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Handlin,, JR. et al.

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(54) **ELASTOMERIC ARTICLES PREPARED FROM CONTROLLED DISTRIBUTION BLOCK COPOLYMERS**

(75) Inventors: **Dale Lee Handlin, JR.**, Houston, TX (US); **Carl Lesley Willis**, Houston, TX (US); **Margaret Ann Burns Clawson**, Houston, TX (US); **Hendrik De Groot**, Amsterdam (NL); **Keith Edward Eiden**, Houston, TX (US)

Correspondence Address:

**PAUL S MADAN
MADAN, MOSSMAN & SRIRAM, PC
2603 AUGUSTA, SUITE 700
HOUSTON, TX 77057-1130 (US)**

(73) Assignee: **Kraton Polymers U.S. LLC**, Houston, TX (US)

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(57) **ABSTRACT**

The present invention relates to elastomeric articles prepared from novel anionic block copolymers of mono alkenyl arenes and conjugated dienes, and to blends of such block copolymers with other polymers. The block copolymers are selectively hydrogenated and have mono alkenyl arene end blocks and controlled distribution blocks of mono alkenyl arenes and conjugated dienes. The block copolymer may be blended with at least one other polymer selected from the group consisting of olefin polymers, styrene polymers, amorphous resins, and engineering thermoplastic resins.

ELASTOMERIC ARTICLES PREPARED FROM CONTROLLED DISTRIBUTION BLOCK COPOLYMERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority from copending, commonly assigned U.S. patent application Serial No. 60/355,210, filed Feb. 7, 2002, entitled Novel Block Copolymers and Method for Making Same.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to elastomeric articles prepared from novel anionic block copolymers of mono alkenyl arenes and conjugated dienes, and to blends of such block copolymers with other polymers. The invention also relates to formed articles and methods for forming articles from such novel block copolymers.

[0004] 2. Background of the Art

[0005] The preparation of block copolymers of monoalkenyl arenes and conjugated dienes is well known. One of the first patents on linear ABA block copolymers made with styrene and butadiene is U.S. Pat. No. 3,149,182. These polymers in turn could be hydrogenated to form more stable block copolymers, such as those described in U.S. Pat. No. 3,595,942 and Re. No. 27,145. Since then, a large number of new styrene diene polymers have been developed. Now a novel anionic block copolymer based on monoalkenyl arene end blocks and controlled distribution mid blocks of mono alkenyl arenes and conjugated dienes has been discovered and is described in copending, commonly assigned U.S. patent application Serial No. 60/355,210, entitled "NOVEL BLOCK COPOLYMERS AND METHOD FOR MAKING SAME". Methods for making such polymers are described in detail in the above-mentioned patent application. What has now been found is that blends or compounds of these novel block copolymers with processing oils and other polymers have surprising property advantages, and show promising utility in a variety of end-use applications, including injection molding, extruded goods and polymer modification.

SUMMARY OF THE INVENTION

[0006] In one aspect of the present invention we have discovered that a novel composition comprising at least one hydrogenated block copolymer having a controlled distribution block of a monoalkenyl arene and conjugated diene, and optionally including another polymer, has superior properties for many applications. We have also discovered that these compositions can be used in various forming processes, and that they also have a number of advantages in processing.

[0007] Accordingly, the broad aspect of the present invention is an elastomeric article comprising at least one hydrogenated block copolymer and, optionally, at least one other polymer selected from the group consisting of olefin polymers, styrene polymers, tackifying resins and engineering thermoplastic resins, wherein said hydrogenated block copolymer has the general configuration: A-B, A-B-A, or (A-B)_nX; where n is an integer from 2 to about 30, and X is

coupling agent residue and wherein (a.) prior to hydrogenation each A block is a mono alkenyl arene homopolymer block and each B block is a controlled distribution copolymer block of at least one conjugated diene and at least one mono alkenyl arene; (b.) subsequent to hydrogenation about 0-10% of the arene double bonds have been reduced, and at least about 90% of the conjugated diene double bonds have been reduced; (c.) each A block having an average molecular weight between about 3,000 and about 60,000 and each B block having an average molecular weight between about 30,000 and about 300,000; (d.) each B block comprises one or more terminal regions adjacent to the A blocks that are rich in conjugated diene units and a region not adjacent to the A blocks that is rich in mono alkenyl arene units; (e.) the total amount of mono alkenyl arene in the hydrogenated block copolymer is about 20 percent weight to about 80 percent weight; and (f.) the weight ratio of conjugated diene to mono alkenyl arene in the B block is between about 5:1 and about 1:2.

[0008] In another aspect of the present invention we have shown that the elastomeric article can be formed in a wide variety of processes, including injection molding, compression molding, over molding, dipping, extrusion, roto molding, slush molding, fiber spinning, blow molding, polymer modification, cast film making, blown film making and foaming.

