invention) is controlled in a conventional manner, e.g., by controlling the amount and nature of the polar compounds used during the polymerization reaction, and the reaction temperature. In one particularly preferred embodiment, the (B) block contains 50% of the 1,2- and 50% of the 1,4- microstructure. If the (B) block is poly-1,3-butadiene, the hydrogenation of the (B) segment containing from 50% to 60% of the 1,2-microstructure content produces an elastomeric center block which is substantially an ethylene-butene-1 copolymer having substantially no crystallinity. If the (B) block is polymerized from 1,3-pentadiene, the microstructure is not critical.

The terms "1,2-", "1,4-", and "3,4-microstructure" or "units" as used in this application refer to the products of polymerization obtained by the 1,2-, 1,4- and 3,4-, respectively, mode of addition of monomer units.

5 We surprisingly discovered that the polymerized conjugated dienes of formula (3), e.g., the dienes employed in (B) blocks, of the polymers of this invention are selectively hydrogenated in our hydrogenation process much faster than the polymerized conjugated dienes of formula (1), e.g., the dienes
10 used in the (I) blocks. This is not evident from the teachings of Falk, discussed above, because Falk teaches that double bonds of the di-substituted 1,4-polybutadiene units are hydrogenated selectively in the presence of double bonds of the tri-substituted 1,4-polyisoprene units (which hydrogenate
15 very slowly). We surprisingly discovered that the di-substituted double bonds of the 1,4-polybutadiene units are hydrogenated along with the monosubstituted double bonds of the 1,2-polybutadiene units, while the di-substituted double bonds of the 3,4-polyisoprene units are hydrogenated at a much
20 slower rate than the aforementioned polybutadienes. Thus, in view of Falk's disclosure it is surprising that the di-substituted double bonds of the 1,4-polybutadiene units are hydrogenated selectively in the presence of the di-substituted double bonds of the 3,4-polyisoprene units. This is also
25 surprising in view of the teachings of Hoxmeier, Published European Patent Application, Publication No. 0 315 280, who discloses that the di-substituted double bonds of the 1,4-polybutadiene units, monosubstituted double bonds of the 1,2-polybutadiene units and di-substituted double bonds of the
30 3,4-polyisoprene units are hydrogenated simultaneously at substantially the same rates. For example, for the block copolymers of this invention, wherein the (I) block is polyisoprene and the (B) block is polybutadiene, Fourier Transform Infrared (FTIR) analysis of selectively hydrogenated
35 block copolymers of the invention, such as I-B-I triblock polymers, indicates that the hydrogenation of the double bonds of the 1,2-polybutadiene units proceeds most rapidly, followed

by the hydrogenation of the double bonds of the 1,4-polybutadiene units. Infrared absorptions caused by these groups disappear prior to appreciable hydrogenation of the polyisoprene units.

5 Accordingly, by controlling the amount and placement of 1,2- versus 1,4-microstructure, as well as the amount and placement of polyisoprene units, it is now possible to control the amount and placement of unsaturation remaining in the polymers after hydrogenation. It follows that the amount and
10 placement of functionalization of the polymeric dispersants of the invention is also controllable to an extent not possible previously.

After the block copolymer is prepared, it is subjected to a selective hydrogenation reaction to hydrogenate primarily
15 the (B) block(s). The selective hydrogenation reaction and the catalyst are described in detail below. After the hydrogenation reaction is completed, the selective hydrogenation catalyst is removed from the block copolymer, and the polymer is isolated by conventional procedures, e.g.,
20 alcohol flocculation, steam stripping of solvent, or non-aqueous solvent evaporation. An antioxidant, e.g., Irganox 1076 (from Ciba-Geigy), is normally added to the polymer solution prior to polymer isolation.

Random Copolymers

25 Random copolymers of this invention have controlled amounts of unsaturation incorporated randomly in an otherwise saturated backbone. In contrast to EPDM, the level of unsaturation can be easily controlled, e.g., to produce polymers having Iodine Number of from 5 to 100, to provide a
30 wide variation in the degree of functionalization.

In one embodiment, the random copolymers are polymerized from the same monomers used to polymerize the block copolymers (I)_x-(B)_y, described elsewhere herein. In particular, the random copolymers may be made by polymerizing at least one
35 conjugated diene of formula (1) with at least one conjugated diene of formula (3), both defined above. This random copolymer contains from 1.0% to 40%, preferably from 1.0% to

20%, by mole of the polymerized conjugated diene of formula (1) and from 60% to 99%, preferably from 80% to 99% by mole of the polymerized conjugated diene of formula (3). Suitable conjugated dienes of formula (1) are exemplified above. The
5 most preferred conjugated diene of formula (1) for the copolymerization of these random copolymers is isoprene. Suitable conjugated dienes of formula (3) are also exemplified above. 1,3-butadiene is the most preferred conjugated diene of formula (3) for the polymerization of the random copolymer
10 of this embodiment. Thus, most preferably, in this embodiment, the random copolymer is polymerized from isoprene and 1,3-butadiene, and it contains from 1% wt. to 20% wt. of the isoprene units and from 80% wt. to 99% wt. of the butadiene units. The isoprene units have primarily (i.e.,
15 from 50% wt. to 90% wt.) the 3,4-microstructure.

The random copolymers are subjected to the selective hydrogenation reaction discussed above for the block copolymers, during which polymerized conjugated diene units of formula (3) are substantially completely hydrogenated, while
20 the conjugated diene units of formula (1) are hydrogenated to a substantially lesser extent, i.e., to such an extent that they retain a sufficient amount of their original unsaturation to functionalize the copolymer, thereby producing dispersants and dispersant VI improvers having random unsaturation
25 proportional to the unsaturation in the polymerized dienes of formula (1). For example, for random copolymer polymerized from a diene of formula (1) and a different diene of formula (3), the Iodine Number before selective hydrogenation for the polymer is 450. After selective hydrogenation, the Iodine
30 Number for the polymer is from 10 to 50, with most of the unsaturation being contributed by the diene of formula (1).

The hydrogenated polymers are functionalized in the same manner as set forth for block copolymers.

Star-Branched Polymers

The invention is also directed to star-branched block and random polymers. The star-branched block polymers are made from any combination of blocks (I) and (B), defined above.

5 The star-branched (I)-(B) block polymers comprise from 0.5% wt. to 25% wt., preferably from 1% wt. to 20% wt., of the (I) blocks, and from 75% wt. to 99.5% wt., preferably from 80% wt. to 99% wt., of the (B) blocks.

10 The star-branched block polymers are selectively hydrogenated in the selective hydrogenation process of this invention to such an extent that blocks (B) contain substantially none of the original unsaturation, while each of the blocks (I) respectively, retains a sufficient amount of the original unsaturation of the conjugated dienes present in
15 these blocks to functionalize the star-branched block polymers. Thus, for the I-(B) star-branched block polymer, after the selective hydrogenation reaction, the Iodine Number for the (I) blocks is from 10% to 100%, preferably from 25% to 100%, more preferably from 50% to 100%, and most preferably
20 100%, of the Iodine Number prior to the selective hydrogenation reaction; and for the (B) blocks it is from 0% to 10%, preferably from 0% to 0.5%, of the Iodine Number prior to the selective hydrogenation reaction.