[0009] In still another aspect of the present invention, the hydrogenated controlled distribution polymer of the present invention may be functionalized in a variety of ways, including reaction with maleic acid or anhydride. Such functionalized polymers have additional polarity that makes them particularly useful where adhesion to other polar polymers is important, such as in over molding applications.

[0010] The elastomeric articles of the present invention have a number of surprising properties. These properties include, for example, the unusual stress-strain response, which shows that a composition of the present invention exhibits a stiffer rubbery response to strain, therefore requiring more stress to extend the same length. This is an extremely useful property that allows the use of less material to achieve the same force in a given product. Elastic properties are also modified, exhibiting increasing modulus with increasing elongation, and there is a reduced occurrence of the rubbery plateau region where large increases in elongation are required to procure an increase in stress. Another surprising property is reduced coefficient of friction while retaining elastomeric properties. This is important for applications where a soft material is desired without a high friction surface. Still another surprising property is increased tear strength.

[0011] The controlled distribution copolymers of the present invention offer additional advantages in their ability to be easily processed using equipment generally designed for processing thermoplastic polystyrene, which is one of the most widely known and used alkenyl arene polymers. Melt processing can be accomplished via extrusion or injection molding using either single screw or twin screw techniques that are common to the thermoplastics industry. Solution or spin casting techniques can also be used as appropriate. A particularly interesting application is in over molding where a composition containing the controlled distribution block copolymer and optionally other thermo-

plastic polymers and process aides are injection molded onto a substrate of a more rigid polymer to impart a softer feel or different frictional characteristics. The polymers of the present invention provide improved adhesion to polar polymers. Adhesion to very polar materials such as polyamides or polyurethanes may be further improved by functionalizing the polymer of the present invention, for example with maleic anhydride.

[0012] In yet another aspect of the present invention, the elastomeric article can be processed into the form of a film, sheet, multi layer laminate, coating, band, strip, profile, molding, foam, tape, fabric, thread, filament, ribbon, fiber, plurality of fibers, or fibrous web. Another particularly interesting application is thermoplastic films which retain the processability of styrenic block copolymers but exhibit a higher "elastic power" similar to spandex polyurethanes. As compounded with polyethylene or with a combination of tackifying resin and polyethylene, the controlled distribution copolymers of the present invention can meet these performance expectations. The resultant films show significant improvements in puncture resistance and strength, and reduced viscosity, when compared with common styrene/ethylene-butylene block copolymers. The same controlled distribution styrene/butadiene (25/75 wt/wt) copolymer can also be formulated in a film compound with oil and polystyrene, wherein it exhibits higher strength and improved energy recovery and transparency in comparison with a control formulation based on a styrene/ethylene-butylene/styrene block copolymer. Molding applications formulated using oil and polypropylene have a reduced viscosity and coefficient of friction, and may be used in applications such as cap seals. It should also be possible to produce such cap seals without using undesirable slip agents.

[0013] Finally, the copolymers of the present invention can be compounded with other components not adversely affecting the copolymer properties. Exemplary materials that could be used as additional components would include, without limitation, pigments, antioxidants, stabilizers, surfactants, waxes, and flow promoters. The polymers of the present invention are useful in a wide variety of applications including, for example, molded and extruded goods such as toys, grips, handles, shoe soles, tubing, sporting goods, sealants, gaskets, and oil gels. The compositions also find use as rubber toughening agents for polyolefins, polyvinyl chloride, polystyrene, polyamide, polyurethane, polyester, polycarbonate and epoxy resins. The polymers of the present invention are also useful in alloys and blends, and as compatibilizers for a variety of polymers and other materials. Improved elasticity when compared with conventional styrenic block copolymers makes these copolymers particularly useful for adhesives, including both pressure-sensitive and hot-melt adhesives.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The key component of the present invention is the novel block copolymer containing monoalkenyl arene end blocks and a unique midblock of a monoalkenyl arene and a conjugated diene. Surprisingly, the combination of (1) a unique order for the monomer addition and (2) the use of diethyl ether or other ethers as a component of the solvent (which will be referred to as "randomizing agents", in keeping with the common usage of the term) results in a

certain marked uniformity of the distribution of the two monomers (herein termed a "controlled distribution" polymerization, i.e., a polymerization resulting in a "controlled distribution" structure), and also results in the presence of certain mono alkenyl arene rich regions and certain conjugated diene rich regions in the polymer block. For purposes hereof, "controlled distribution" is defined as referring to a molecular structure lacking well-defined blocks of either monomer, with "runs" of any given single monomer attaining a preferred maximum number average of about 20 units, as shown by either the presence of only a single T_g, intermediate between the T_g's of either monomer alone, when analyzed using differential scanning calorimetry ("DSC") (thermal) methods or via mechanical methods, or as shown via proton nuclear magnetic resonance ("H-NMR") methods. This controlled distribution structure is very important in maintaining the rubbery properties of the polymer with a single, narrow T_g, because the controlled distribution structure ensures that there is virtually no phase separation of the two monomers, i.e., in contrast with block copolymers in which the monomers actually remain as separate "microphases", with distinct T_g's, but are actually chemically bonded together which produces much more plastic physical properties. The presence of the arene monomer in the rubber segment allows preferential interactions that improve tensile and tear strength as well as adhesion to styrene containing polymers. The controlled distribution structure assures that only one T_g is present and that, therefore, the thermal performance of the resulting copolymer is predictable and, in fact, predeterminable. Furthermore, when a copolymer having such a controlled distribution structure is then used as one block in a di-block, tri-block or multi-block copolymer, it provides the properties of a rubbery block with the adhesion characteristics of a more polar block. Modification of certain other properties is also achievable.

[0015] It is also an important aspect of the present invention that the subject copolymer block also has three distinct regions—conjugated diene rich regions on the end of the block and adjacent to the A blocks and a mono alkenyl arene rich region not adjacent to the A block and near the middle or center of the block. What is desired is a mono alkenyl arene/conjugated diene controlled distribution copolymer block, wherein the proportion of mono alkenyl arene units increases gradually to a maximum near the middle or center of the block and then decreases gradually until the polymer block is fully polymerized. For sequentially prepared block copolymers A-B-A, the B block will have terminal regions rich in conjugated diene units, and a center region that is rich in mono alkenyl arene units. When the block copolymer is prepared via a coupling route, it will have a structure (A-B)_nX. In that case each B block will have at least one region adjacent to the A block that is rich in conjugated diene units. The other end not adjacent to the A block may or may not be rich in conjugated diene units. The remainder of the block will be therefore rich in mono alkenyl arene units.

[0016] Another important aspect of the present invention is to control the microstructure or vinyl content of the conjugated diene in the controlled distribution copolymer block. The term "vinyl content" refers to the fact that a conjugated diene is polymerized via 1,2-addition (in the case of butadiene—it would be 3,4-addition in the case of isoprene). Although a pure "vinyl" group is formed only in the case of 1,2-addition polymerization of 1,3-butadiene, the

effects of 3,4-addition polymerization of isoprene (and similar addition for other conjugated dienes) on the final properties of the block copolymer will be similar. The term "vinyl" refers to the presence of a pendant vinyl group on the polymer chain. When referring to the use of butadiene as the conjugated diene, it is preferred that about 20 to about 80 mol percent of the condensed butadiene units in the copolymer block have 1,2 vinyl configuration. Preferably about 30 to about 70 mol percent of the condensed butadiene units should have 1,2 configuration. This is effectively controlled by varying the relative amount of the randomization agent. As will be appreciated, the randomization agent serves two purposes—it creates the controlled distribution of the mono alkenyl arene and conjugated diene, and also controls the microstructure of the conjugated diene. Suitable ratios of randomization agent to lithium are disclosed and taught in U.S. Pat. Re No. 27,145.

[0017] Regarding the monomers used in preparing the novel controlled distribution copolymers of the present invention, the alkenyl arene can be selected from styrene, alpha-methylstyrene, para-methylstyrene, vinylnaphthalene, and para-butyl styrene, including mixtures thereof. Of these, styrene is most preferred and is commercially available, and relatively inexpensive, from a variety of manufacturers. The conjugated dienes for use herein are 1,3-butadiene and substituted butadienes such as isoprene, piperylene, 2,3-dimethyl-1,3-butadiene, and 1-phenyl-1,3-butadiene, or mixtures thereof. Of these, 1,3-butadiene is most preferred.

[0018] As discussed above, the controlled distribution polymer block has diene rich region(s) adjacent to the A block and an arene rich region not adjacent to the A block, and typically near the center of the block. Typically the region adjacent to the A block comprises the first 15 to 25% of the block and comprises the diene rich region(s), with the remainder considered to be arene rich. The term "diene rich" means that the region has a measurably higher ratio of diene to arene than the arene rich region. Another way to express this is the proportion of mono alkenyl arene units increases gradually along the polymer chain to a maximum near the middle or center of the block (if we are describing an ABA structure) and then decreases gradually until the polymer block is fully polymerized. For the controlled distribution block the weight ratio of conjugated diene to mono alkenyl arene is between about 5:1 and about 1:2, preferably between about 3:1 and about 1:1.

[0019] A particular feature of the present invention is that the resultant copolymer is relatively uniform in its distribution of the two monomers within a polymer chain, thus offering the improvements in T_g and property modification suggested by the identity of the starting monomers. A proton (hydrogen) nuclear magnetic resonance (H-NMR) procedure may preferably be used to assay for this advantageous controlled distribution, using techniques known to those skilled in the art. Alternatively, a DSC method may be used as an assay, determining the controlled structure of the polymerization by confirming the presence of a desired single T_g as is characteristic of a controlled distribution copolymer.