25 The star-branched random polymers are made from any combination of at least one diene of formula (1) and at least one diene of formula (3), different from the diene of formula (1), or from any combination of at least one aryl-substituted olefin and at least one diene of formula (1) or (3), all of which are the same as those discussed above. The star-
30 branched random polymers of the dienes of formula (1) and (3), which must be different from each other, comprise from 0.5% wt. to 25% wt., preferably from 1% wt. to 20% wt., of the diene of formula (1), and from 75% wt. to 99.5% wt., preferably from 80% wt. to 99% wt., of the diene of formula
35 (3). The star-branched random polymers of the aryl-substituted olefin and the diene of formula (1) or (3) comprise from 0.5% wt. to 50% wt., preferably from 1% wt. to

25% wt., of the aryl-substituted olefin, and from 50% wt. to 99.5% wt., preferably from 75% wt. to 99% wt., of the diene of formula (1) or (3).

The star-branched random diene polymers are also selectively hydrogenated in the selective hydrogenation process of this invention to such an extent that the polymerized dienes of formula (3) contain substantially none of the original unsaturation, while the polymerized dienes of formula (1) retain a sufficient amount of the original unsaturation to functionalize the star-branched random polymers. Thus, for the star-branched random polymer of the conjugated diene of formula (1) and a different diene of formula (3), both identified above, the Iodine Number for the polymerized diene of formula (1), after the selective hydrogenation reaction, is from 10% to 100%, preferably from 25% to 100%, more preferably from 50% to 100%, and most preferably 100%, of the Iodine Number prior to the selective hydrogenation reaction; and for the polymerized diene of formula (3) it is from 0% to 10%, preferably from 0% to 0.5%, of the Iodine Number prior to the selective hydrogenation reaction.

Polymerization Reaction

The polymers of this invention are polymerized by any known polymerization processes, preferably by an anionic polymerization process. Anionic polymerization is well known in the art and it is utilized in the production of a variety of commercial polymers. An excellent comprehensive review of the anionic polymerization processes appears in the text Advances in Polymer Science 56, Anionic Polymerization, pp. 1-90, Springer-Verlag, Berlin, Heidelberg, New York, Tokyo 1984 in a monograph entitled Anionic Polymerization of Non-polar Monomers Involving Lithium, by R.N. Young, R.P. Quirk and L.J. Fetters. The anionic polymerization process is conducted in the presence of a suitable anionic catalyst (also known as an initiator), such as n-butyl-lithium, sec-butyl-lithium, t-butyl-lithium, sodium naphthalide or, cumyl potassium. The amount of the catalyst and the amount of the monomer in the

polymerization reaction dictate the molecular weight of the polymer. The polymerization reaction is conducted in solution using an inert solvent as the polymerization medium, e.g., aliphatic hydrocarbons, such as hexane, cyclohexane, or heptane, or aromatic solvents, such as benzene or toluene. In certain instances, inert polar solvents, such as tetrahydrofuran, can be used alone as a solvent, or in a mixture with a hydrocarbon solvent.

The polymerization process will be exemplified below for the polymerization of one of the embodiments of the invention, e.g., a triblock of polyisoprene-polybutadiene-polyisoprene. However, it will be apparent to those skilled in the art that the same process principles can be used for the polymerization of all polymers of the invention.

The process, when using a lithium-based catalyst, comprises forming a solution of the isoprene monomer in an inert hydrocarbon solvent, such as cyclohexane, modified by the presence therein of one or more polar compounds selected from the group consisting of ethers, thioethers, and tertiary amines, e.g., tetrahydrofuran. The polar compounds are necessary to control the microstructure of the butadiene center block, i.e., the content of the 1,2-structure thereof. The higher the content of the polar compounds, the higher will be the content of the 1,2-structure in these blocks. Since the presence of the polar compound is not essential in the formation of the first polymer block with many initiators unless a high 3,4-structure content of the first block is desired, it is not necessary to introduce the polar compound at this stage, since it may be introduced just prior to or together with the addition of the butadiene in the second polymerization stage. Examples of polar compounds which may be used are dimethyl ether, diethyl ether, ethyl methyl ether, ethyl propyl ether, dioxane, diphenyl ether, dipropyl ether, tripropyl amine, tributyl amine, trimethyl amine, triethyl amine, and N-N'-N'-tetramethyl ethylene diamine. Mixtures of the polar compounds may also be used. The amount of the polar compound depends on the type of the polar compound and

the polymerization conditions as will be apparent to those skilled in the art. The effect of polar compounds on the polybutadiene microstructure is detailed in Antkowiak et al. The polar compounds also accelerate the rate of
5 polymerization. If monomers other than 1,3-butadiene, e.g., pentadiene, are used to polymerize the central blocks (B), polar compounds are not necessary to control the microstructure because such monomers will inherently produce polymers which do not possess crystallinity after
10 hydrogenation.

When the alkyl lithium-based initiator, a polar compound and an isoprene monomer are combined in an inert solvent, polymerization of the isoprene proceeds to produce the first terminal block whose molecular weight is determined by the
15 ratio of the isoprene to the initiator. The living polyisoprenyl anion formed in this first step is utilized as the catalyst for further polymerization. At this time, butadiene monomer is introduced into the system and block polymerization of the second block proceeds, the presence of
20 the polar compound now influencing the desired degree of branching (1,2-structure) in the polybutadiene block. The resulting product is a living diblock polymer having a terminal anion and a lithium counterion. The living diblock polymer serves as a catalyst for the growth of the final
25 isoprene block, formed when isoprene monomer is again added to the reaction vessel to produce the final polymer block, resulting in the formation of the I-B-I triblock. Upon completion of polymerization, the living anion, now present at the terminus of the triblock, is destroyed by the addition of
30 a proton donor, such as methyl alcohol or acetic acid. The polymerization reaction is usually conducted at a temperature of between 0°C and 100°C, although higher temperatures can be used. Control of a chosen reaction temperature is desirable since it can influence the effectiveness of the polar compound
35 additive in controlling the polymer microstructure. The reaction temperature can be, for example, from 50°C to 80°C.

The reaction pressure is not critical and varies from atmospheric to 100 psig.

If the polar compounds are utilized prior to the polymerization of the first (I) segment, (I) blocks with high 3,4-unit content are formed. If polar compounds are added after the initial (I) segment is prepared, the first (I) segment will possess a high percentage of 1,4-microstructure (which is tri-substituted), and the second (I) segment will have a high percentage of 3,4-microstructure.

The production of triblock polymers having a high 1,4-unit content on both of the terminal (I) blocks is also possible by the use of coupling techniques illustrated below for a polyisoprene-polybutadiene-polyisoprene block copolymer:

ISOPRENE	RLi	1,4-POLYISOPRENE
POLAR COMPOUND		
----->		1,4-POLYISOPRENE-POLYBUTADIENE
BUTADIENE		
COUPLING AGENT 1,4-POLYISOPRENE-POLYBUTADIENE-1,4-		
POLYISOPRENE		
----->		

The substitution of myrcene for the isoprene during the polymerization of the (I) blocks insures the incorporation of a high proportion of tri-substituted double bonds, even in the presence of polar compounds since myrcene contains a pendant tri-substituted double bond which is not involved in the polymerization process. In a coupling process, similar to that described above, block polymers containing polyisoprene end blocks (or any other polymerized monomer suitable for use in the (I) block) having a high 3,4-microstructure content can be obtained by adding the polar compound prior to the isoprene (or another monomer) polymerization.

The use of the coupling technique for the production of triblock polymers reduces the reaction time necessary for the completion of polymerization, as compared to sequential addition of isoprene, followed by butadiene, followed by

isoprene. Such coupling techniques are well known and utilize coupling agents such as esters, CO₂, iodine, dihaloalkanes, silicon tetrachloride, divinyl benzene, alkyl trichlorosilanes and dialkyl dichlorosilanes. The use of tri- or tetra-
5 functional coupling agents, such as alkyl trichlorosilanes or silicon tetrachloride, permits the formation of macromolecules having 1- or 2- main chain branches, respectively. The addition of divinyl benzene as a coupling agent has been documented to produce molecules having up to 20 or more
10 separately joined segments.

The use of some of the coupling agents provides a convenient means of producing star-branched block and random polymers. The star-branched block polymers are made from any combination of blocks (I) and (B), defined above. The star-
15 branched random polymers are made from any combination of at least one diene of formula (1) and at least one diene of formula (3), different from the diene of formula (1), or from at least one aryl-substituted olefin, at least one diene of formula (1) and at least one diene of formula (3), different
20 from the diene of formula (1). The molecular weight of the star-branched block and random copolymers will depend on the number of branches in each such copolymer, as will be apparent to those skilled in the art. Suitable coupling agents and reactions are disclosed U.S. Patent Nos. 3,949,020; 3,594,452;
25 3,598,887; 3,465,065; 3,078,254; 3,766,301; 3,632,682; 3,668,279; and Great Britain Patent Nos. 1,014,999; 1,074,276 and 1,121,978.

Selective Hydrogenation

Following polymerization, selective hydrogenation of the
30 polymer may be accomplished using techniques similar to those known in the art. A preferred method and catalyst are described in U.S. Patent No. 5,187,236. The procedure and catalyst are described in greater detail below. In general, however, the previously described polymers can be contacted
35 with hydrogen and a hydrogenation catalyst synthesized from a transition metal compound, typically nickel or cobalt, and an organometallic reducing agent, e.g., triethylaluminum. The

hydrogenation proceeds at temperatures typically not in excess of 40°C and at pressures of from 30 psi to 200 psi.

Generally, the polymers are hydrogenated such that substantially all of the unsaturation in formula (4) is removed, while much of that from formula (2) is retained.

The selective hydrogenation reaction will also be described below using a triblock of polyisoprene-polybutadiene-polyisoprene as an example. However, it will be apparent to those skilled in the art that any polymers of this invention can be selectively hydrogenated in the same manner.

In Example II below, the block copolymer is selectively hydrogenated to saturate the middle (polybutadiene) block. The method of selectively hydrogenating the polybutadiene block is similar to that of Falk, *Coordination Catalysts for the Selective Hydrogenation of Polymeric Unsaturation*, Journal of Polymer Science: Part A-1, 9:2617-23 (1971), but it is conducted with a novel hydrogenation catalyst and process used herein. Any other known selective hydrogenation methods may also be used, as will be apparent to those skilled in the art, but it is preferred to use the method described herein. In summary, the selective hydrogenation method preferably used herein comprises contacting the previously-prepared block copolymer with hydrogen in the presence of the novel catalyst composition.

The novel hydrogenation catalyst composition and hydrogenation process are described in detail in previously cited Application Serial No. 07/466,136. The hydrogenation catalyst composition is synthesized from at least one transition metal compound and an organometallic reducing agent. Suitable transition metal compounds are compounds of metals of Group IVb, Vb, VIb or VIII, preferably IVb or VIII of the Periodic Table of the Elements, published in Lange's Handbook of Chemistry, 13th Ed., McGraw-Hill Book Company, New York (1985) (John A. Dean, ed.). Non-limiting examples of such compounds are metal halides, e.g., titanium tetrachloride, vanadium tetrachloride, vanadium oxytrichloride, titanium and vanadium alkoxides, wherein the

alkoxide moiety has a branched or unbranched alkyl radical of 1 to 20 carbon atoms, preferably 1 to 6 carbon atoms.

Preferred transition metal compounds are metal carboxylates or alkoxides of Group IVb or VIII of the Periodic Table of the Elements, such as nickel (II) 2-ethylhexanoate, titanium isopropoxide, cobalt (II) octoate, nickel (II) phenoxide and ferric acetylacetonate.

The organometallic reducing agent is any one or a combination of any of the materials commonly employed to activate Ziegler-Natta olefin polymerization catalyst components containing at least one compound of the elements of Groups Ia, IIa, IIb, IIIa, or IVa of the Periodic Table of the Elements. Examples of such reducing agents are metal alkyls, metal hydrides, alkyl metal hydrides, alkyl metal halides, and alkyl metal alkoxides, such as alkyllithium compounds, dialkylzinc compounds, trialkylboron compounds, trialkylaluminum compounds, alkylaluminum halides and hydrides, and tetraalkylgermanium compounds. Mixtures of the reducing agents may also be employed. Specific examples of useful reducing agents include n-butyllithium, diethylzinc, di-n-propylzinc, triethylboron, diethylaluminummethoxide, triethylaluminum, trimethylaluminum, triisobutylaluminum, tri-n-hexylaluminum, ethylaluminum dichloride, dibromide, and dihydride, isobutyl aluminum dichloride, dibromide, and dihydride, diethylaluminum chloride, bromide, and hydride, di-n-propylaluminum chloride, bromide, and hydride, diisobutylaluminum chloride, bromide and hydride, tetramethylgermanium, and tetraethylgermanium. Organometallic reducing agents which are preferred are Group IIIa metal alkyls and dialkyl metal halides having 1 to 20 carbon atoms per alkyl radical. More preferably, the reducing agent is a trialkylaluminum compound having 1 to 6 carbon atoms per alkyl radical. Other reducing agents which can be used herein are disclosed in Stevens et al., U.S. Patent No. 3,787,384, column 4, line 45 to column 5, line 12 and in Strobel et al., U.S. Patent No. 4,148,754, column 4, line 56 to column 5, line 59. Particularly preferred reducing agents are metal alkyl or

hydride derivatives of a metal selected from Groups Ia, IIa and IIIa of the Periodic Table of the Elements, such as n-butyl lithium, sec-butyl lithium, n-hexyl lithium, phenyl-lithium, triethylaluminum, tri-isobutylaluminum, trimethyl-
5 aluminum, diethylaluminum hydride and dibutylmagnesium.

The molar ratio of the metal derived from the reducing agent to the metal derived from the transition metal compound will vary for the selected combinations of the reducing agent and the transition metal compound, but in general it is 1:1 to
10 12:1, preferably 1.5:1 to 8:1, more preferably 2:1 to 7:1, and most preferably 2.5:1 to 6:1. It will be apparent to those skilled in the art that the optimal ratios will vary depending upon the transition metal and the organometallic agent used, e.g., for the trialkylaluminum/nickel(II) systems, the
15 preferred aluminum:nickel molar ratio is 2.5:1 to 4:1, for the trialkylaluminum/cobalt(II) systems, the preferred aluminum:cobalt molar ratio is 3:1 to 4:1, and for the trialkylaluminum/titanium(IV) alkoxides systems, the preferred aluminum: titanium molar ratio is 3:1 to 6:1.

20 The mode of addition and the ratio of the reducing agent to the transition metal compound are important in the production of the novel hydrogenation catalyst having superior selectivity, efficiency and stability, as compared to prior art catalytic systems. During the synthesis of the catalysts
25 it is preferred to maintain the molar ratio of the reactants used to synthesize the catalyst substantially constant. This can be done either by the addition of the reducing agent, as rapidly as possible, to a solution of the transition metal compound, or by a substantially simultaneous addition of the
30 separate streams of the reducing agent and the transition metal compound to a catalyst synthesis vessel in such a manner that the selected molar ratios of the metal of the reducing agent to the metal of the transition metal compound are maintained substantially constant throughout substantially the
35 entire time of addition of the two compounds. The time required for the addition must be such that excessive pressure and heat build-up are avoided, i.e., the temperature should

not exceed 80°C and the pressure should not exceed the safe pressure limit of the catalyst synthesis vessel.