[0020] The potential for blockiness can also be inferred from measurement of the UV-visible absorbance in a wavelength range suitable for the detection of polystyryllithium end groups during the polymerization of the B block. A

sharp and substantial increase in this value is indicative of a substantial increase in polystyryllithium chain ends. In this process, this will only occur if the conjugated diene concentration drops below the critical level to maintain controlled distribution polymerization. Any styrene monomer that is present at this point will add in a blocky fashion. The term "styrene blockiness" is defined to be the proportion of S units in the polymer having two S nearest neighbors on the polymer chain. Expressed thus, Polymer-Bd-S-(S)_n-S-Bd-Polymer, where n greater than zero is defined to be blocky styrene. For example, if n equals 8 in the example above, then the blockiness index would be 80%.

[0021] As used herein, "thermoplastic block copolymer" is defined as a block copolymer having at least a first block of a mono alkenyl arene, such as styrene and a second block of a controlled distribution copolymer of diene and mono alkenyl arene. The method to prepare this thermoplastic block copolymer is via any of the methods generally known for block polymerizations. The present invention includes as an embodiment a thermoplastic copolymer composition, which may be either a di-block, tri-block copolymer or multi-block composition. In the case of the di-block copolymer composition, one block is the alkenyl arene-based homopolymer block and polymerized therewith is a second block of a controlled distribution copolymer of diene and alkenyl arene. In the case of the tri-block composition, it comprises, as end-blocks the glassy alkenyl arene-based homopolymer and as a mid-block the controlled distribution copolymer of diene and alkenyl arene. Where a tri-block copolymer composition is prepared, the controlled distribution diene/alkenyl arene copolymer can be herein designated as "B" and the alkenyl arene-based homopolymer designated as "A".

[0022] The A-B-A, tri-block compositions can be made by either sequential polymerization or coupling. In the sequential solution polymerization technique, the mono alkenyl arene is first introduced to produce the relatively hard aromatic block, followed by introduction of the controlled distribution diene/alkenyl arene mixture to form the mid block, and then followed by introduction of the mono alkenyl arene to form the terminal block. In addition to the linear, A-B-A configuration, the blocks can be structured to form a radial (branched) polymer, (A-B)_nX, or both types of structures can be combined in a mixture. Some A-B diblock polymer can be present but preferably at least about 70 weight percent of the block copolymer is A-B-A or radial (or otherwise branched so as to have 2 or more terminal resinous blocks per molecule) so as to impart strength.

[0023] It is also important to control the molecular weight of the various blocks. For an AB diblock, desired block weights are 3,000 to about 60,000 for the mono alkenyl arene A block, and 30,000 to about 300,000 for the controlled distribution conjugated diene/mono alkenyl arene B block. Preferred ranges are 5000 to 45,000 for the A block and 50,000 to about 250,000 for the B block. For the triblock, which may be a sequential ABA or coupled (AB)₂X block copolymer, the A blocks should be 3,000 to about 60,000, preferably 5000 to about 45,000, while the B block for the sequential block should be about 30,000 to about 300,000, and the B blocks (two) for the coupled polymer half that amount. The total average molecular weight for the triblock copolymer should be from about 40,000 to about 400,000, and for the radial copolymer from about 60,000 to

about 600,000. These molecular weights are most accurately determined by light scattering measurements.

[0024] An important feature of the thermoplastic elastomeric di-block and tri-block polymers of the present invention, including one or more controlled distribution diene/alkenyl arene copolymer blocks and one or more mono alkenyl arene blocks, is that they have at least two Tg's, the lower being the combined Tg of the controlled distribution copolymer block which is an intermediate of its constituent monomers' Tg's. Such Tg is preferably at least about -60 degrees C., more preferably from about -40 degrees C. to about zero degrees C., and most preferably from about -40 degrees C. to about -10 degrees C. The second Tg, that of the mono alkenyl arene "glassy" block, is preferably more than about 80 degrees C., more preferably from about 80 degrees C. to about 105 degrees C. The presence of the two Tg's, illustrative of the microphase separation of the blocks, contributes to the notable elasticity and strength of the material in a wide variety of applications, and its ease of processing and desirable melt-flow characteristics.

[0025] The block copolymer is selectively hydrogenated. Hydrogenation can be carried out via any of the several hydrogenation or selective hydrogenation processes known in the prior art. For example, such hydrogenation has been accomplished using methods such as those taught in, for example, U.S. Pat. Nos. 3,494,942; 3,634,594; 3,670,054; 3,700,633; and Re. No. 27,145. Hydrogenation can be carried out under such conditions that at least about 90 percent of the conjugated diene double bonds have been reduced, and between zero and 10 percent of the arene double bonds have been reduced. Preferred ranges are at least about 95 percent of the conjugated diene double bonds reduced, and more preferably about 98 percent of the conjugated diene double bonds are reduced. Alternatively, it is possible to hydrogenate the polymer such that aromatic unsaturation is also reduced beyond the 10 percent level mentioned above. In that case, the double bonds of both the conjugated diene and arene may be reduced by 90 percent or more.