In a preferred embodiment, the reducing agent and the transition metal compound are added substantially
5 simultaneously to the catalyst synthesis vessel in such a manner that the selected molar ratio of the reducing agent to the transition metal compound is maintained substantially constant during substantially the entire time of the addition
10 of the two compounds. This preferred embodiment permits the control of the exothermic reaction so that the heat build-up is not excessive, and the rate of gas production during the catalyst synthesis is also non-excessive -- accordingly, the gas build-up is relatively slow. In this embodiment, carried
15 out with or without a solvent diluent, the rate of addition of the catalyst components is adjusted to maintain the synthesis reaction temperature at or below 80°C, which promotes the formation of the selective hydrogenation catalyst.
Furthermore, the selected molar ratios of the metal of the reducing agent to the metal of the transition metal compound
20 are maintained substantially constant throughout the entire duration of the catalyst preparation when the simultaneous mixing technique of this embodiment is employed.

In another embodiment, the catalyst is formed by the addition of the reducing agent to the transition metal
25 compound. In this embodiment, the timing and the order of addition of the two reactants is important to obtain the hydrogenation catalyst having superior selectivity, efficiency and stability. Thus, in this embodiment, it is important to add the reducing agent to the transition metal compound in
30 that order in as short a time period as practically possible. In this embodiment, the time allotted for the addition of the reducing agent to the transition metal compound is critical for the production of the novel catalyst. The term "as short
35 a time period as practically possible" means that the time of addition is as rapid as possible, such that the reaction temperature is not higher than 80°C and the reaction pressure does not exceed the safe pressure limit of the catalyst

synthesis vessel. As will be apparent to those skilled in the art, that time will vary for each synthesis and will depend on such factors as the types of the reducing agents, the transition metal compounds and the solvents used in the synthesis, as well as the relative amounts thereof, and the type of the catalyst synthesis vessel used. For purposes of illustration, a solution of 15 mL of triethylaluminum in hexane should be added to a solution of nickel(II) octoate in mineral spirits in 10-30 seconds. Generally, the addition of the reducing agent to the transition metal compound should be carried out in 5 seconds (sec) to 5 minutes (min), depending on the quantities of the reagents used. If the time period during which the reducing agent is added to the transition metal compound is prolonged, e.g., more than 15 minutes, the synthesized catalyst is less selective, less stable, and may be heterogeneous.

In the embodiment wherein the reducing agent is added as rapidly as possible to the transition metal compound, it is also important to add the reducing agent to the transition metal compound in the aforementioned sequence to obtain the novel catalyst. The reversal of the addition sequence, i.e., the addition of the transition metal compound to the reducing agent, or the respective solutions thereof, is detrimental to the stability, selectivity, activity, and homogeneity of the catalyst and is, therefore, undesirable.

In all embodiments of the hydrogenation catalyst synthesis, it is preferred to use solutions of the reducing agent and the transition metal compound in suitable solvents, such as hydrocarbon solvents, e.g., cyclohexane, hexane, pentane, heptane, benzene, toluene, or mineral oils. The solvents used to prepare the solutions of the reducing agent and of the transition metal compound may be the same or different, but if they are different, they must be compatible with each other so that the solutions of the reducing agent and the transition metal compound are fully soluble in each other.

The hydrogenation process comprises contacting the unsaturated polymer to be hydrogenated with an amount of the catalyst solution containing 0.1 to 0.5, preferably 0.2 to 0.3 mole percent of the transition metal based on moles of the polymer unsaturation. The hydrogen partial pressure is generally from 5 psig to several hundred psig, but preferably it is from 10 psig to 100 psig. The temperature of the hydrogenation reaction mixture is generally from 0°C to 150°C, preferably from 25°C to 80°C, more preferably from 30°C to 60°C, since higher temperatures may lead to catalyst deactivation. The length of the hydrogenation reaction may be as short as 30 minutes and, as will be apparent to those skilled in the art, depends to a great extent on the actual reaction conditions employed. The hydrogenation process may be monitored by any conventional means, e.g., infra-red spectroscopy, hydrogen flow rate, total hydrogen consumption, or any combination thereof.

Upon completion of the hydrogenation process, unreacted hydrogen is either vented or consumed by the introduction of the appropriate amount of an unsaturated material, such as 1-hexene, which is converted to an inert hydrocarbon, e.g., hexane. Subsequently, the catalyst is removed from the resulting polymer solution by any suitable means, selected depending on the particular process and polymer. For a low molecular weight material, for example, catalyst residue removal may consist of a treatment of the solution with an oxidant, such as air, and subsequent treatment with ammonia and optionally methanol in amounts equal to the molar amount of the metals (i.e., the sum of the transition metal and the metal of the reducing agent) present in the hydrogenation catalyst to yield the catalyst residues as a filterable precipitate, which is filtered off. The solvent may then be removed by any conventional methods, such as vacuum stripping, to yield the product polymer as a clear, colorless fluid.

Alternatively, and in a preferred embodiment, upon completion of the hydrogenation reaction, the mixture is treated with ammonia in the molar amount equal to that of the

metals (i.e., the sum of the transition metal and the metal of the reducing agent) and aqueous hydrogen peroxide, in the molar amount equal to one half to one, preferably one half, of the amount of the metals. Other levels of the ammonia and peroxide are also operative, but those specified above are particularly preferred. In this method, a precipitate forms, which may be filtered off as described above.

In yet another alternative method, the catalyst may be removed by extraction with an aqueous mineral acid, such as sulfuric, phosphoric, or hydrochloric acid, followed by washing with distilled water. A small amount of a material commonly used as an aid in removing transition metal-based catalysts, such as a commercially available high molecular weight diamine, e.g., Jeffamine D-2000 from Huntsman, may be added to aid in phase separation and catalyst removal during the extractions. The resultant polymer solution is then dried over a drying agent, such as magnesium sulfate, separated from the drying agent and the solvent is then separated by any conventional methods, such as vacuum stripping, to yield a polymer as a clear fluid. Other methods of polymer isolation, such as steam or alcohol flocculation, may be employed depending upon the hydrogenated polymer properties.

After hydrogenation and purification is complete, the polymer can be functionalized and used in the lubricant compositions of the invention: the liquids will serve as dispersants and the solids as dispersant VI improvers.

Functionalization of the Polymers

The unsaturated terminal blocks of the block polymers of this invention can be chemically modified or functionalized to provide benefits which enhance the dispersancy and viscosity improving qualities of the materials of the invention. Such benefits may be obtained through methods similar to those employed for the modification of existing commercial materials, such as polyisobutylene or EPDM.

Following the selective hydrogenation step, the remaining sites of unsaturation may be chemically modified. Such methods include reacting the unsaturated groups in the polymer

with any of various reagents to produce functional groups, such as halogen, hydroxyl, epoxy, sulfonic acid, mercapto, acrylate or carboxyl groups. Functionalization methods are well known in the art.

- 5 A preferred chemical modification method involves reaction of the polymer with an unsaturated carboxylic acid and/or derivatives, such as acrylic acid, maleic acid, fumaric acid, maleic anhydride, methacrylic acid, esters of these acids, and the like. Most preferably, maleic anhydride is
10 used for the chemical modification of unsaturation. Numerous methods are known for the chemical modification of polyisobutylene and EPDM via the ene reaction. Methods are also known for the reaction of maleic anhydride with EPDM via a radical reaction in the presence of a radical initiator.
15 These methods can be adapted to incorporate the unsaturated carboxylic acid derivatives into the polymeric dispersants of the invention.

- Subsequent to the acylation reaction (or other suitable chemical modifications as outlined above), the chemically
20 modified polymers may be reacted with a Lewis base, such as a monoamine, a polyamine, a polyhydroxy compound, a reactive polyether, or a combination thereof. Amines which are useful for this modification reaction are characterized by the presence of at least one primary (i.e., H_2N-) or secondary
25 (i.e., $HN=$) amino group. The monoamines and polyamines can be aliphatic amines, cycloaliphatic amines, heterocyclic amines, aromatic amines, or hydroxyamines. Preferably, the polyamines contain only one primary or secondary amine, with the remaining amines being tertiary (i.e., $-N=$) or aromatic
30 amines. The amination can be accomplished by heating the maleic anhydride-modified diene polymer to $150^{\circ}C$ in the presence of the amine, followed by stripping off the water. A useful monoamine is ethanol amine. Useful polyamines include aminopropylmorpholine and tetraethylenepentamine. Useful
35 polyhydroxy compounds include ethylene glycol and pentaerythritol. Useful reactive polyethers include polyethers which contain hydroxy or amino groups which will

react with the modified polymer, such as polyethylene glycol monoalcohol. In addition; when the modified polymers react with an aromatic polyamine, the resultant dispersant has improved antioxidant properties.

5 In a preferred functionalization of diene copolymers, the selectively hydrogenated copolymer is functionalized with functional groups selected from among halogens IV, epoxies, sulfonic acids, mercapto acid and/or derivatives and carboxylic acid derivatives, and subsequently modified further
10 by reacting with a monoamine, a polyamine, a polyhydroxy compound, a reactive polyether, or a combination thereof.

The ene reaction of maleic anhydride with materials of the invention can be performed on neat polymers or solutions of the polymers in light mineral oil or polyalphaolefin at
15 temperatures of from 150°C to 250°C, typically under an inert atmosphere. Such modification of the polymers of any embodiments of our invention occurs readily, since the residual isoprene unsaturation, primarily of the 3,4-type, illustrated above, is known to be more reactive with maleic
20 anhydride than are the internal bonds found in EPDM.

In addition, the selectively hydrogenated polymer may be functionalized by other methods which enhance the dispersancy, including but not limited to: grafting of heteroatom-containing olefins; formation of Mannich base condensates at
25 the sites of unsaturation; hydroformylation/reductive amination; addition of nitrosamines or nitrosophenols; lithiation followed by reaction with electrophilic compounds capable of displacement or addition reactions to provide carboxy, nitrilo, or amino groups; 1,3-dipolar addition of
30 nitrile oxides, nitrones, and the like; light catalyzed cycloaddition of activated olefins; and light catalyzed insertion reactions.

Grafting of heteroatom-containing olefins may be accomplished by reacting the polymer with a vinyl monomer in
35 the presence of a free radical initiator, such as t-butylperoxybenzoate, to directly form a dispersant molecule. Nitrogen and/or oxygen-containing vinyl monomers, such as

vinyl imidazole and maleic anhydride, may be used. The number of vinyl monomers appended to the polymer in this fashion can be from 1 to 20 or more per 10,000 molecular weight.

Suitable vinyl monomers are disclosed in U.S. Patent Nos.
5 5,663,126; 5,140,075; 5,128,086; 4,146,489; 4,092,255 and 4,810,754.

Suitable free radical initiators are disclosed in U.S. Patent Nos. 5,663,126 and 4,146,489.

Any conventional grafting method may be used. For
10 example, the grafting may be performed by dissolving the polymer in a solvent, preferably a hydrocarbon solvent, adding a free radical initiator and a nitrogen and/or oxygen-containing vinyl monomer. The mixture is then heated to obtain a grafted polymer. The grafted polymer may be isolated by
15 conventional methods. For example, the graft copolymer may be converted to a concentrate by evaporative distillation of solvent, non-reacted vinyl monomer, and reaction by-products. For ease of handling, a mineral oil diluent may be added before or after the evaporative procedure.

20 The grafted polymer may be further reacted with an amine, preferably containing at least one -NH group. Suitable amines include monoamines, polyamines, amino alcohols, amino acids or derivatives thereof, and amino terminated polyethers.

The selectively hydrogenated polymer may also be
25 functionalized by a Mannich base condensation reaction or chemical modification followed by a Mannich base condensation reaction. The polymer is reacted with a phenol to provide a hydroxy aromatic functionalized polymer which is subsequently reacted with an aldehyde or aldehyde precursor and at least
30 one amino or polyamino compound having at least one -NH group to form a dispersant molecule. The number of phenolic groups (Mannich condensates) per molecule can be from 1 to 20 or more per 10,000 molecular weight.

Useful amines in the preparation of the Mannich
35 condensate dispersants of this invention include monoamines, polyamines, amino alcohols, amino acids or derivatives

thereof, and amino terminated polyethers with the proviso that the amine has at least one -NH group.

Suitable aldehydes include C₁ to C₁₀ linear, cyclic or branched aldehydes.

5 Mannich base condensation reactions are described in U.S. Patent. Nos. 3,413,347; 3,697,574; 3,634,515; 3,649,229; 3,442,808; 3,798,165; 3,539,633; 3,725,277; 3,725,480; 3,726,882; 4,454,059; 5,102,566 and 5,663,130.

10 Alternatively, the selectively hydrogenated polymer may be functionalized by aminomethylation or hydroformylation followed by reductive amination. The polymer is reacted with carbon monoxide and hydrogen, in the presence of a transition metal catalyst to provide carbonyl derivatives of the polymer. The functionalized polymer is subsequently modified by
15 reductive amination. Useful amines include, but are not limited to, monoamines, polyamines, amino alcohols, amino acids or derivatives thereof, and amino terminated polyethers with the proviso that the amine has at least one -NH group. The number of suitable reaction sites per molecule can be from
20 1 to 20 or more per 10,000 molecular weight.

Aminomethylation and hydroformylation followed by reductive amination are described in U.S. Patent Nos. 3,311,598; 3,438,757; 4,832,702 and 5,691,422.

The above description illustrates only some of the
25 potentially valuable chemical modification of the polymers of this invention. The polymers of this invention provide a means for a wide variety of chemical modifications at selected sites in the polymer, e.g., at select ends, in the middle, or randomly, thereby presenting the opportunity to prepare
30 materials previously impossible because of the lack of availability of such polymers. Some examples of well known chemical reactions which can be performed on polymers of this invention are found in E.M. Fettes, "Chemical Reactions of Polymers", High Polymers, Vol. 19, John Wiley, New York,
35 (1964).

Post Treatment of the Polymers

Post treatment compositions of this invention include those formed by contacting the dispersants of this invention with one or more post-treating agents to give improved
5 properties to finished lubricants. Such improved properties include enhanced performance in high temperature oxidation tests and in deposit and wear related full-scale engine tests.

Suitable post-treating agents include boronating agents; phosphorylating agents; alkaline earth metal oxidating,
10 sulfonating and carbonating agents; and IB and IIB metal oxidating, sulfating and sulfonating agents.