[0026] In an alternative, the block copolymer of the present invention may be functionalized in a number of ways. One way is by treatment with an unsaturated monomer having one or more functional groups or their derivatives, such as carboxylic acid groups and their salts, anhydrides, esters, imide groups, amide groups, and acid chlorides. The preferred monomers to be grafted onto the block copolymers are maleic anhydride, maleic acid, fumaric acid, and their derivatives. A further description of functionalizing such block copolymers can be found in Gergen et al, U.S. Pat. No. 4,578,429 and in U.S. Pat. No. 5,506,299. In another manner the selectively hydrogenated block copolymer of the present invention may be functionalized by grafting silicon or boron containing compounds to the polymer as taught in U.S. Pat. No. 4,882,384. In still another manner, the block copolymer of the present invention may be contacted with an alkoxy-silane compound to form silane-modified block copolymer. In yet another manner, the block copolymer of the present invention may be functionalized by grafting at least one ethylene oxide molecule to the polymer as taught in U.S. Pat. No. 4,898,914, or by reacting the polymer with carbon dioxide as taught in U.S. pat. No. 4,970,265. Still further, the block copolymers of the present invention may be metallated as taught in U.S.

Pat. Nos. 5,206,300 and 5,276,101, wherein the polymer is contacted with an alkali metal alkyl, such as a lithium alkyl. And still further, the block copolymers of the present invention may be functionalized by grafting sulfonic groups to the polymer as taught in U.S. Pat. No. 5,516,831.

[0027] One of the surprising compositions of the present invention is the combination of the hydrogenated block copolymer and a polymer extending oil. While in the absence of oil, these polymers exhibit a stiffer elastomeric behavior than a traditional triblock polymer, in the presence of oil, they exhibit a softer elastomeric behavior. Especially preferred are the types of oil that are compatible with the elastomeric segment of the block copolymer. While oils of higher aromatics content are satisfactory, those petroleum-based white oils having low volatility and less than 50% aromatic content are preferred. The oils should additionally have low volatility, preferable having an initial boiling point above about 500° F. The amount of oil employed varies from about 0 to about 300 parts by weight per hundred parts by weight rubber, or block copolymer, preferably about 20 to about 150 parts by weight.

[0028] The block copolymers of the present invention may be blended with a large variety of other polymers, including olefin polymers, styrene polymers, tackifying resins, and engineering thermoplastic resins.

[0029] Olefin polymers include, for example, ethylene homopolymers, ethylene/alpha-olefin copolymers, propylene homopolymers, propylene/alpha-olefin copolymers, high impact polypropylene, butylene homopolymers, butylene/alpha olefin copolymers, and other alpha olefin copolymers or interpolymers. Representative polyolefins include, for example, but are not limited to, substantially linear ethylene polymers, homogeneously branched linear ethylene polymers, heterogeneously branched linear ethylene polymers, including linear low density polyethylene (LLDPE), ultra or very low density polyethylene (ULDPE or VLDPE), medium density polyethylene (MDPE), high density polyethylene (HDPE) and high pressure low density polyethylene (LDPE). Other polymers included hereunder are ethylene/acrylic acid (EEA) copolymers, ethylene/methacrylic acid (EMAA) ionomers, ethylene/vinyl acetate (EVA) copolymers, ethylene/vinyl alcohol (EVOH) copolymers, ethylene/cyclic olefin copolymers, polypropylene homopolymers and copolymers, propylene/styrene copolymers, ethylene/propylene copolymers, polybutylene, ethylene carbon monoxide interpolymers (for example, ethylene/carbon monoxide (ECO) copolymer, ethylene/acrylic acid/carbon monoxide terpolymer and the like. Still other polymers included hereunder are polyvinyl chloride (PVC) and blends of PVC with other materials.

[0030] Styrene polymers include, for example, crystal polystyrene, high impact polystyrene, medium impact polystyrene, styrene/acrylonitrile copolymers, styrene/acrylonitrile/butadiene (ABS) polymers, syndiotactic polystyrene and styrene/olefin interpolymers. Representative styrene/olefin interpolymers are substantially random ethylene/styrene interpolymers, preferably containing at least 20, more preferably equal to or greater than 25 weight percent interpolymerized styrene monomer.

[0031] For the purposes of the specification and claims, the term "engineering thermoplastic resin" encompasses the various polymers found in the classes listed in Table A

below, and further defined in U.S. Pat. No. 4,107,131, the disclosure of which is hereby incorporated by reference.