Suitable boronating agents or boron-containing compounds include boron acids, particularly boric acid or metaboric acid, boron oxide, boron oxide hydrate, boron esters, boron
15 salts, particularly an ammonium borate, and boron halides.

Suitable phosphorylating agents include an inorganic acid of phosphorus, such as phosphorous acid and phosphoric acid, an anhydride thereof, a partial or complete sulfur analog thereof and an organic acid phosphate, such as 2-ethylhexyl acid
20 phosphate.

Suitable alkaline earth oxidating, sulfonating and carbonating agents include calcium oxide, calcium sulfonate, calcium carbonate, barium oxide, barium sulfonate and barium carbonate.

25 Suitable IB and IIB metal oxidating, sulfating and sulfonating agents include zinc sulfate, zinc oxide, zinc sulfonate and cuprous oxide.

Post-treating agents and methods by which they can be employed in effecting post treatment of ashless dispersants
30 are disclosed in U.S. Patent Nos. 5,464,549 and 4,234,435.

Dispersant and VI-Improving Applications

The polymers of the invention, whether block copolymers, tapered block copolymers, branched and star branched polymers, or random copolymers, have been found to have an unexpected
35 capacity to modify the dispersancy and/or viscometric properties of fluids, such as mineral and synthetic oil lubricants and normally liquid fuels. Accordingly, it is

within the scope of the invention that the dispersant polymers of the invention be employed in dispersant substances which can be added to fluids to modify the dispersancy and/or viscometric properties of the fluids. The invention, thus, also includes a method of modifying or improving the dispersancy and/or viscometric properties of a fluid by admixing with the fluid a sufficient amount of a dispersant substance of the invention so as to obtain or provide a modified or improved fluid having modified or improved dispersancy and/or viscometric properties. Moreover, the invention also includes dispersant-modified or dispersant-improved fluids to which have been added a dispersant substance of the invention so as to modify the dispersancy and/or viscometric properties of the fluid.

The improvement of viscometric properties includes any one or more of the properties of fluids which are related to viscosity. The dispersant VI improvers of the invention specifically improve the viscosity index of such fluids. Viscosity index is a property characterizing the relationship between the viscosity of a fluid and temperature. Improvement in viscosity index is characterized by a decrease in the rate of change of viscosity per unit of temperature change. Typical properties which are modified or improved by the dispersant VI improvers of the invention include relative thickening power (RTP), borderline pumpability, permanent shear stability (DIN), temporary shear stability at low temperatures (CCS), and temporary shear stability at high temperatures (HTHS). Each of these properties can be determined or characterized by conventional methods.

The polymers of the invention may be employed as dispersants and/or dispersant VI improvers in a variety of lubricant fluids. Typically, such fluid is a mineral oil such as a mineral oil lubricant system, e.g., motor oils, automatic transmission fluids, tractor hydraulic fluids, gear oils, aviation oils, and the like. Other suitable applications include normally liquid fuels. The lubricant or fuel may be naturally occurring or synthetic, or a combination thereof.

Natural oils include mineral oils obtained from petroleum, including distillate and residual lubricating oils, and the like. Synthetic oils can include synthetic hydrocarbon fluids e.g. PAOs, liquid esters, fluorocarbons, polyethers and polysilicones. The dispersants can be added to a lubricant or fuel formulation in any suitable and effective amount to modify the dispersancy and/or viscometric properties of the formulation. An exemplary broad range is from 0.001% wt. to 20% wt., preferably from 0.1% wt. to 10% wt., more preferably from 0.5% wt. to 7% wt., of the formulation.

The polymers of the invention can be supplied neat or as an oil concentrate for ease of handling. Typically, such dispersant concentrates include a polymer of the invention in an amount of from 5% wt. to 90% wt., preferably from 10% wt. to 70% wt., of the concentrate.

In addition to the polymers described in this invention, the dispersant formulations and the fluid formulations can further include one or more additional additives known to those skilled in the art. Such additives include, for example, antioxidants, pour point depressants, detergents, dispersants, friction modifiers, anti-wear agents, VI improvers, anti-foam agents, corrosion and rust inhibitors, etc. Indeed, it is among the advantages of the compositions of the invention that they are unusually efficient modifiers of dispersancy and/or viscometric properties, such that in many cases significantly less of these additives need be added to achieve a desired combination of fluid properties.

Examples

The following examples are intended to assist in a further understanding of the invention. The particular materials and conditions employed are intended to be further illustrative of the invention and are not limiting upon the reasonable scope thereof.

In all of the following examples, the experimental polymerization and functionalization work was performed with dried reactors and equipment and under strictly anaerobic conditions. Extreme care must be used to exclude air,

moisture and other impurities capable of interfering with the delicate chemical balance involved in the synthesis of the polymers of this invention, as will be apparent to those skilled in the art.

5 **Example I - Preparation of Dispersant Precursor Backbones**

Using the procedure described in Example VII of U.S. Patent 5,633,415, an isoprene-butadiene diblock polymer having an approximate number average molecular weight of 15000 is prepared.

10 **Example II - Selective Hydrogenation of Polymer of Example I**

The polymer solution of Example I is subjected to a selective hydrogenation procedure using a catalyst prepared by diethylaluminum ethoxide and cobalt octoate (3.5 to 1 molar ratio) and following general procedures as described in
15 Example VIII of U.S. Patent 5,633,415. The extent of hydrogenation is followed by Fourier Transfer infrared (FTIR) and is continued until no absorption remains at 910 cm⁻¹ and 990 cm⁻¹ (-1,2 polybutadiene structure) and essentially no residual trans double bonds are present as seen by
20 disappearance of the 968 cm⁻¹ absorption. The FTIR analysis of the polymers at the end of the selective hydrogenation typically indicates 0 to 10 trans polybutadiene double bonds and 50 to 100 vinylidene (-3, 4 polyisoprene) double bonds remain - normalized to 100,000 molecular weight polymer chain.
25 That is, a 15,000 molecular weight polymer would typically have 0 to 1.5 residual trans double bonds and 7.5 to 15 vinylidene double bonds (for subsequent functionalization).

The hydrogenation catalyst is removed by washing, as described in '415, or by a filtration procedure preceded by
30 precipitation of the catalyst with essentially stoichiometric levels of acetic acid and hydrogen peroxide. After catalyst removal, the polymer is isolated by removal of the solvent under reduced pressure to give polymer.

Example III - Two Step Hydroformylation/Reductive Amination of the Polymer of Example II
35

The polymer, before hydroformylation, contains 0.007 equivalents of unsaturation per gram. A solution of 250 grams

(0.017 moles) of polymer in 250 grams of 100N mineral oil is added to a 2 liter Parr reactor. Five hundred mL of cyclohexane and 0.2 grams of (acetylacetonato)dicarbonyl rhodium catalyst are added. The reactor is sealed and purged with N₂, then pressurized to 1000 psig (7000 kPaa) with hydrogen and carbon monoxide (volume ratio of 1/1). The reactor is heated to 150°C for 12 hours. Then, 37.4 grams (0.20 moles) of aminopropyl morpholine is added and heating continued for 12 hours at 1000 psig (7000 kPaa). Upon reaction completion and cooling, the catalyst is removed by consecutive extractions with 10% aqueous citric acid and water. The reaction product is dried and stripped of volatiles by vacuum distillation. After cooling, a sufficient amount of 100N mineral oil is added to provide a 50% solution of an aminomethylated dispersant in 100N mineral oil.

Example IV - One Step Hydroformylation/Aminomethylation of the Polymer of Example II

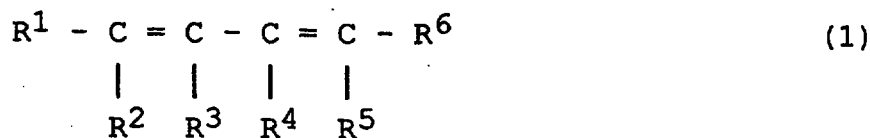
The polymer, before hydroformylation, contains 0.007 equivalents of unsaturation per gram. A solution of 250 grams (0.017 moles) of polymer in 250 grams of 100N mineral oil is added to a 2 liter Parr reactor. An amount of 0.2 grams of (acetylacetonato)dicarbonyl rhodium catalyst is added followed by a solution of 37.4 grams (0.20 moles) of aminopropyl morpholine in 500 mL of cyclohexane. The reactor is sealed and purged with N₂, then pressurized to 1000 psig (7000 kPaa) with hydrogen and carbon monoxide (volume ratio of 1/1). The reactor is heated to 150°C for 28 hours. Upon reaction completion and cooling, the catalyst is removed by consecutive extractions with 10% aqueous citric acid and water. The reaction product is dried and stripped of volatiles by vacuum distillation. After cooling, a sufficient amount 100N mineral oil is added to provide a 50% solution of an aminomethylated dispersant in 100N mineral oil.

CLAIMS:

1. A dispersant substance for modifying the dispersancy or viscometric properties of a fluid, comprising:

5 a copolymer of a first conjugated diene and a second conjugated diene, wherein:

the first conjugated diene comprises at least one relatively more substituted conjugated diene having at least five carbon atoms and the formula:

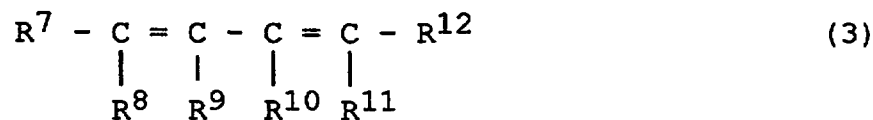


15 wherein R^1 - R^6 are each hydrogen or a hydrocarbyl group, provided that at least one of R^1 - R^6 is a hydrocarbyl group, provided that after polymerization, the unsaturation of the polymerized conjugated diene of formula (1) has the formula:



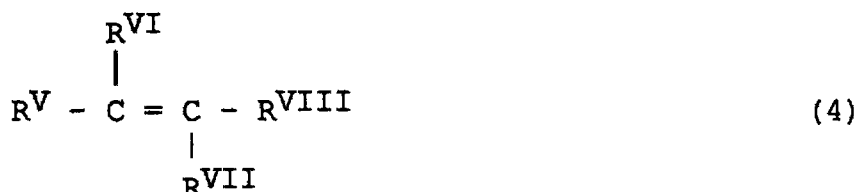
25 wherein R^I , R^{II} , R^{III} and R^{IV} are each hydrogen or a hydrocarbyl group, provided that either both R^I and R^{II} are hydrocarbyl groups or both R^{III} and R^{IV} are hydrocarbyl groups; and

30 the second conjugated diene comprises at least one relatively less substituted conjugated diene different from the first conjugated diene and having at least four carbon atoms and the formula:





wherein R⁷-R¹² are each hydrogen or a hydrocarbyl group, provided that after polymerization, the unsaturation of the polymerized conjugated diene of formula (3) has the formula:



wherein R^V, R^{VI}, R^{VII} and R^{VIII} are each hydrogen or a hydrocarbyl group, provided that one of R^V or R^{VI} is hydrogen, one of R^{VII} or R^{VIII} is hydrogen, and at least one of R^V, R^{VI}, R^{VII} and R^{VIII} is a hydrocarbyl group; and

wherein the copolymer has been functionalized by a method comprising:

selectively hydrogenating the copolymer to provide a selectively hydrogenated copolymer;

functionalizing the selectively hydrogenated copolymer by hydroformylation to provide a functionalized copolymer having at least one polar functional group; and

reductively aminating the functionalized copolymer.

2. The dispersant substance of Claim 1, wherein the hydroformylation comprises contacting the selectively hydrogenated copolymer with carbon monoxide and hydrogen.

3. The dispersant substance of Claim 1, wherein the reductive amination comprises contacting the functionalized copolymer with an amine having at least one -NH group selected from the group consisting of monoamines, polyamines, amino alcohols, amino acids, amino terminated polyethers, or a combination thereof.

4. The dispersant substance of Claim 1, wherein the hydroformylation and reductive amination is in one step.



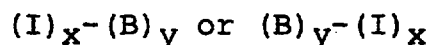
5. The dispersant substance of Claim 1, wherein the reductively aminated copolymer is treated with a post-treating agent.

5 6. The dispersant substance of Claim 5, wherein the post-treating agent is a boron-containing compound.

7. The dispersant substance of Claim 6, wherein the boron-containing compound is selected from the group
10 consisting of boric acids, boron oxide, boron oxide hydrate, boron esters, boron salts, boron halides, or a combination thereof.

8. The dispersant substance of Claim 7, wherein the
15 boron-containing compound is boron ester.

9. The dispersant substance of Claim 1, wherein the first and second conjugated dienes are polymerized as a block copolymer comprising at least two alternating blocks:
20



wherein the block (I) comprises at least one polymerized conjugated diene of formula (1);

the block (B) comprises at least one polymerized
25 conjugated diene of formula (3);

x is the number of polymerized monomer units in block (I) and is at least 1, and

y is the number of polymerized monomer units in block (B) and is at least 25.
30

10. The dispersant substance of Claim 1, wherein the conjugated diene of formula (1) comprises isoprene and the conjugated diene of formula (3) comprises 1,3-butadiene.

35 11. The dispersant substance of Claim 1, wherein the polymer is distributed in a carrier fluid to provide a dispersant concentrate.



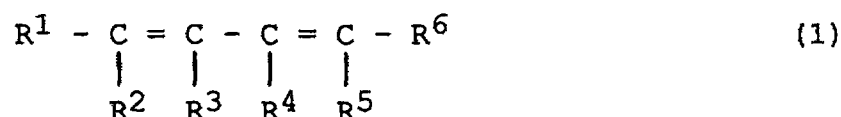
12. The dispersant substance of Claim 1, further comprising at least one additive selected from the group consisting of antioxidants, pour point depressants, detergents, dispersants, friction modifiers, anti-wear agents, anti-foam agents, corrosion and rust inhibitors and viscosity index improvers.