TABLE A

1. Thermoplastic Polyester
2. Thermoplastic Polyurethane
3. Poly(aryl ether) and Poly(aryl sulfone)
4. Polycarbonate
5. Acetal resin
6. Polyamide
7. Halogenated thermoplastic
8. Nitrile barrier resin
9. Poly(methyl methacrylate)

[0032] Tackifying resins include polystyrene block compatible resins and midblock compatible resins. The polystyrene block compatible resin may be selected from the group of coumarone-indene resin, polyindene resin, poly(methyl indene) resin, polystyrene resin, vinyltoluene-alpha-methylstyrene resin, alpha-methylstyrene resin and polyphenylene ether, in particular poly(2,6-dimethyl-1,4-phenylene ether). Such resins are e.g. sold under the trademarks "HERCURES", "ENDEX", "KRISTALEX", "NEVCHEM" and "PICCOTEX". Resins compatible with the hydrogenated (mid) block may be selected from the group consisting of compatible C₈ hydrocarbon resins, hydrogenated C₅ hydrocarbon resins, styrenated C₅ resins, C₅/C₉ resins, styrenated terpene resins, fully hydrogenated or partially hydrogenated C₆ hydrocarbon resins, rosins esters, rosins derivatives and mixtures thereof. These resins are e.g. sold under the trademarks "REGALITE", "REGALREZ", "ESCOREZ" and "ARKON". The resin employed will typically have a viscosity at 350° F., of no more than 300 centipoise.

[0033] The polymer blends of the present invention may be compounded further with other polymers, oils, fillers, reinforcements, antioxidants, stabilizers, fire retardants, antiblocking agents, lubricants and other rubber and plastic compounding ingredients without departing from the scope of this invention.

[0034] Examples of various fillers that can be employed are found in the 1971-1972 Modern Plastics Encyclopedia, pages 240-247. A reinforcement may be defined simply as the material that is added to a resinous matrix to improve the strength of the polymer. Most of these reinforcing materials are inorganic or organic products of high molecular weight. Various examples include glass fibers, asbestos, boron fibers, carbon and graphite fibers, whiskers, quartz and silica fibers, ceramic fibers, metal fibers, natural organic fibers, and synthetic organic fibers. Especially preferred are reinforced polymer blends of the instant invention containing about 2 to about 80 percent by weight glass fibers, based on the total weight of the resulting reinforced blend. Coupling agents, such as various silanes, may be employed in the preparation of the reinforced blends.

[0035] Regarding the relative amounts of the various ingredients, this will depend in part upon the particular end use and on the particular block copolymer that is selected for the particular end use. Table B below shows some notional compositions expressed in percent weight, which are included in the present invention:

TABLE B

Applications, Compositions and Ranges		
Application	Ingredients	Composition % w.
Films, Molding, Alloys	Polymer	1-99%
	Ethylene copolymers: EVA, Ethylene/styrene	99-1%
Personal Hygiene Films and Fibers	Polymer	0-75%
	PE	0-30%
	PP	0-30%
	Tackifying Resin	5-30%
Personal Hygiene Films and Fibers	End Block Resin	5-20%
	Polymer	50-90%
Personal Hygiene Films and Fibers	PE	5-30%
	Tackifying Resin	0-40%
Injection Molded articles	Polymer	45-85%
	PS	10-25%
	Oil	5-30%
Injection molded/extrusion	Polymer	25-85%
	Polyolefin	5-50%
	Oil	10-50%
	Polymer	55-90%
Cap Seals	PPO	10-50%
	PS	10-50%
	Engineering Plastic	10-50%
	Oil	0-50%
	Polymer	25-60%
Engineering Thermoplastic toughening	Oil	25-50%
	PP	10-30%
	Filler	0-25%
	Lubricant	0 to 3%
Asphalt Modification	Polymer or Maleated Polymer Engineering thermoplastic, e.g. Nylon 6,6, TPU	5-30%
	Polymer Engineering thermoplastic,	70-95%
Dipped Goods	Polymer	2-15%
	Asphalt	85-98%
Polymer Modification	Polymer	60-100%
	Plasticizer, oil	0-40%
Polymer Modification	Polymer	5-30%
	ABS, PS, HIPS	70-95%

[0036] The polymer of the present invention may be used in a large number of applications, either as a neat polymer or in a compound. The following various end uses and/or processes are meant to be illustrative, and not limiting to the present invention:

- [0037] Polymer modification applications
- [0038] Injection molding of toys, medical devices
- [0039] Extruding films, tubing, profiles
- [0040] Over molding applications for personal care, grips, soft touch applications, for automotive parts, such as airbags, steering wheels, etc
- [0041] Dipped goods, such as gloves
- [0042] Thermoset applications, such as in sheet molding compounds or bulk molding compounds for trays
- [0043] Roto molding for toys and other articles
- [0044] Slush molding of automotive skins
- [0045] Thermal spraying for coatings
- [0046] Blown film for medical devices
- [0047] Blow molding for automotive/industrial parts
- [0048] Asphalt modification

[0049] Films and fibers for personal hygiene applications

EXAMPLES

[0050] The following examples are provided to illustrate the present invention. The examples are not intended to limit the scope of the present invention and they should not be so interpreted. Amounts are in weight parts or weight percentages unless otherwise indicated.