13. A method of modifying the dispersancy or viscometric properties of a fluid, comprising:

admixing with a fluid an amount of dispersant substance sufficient to provide a dispersant-modified fluid having modified dispersant or viscometric properties; wherein the dispersant substance comprises:

a copolymer of a first conjugated diene and a second conjugated diene, wherein:

the first conjugated diene comprises at least one relatively more substituted conjugated diene having at least five carbon atoms and the formula:



wherein R^1 - R^6 are each hydrogen or a hydrocarbyl group, provided that at least one of R^1 - R^6 is a hydrocarbyl group, provided that after polymerization, the unsaturation of the polymerized conjugated diene of formula (1) has the formula:

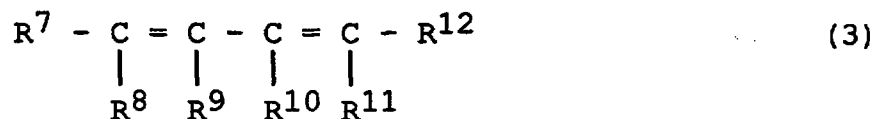


wherein R^I , R^{II} , R^{III} and R^{IV} are each hydrogen or a hydrocarbyl group, provided that either both R^I and R^{II} are hydrocarbyl groups or both R^{III} and R^{IV} are hydrocarbyl groups; and



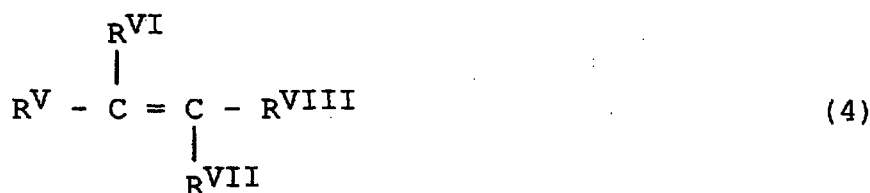
the second conjugated diene comprises at least one relatively less substituted conjugated diene different from the first conjugated diene and having at least four carbon atoms and the formula:

5



10 wherein R^7 - R^{12} are each hydrogen or a hydrocarbyl group, provided that after polymerization, the unsaturation of the polymerized conjugated diene of formula (3) has the formula:

15



20 wherein R^V , R^{VI} , R^{VII} and R^{VIII} are each hydrogen or a hydrocarbyl group, provided that one of R^V or R^{VI} is hydrogen, one of R^{VII} or R^{VIII} is hydrogen, and at least one of R^V , R^{VI} , R^{VII} and R^{VIII} is a hydrocarbyl group; and

25 wherein the copolymer has been functionalized by a method comprising:

selectively hydrogenating the copolymer to provide a selectively hydrogenated copolymer;

functionalizing the selectively hydrogenated copolymer by hydroformylation to provide a functionalized copolymer having
30 at least one polar functional group: and

reductively aminating the functionalized copolymer.

14. The method of Claim 13 further comprising post
treating the reductively aminated copolymer with a post-
35 treating agent.

15. The method of Claim 13, comprising admixing the dispersant substance in an amount of from 0.001% wt. to 20% wt. of the dispersant-modified fluid.

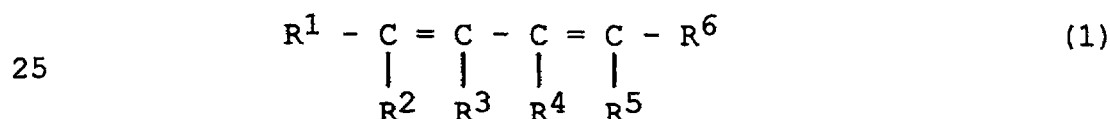


16. The method of Claim 13, wherein the fluid is selected from the group consisting of motor oils, transmission fluids, hydraulic fluids, gear oils, aviation oils, normally liquid fuels and lubricants.

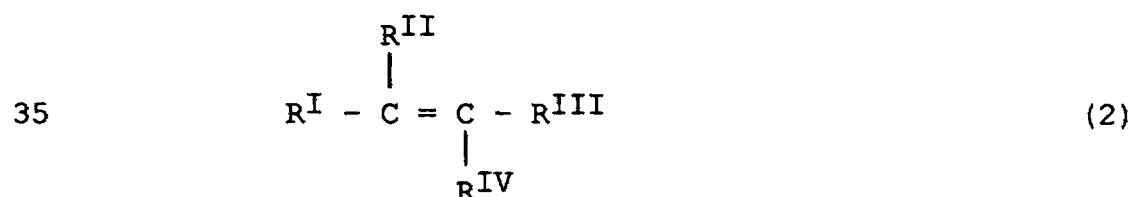
17. The method of Claim 13, further comprising admixing with the fluid at least one additive selected from the group consisting of antioxidants, pour point depressants, detergents, dispersants, friction modifiers, anti-wear agents, anti-foam agents, corrosion and rust inhibitors, viscosity index improvers, and the like.

18. A dispersant-modified fluid having modified dispersancy or viscometric properties comprising:
a fluid; and
a dispersant substance comprising;
a copolymer of a first conjugated diene and a second conjugated diene, wherein:

the first conjugated diene comprises at least one relatively more substituted conjugated diene having at least five carbon atoms and the formula:



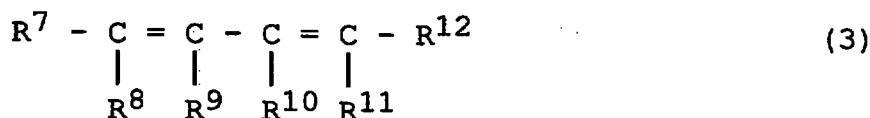
wherein R^1 - R^6 are each hydrogen or a hydrocarbyl group, provided that at least one of R^1 - R^6 is a hydrocarbyl group, provided that after polymerization, the unsaturation of the polymerized conjugated diene of formula (1) has the formula:



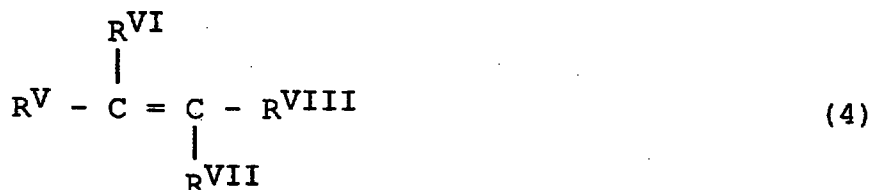


wherein R^I , R^{II} , R^{III} and R^{IV} are each hydrogen or a hydrocarbyl group, provided that either both R^I and R^{II} are hydrocarbyl groups or both R^{III} and R^{IV} are hydrocarbyl groups; and

the second conjugated diene comprises at least one relatively less substituted conjugated diene different from the first conjugated diene and having at least four carbon atoms and the formula:



wherein R^7 - R^{12} are each hydrogen or a hydrocarbyl group, provided that after polymerization, the unsaturation of the polymerized conjugated diene of formula (3) has the formula:



wherein R^V , R^{VI} , R^{VII} and R^{VIII} are each hydrogen or a hydrocarbyl group, provided that one of R^V or R^{VI} is hydrogen, one of R^{VII} or R^{VIII} is hydrogen, and at least one of R^V , R^{VI} , R^{VII} and R^{VIII} is a hydrocarbyl group; and

wherein the copolymer has been functionalized by a method comprising:

selectively hydrogenating the copolymer to provide a selectively hydrogenated copolymer;

functionalizing the selectively hydrogenated copolymer by hydroformylation to provide a functionalized copolymer having at least one polar functional group; and

reductively aminating the functionalized copolymer.

19. The dispersant-modified fluid of Claim 18, wherein the reductively aminated copolymer is treated with a post-treating agent.

20. The dispersant-modified fluid of Claim 18, wherein the dispersant substance is included in an amount of from 0.001% wt. to 20% wt.

5

21. The dispersant-modified fluid of Claim 18, wherein the fluid is selected from the group consisting of motor oils, transmission fluids, hydraulic fluids, gear oils, aviation oils, greases, normally liquid fuels, and lubricants.

10

22. The dispersant-modified fluid of Claim 18, wherein the lubricant fluid further comprises at least one additive selected from the group consisting of antioxidants, pour point depressants, detergents, dispersants, friction modifiers, anti-wear agents, anti-foam agents, corrosion and rust inhibitors, and viscosity index improvers.

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