Example 1

[0051] Various controlled distribution block copolymers of the present invention were prepared according to the process disclosed in copending patent application Serial No. 60/355,210 referenced above. All polymers were selectively hydrogenated linear ABA block copolymers where the A blocks were polystyrene blocks and the B block prior to hydrogenation was a styrene butadiene controlled distribution block having terminal regions that are rich in butadiene units and a center region that was rich in styrene units. The various polymers are shown in Table 1 below. These polymers were then used in the various applications described in the other Examples. Step I MW is the molecular weight of the first A block, Step II MW is the molecular weight of the AB blocks and Step III MW is the molecular weight of the ABA blocks. The polymers were hydrogenated such that greater than about 95% of the diene double bonds have been reduced.

TABLE 1

Controlled Distribution Polymers							
Polymer Number	Step I MW(k)	Step II MW(k)	Step III MW(k)	% Styrene in Step II	Styrene Blockiness	1,2-BD (%)	PSC (%)
1	10.5	106.3	118.6	12.6	65.6	34.5	29.75
2	10.5	98.6	110.8	12.5	65	38	29.53
3	9.2	90.6	99.9	24.9	50	35.8	40.12
4	9.7	92.3	102.8	37.6	43	35.3	48.3
5	13.9	140.8	158.2	37.6	43	35	50.15
6	10.6	101.4	112.6	25.1	49	36.2	40
7	10.3	99.3	111.9	25.2	51	37.1	40.31

TABLE 1-continued

Controlled Distribution Polymers							
Polymer Number	Step I MW(k)	Step II MW(k)	Step III MW(k)	% Styrene in Step II	Styrene Blockiness	1,2-BD (%)	PSC (%)
8	8.2	91.2	98.9	25.1	43.9	37	37
9	32	162	194.8	37.8	58	34.3	58.1
10	29.4	159.4	189.2	50	49	33.6	65.8
11	24	120.9	145.8	40	59	33.6	58.9
12	30.3	164.3	196.8	24	65	35.4	48.2
13	29.9	163.3	195.9	38	57	34.5	58.2
14	8.4	88.5	95.8	25	46	36.1	38.3
15	9	86.8	95.5	25	48	35.9	39.3

where "MW(k)" = molecular weight in thousands, "Styrene Blockiness" = the blockiness of all of the styrene units where "MW(k)" = molecular weight in thousands, "Styrene Blockiness" = the blockiness of all of the styrene units polymer and "PSC(%)" = wt % of styrene in the final polymer

Example 2

[0052] In this example three different block copolymers were compounded with varying amounts of an ethylene vinyl acetate copolymer (EVA) and the compounds were extruded into films. One of the block copolymers was a selectively hydrogenated SBS block copolymer (KRATON G 1652) and the other two block copolymers were controlled distribution block copolymers #14 and #15. The relative amounts and test results are shown in Table 2 below. As shown in Table 2, adding 20% KRATON polymer to EVA increases impact resistance, decreases hysteresis set and increases recoverable energy in films. The improved impact resistance is important to reduce failure of a film from an external force, such as dropping. The increased recoverable energy and decreased hysteresis set is desirable for improved elasticity of a film. The advantage of polymers 14 and 15 over G11652 shows in the increased isotropic behavior seen in the Elmendorf Tear data. Isotropic tear is advantageous in film applications where straight tear along a seam is necessary, such as food wrap or wrapping for sterile surgical kits.

TABLE 2

Compound	Unit	Direction	EVA	2-1	2-2	2-3	2-4	2-5
Block Copolymer Type				# 14	# 15	G-1652	# 15	G-1652
Block Copolymer Amount %/wt	0%	20%	20%	20%	80%	80%		
EVA Copolymer Amount %/wt	100%	80%	80%	80%	20%	20%		
Property								
Tensile Properties								
Tensile	psi	MD	4727	3855	3846	4072	3344	6392
		TD	4979	3752	3933	4023	3102	6889
Ultimate elongation	%	MD	655	601	603	630	698	839
		TD	885	782	781	758	812	765
100% modulus	psi	MD	737	570	663	574	404	385
		TD	532	416	484	509	299	535
300% modulus	psi	MD	1423	1055	1202	1044	683	638
		TD	797	622	724	763	439	1003
Elmendorf Tear	g/mil	MD	81.9	24.9	26.9	31.7	16.1	80.6
		TD	128.3	22.2	25.8	51.4	47.2	130.8
Impact resistance	in-lbf/mls		4.7	no failure				

TABLE 2-continued

Compound	Unit	Direction	EVA	2-1	2-2	2-3	2-4	2-5
<u>Cyclic hysteresis to 100% extension</u>								
Stress at 100% extension	psi	MD	475	466	492	511	338	444
		TD	358	387	379	399	254	277
Recoverable energy after 1 cycle	%	MD	33.4	41.6	42.8	43.3	64.1	48.1
		TD	32.6	44.3	42.3	41.6	68.3	63
Hysteresis set @ 1 cycle	%	MD	29.3	18.5	17	15	11	11
		TD	36.1	16.4	18.5	19.1	11.7	9.9
<u>Cyclic hysteresis to 300% extension</u>								
Stress at 300% extension	psi	MD	958	941	818	987	504	667
		TD	539	554	458	568	384	462
Recoverable energy after 1 cycle	%	MD	13.5	19.3	18.3	18.6	50.7	40.1
		TD	16	23.5	21.8	22.3	57.8	51.5
Hysteresis set @ 1 cycle	%	MD	190	133	141	141	37	32.7
		TD	186	125	139	134	34.6	27.4

Example 3

[0053] In this example three different block copolymers were compounded with varying amounts of a propylene homopolymer (Valtec HH442H PP), a low-density polyethylene (Petrothene NA601-04) and two different resins (Regalite R-1125 and Kristalex F-100). Regalite R-1125 is a midblock-compatible resin, and Kristalex F-100 is a styrene containing end block resin. The block copolymers were controlled distribution block copolymers #14 and #15, and a selectively hydrogenated SBS block copolymer (KRA-TON G 1657).

[0054] The compounds were formed into fibers and tested. Table 3 below shows the compounds used and the test results. As shown in Table 3 Polymers 14 and 15 exhibit lower permanent set and retain their properties better under stress, as shown by the stress-decay values, than normal SEBS triblock copolymers. This is true for simple blends with LDPE and PP (examples 3-1 to 3-6) and in more complex formulations with resins (examples 3-7 and 3-8).

TABLE 3A

Formulation, % weight	Compound Number					
	3-1	3-2	3-3	3-4	3-5	3-6
Kraton G-1657	75			75		
Polymer #14		75			75	
Polymer #15			75			75
Valtec HH442H PP				25	25	25
Petrothene NA601-04 LDPE	25	25	25			
MFR (230° C./2.16 kg)	29	10.2	9.5	22	7.6	7.3
<u>Fiber Data</u>						
50% modulus, MPa	1.5	1.70	1.77	3.5	2.32	4.10
100% modulus, MPa	1.8	2.08	2.14	3.8	3.19	5.10
50% modulus at 40° C., MPa	1.33	1.43	1.49	2	2.16	3.66
50% modulus at 40° C. after 2 hrs Mpa	0.72	0.83	0.92	0.51	1.10	1.69

TABLE 3A-continued

Formulation, % weight	Compound Number					
	3-1	3-2	3-3	3-4	3-5	3-6
Stress-decay, (%)	46	42	38	75	49	54
Permanent set (%)	12	10	11	16	11.5	21

[0055]

TABLE 3B

Formulation, % weight	Compound Number	
	3-7	3-8
<u>Kraton G-1657</u>		
Polymer #14	65	
Polymer #15		65
Valtec HH442H PP	15	15
Petrothene NA601-04 LDPE		
Regalite R-1125 resin	10	10
Kristalex F-100 resin	10	10
MFR (230° C./2.16 kg)	12.4	11.5
<u>Fiber Data</u>		
50% modulus, Mpa	1.39	1.68
100% modulus, Mpa	1.85	2.23
50% modulus at 40° C., MPa	1.30	1.43
50% modulus at 40° C. after 2 hours, Mpa	0.79	0.89
Stress-decay (%)	39	38
Permanent set (%)	7.5	8.5

Example 4

[0056] In this example three different block copolymers were compounded with mineral oil (Drakeol 34 mineral oil) and crystal polystyrene (EA3000). The block copolymers were controlled distribution block copolymers #3 and #4,

and a selectively hydrogenated SBS block copolymer (GRP 6926). All three of the block copolymers had approximately the same molecular weights for the end blocks and mid block. The various components were compounded and then formed into films, and tested. The amounts are expressed in percent weight. The various formulations and test results are shown below in Table 4. As shown in Table 4 the modulus and hysteresis values for the comparison example 4-1 vary by almost a factor of two between the machine direction, MD, and transverse direction, TD. This indicates a high degree of orientation during film casting resulting in film with highly anisotropic properties and dimensional instability. By comparison examples 4-2 and 4-3 show a much smaller difference in Modulus, recoverable energy and permanent set at all elongations between the MD and TD directions. The values of recoverable energy and permanent set in the MD for examples 4-2 and 4-3 are surprisingly low, indicating a much more elastic film than a traditional SEBS triblock copolymer.

TABLE 4A

Formulation	Compound Number		
	4-1 %	4-2 %	4-3 %
GRP 6926 SEBS	58.4		
Polymer #3		58.83	
Polymer #4			58.83
GI650			
Drakeol 34 mineral oil	23.66	23.81	23.81
EA3000 Polystyrene	17.94	17.35	17.35
Tensile			
Max. Stress, psi TD	3716	3503	3580
Max. Stress, psi MD	3151	3831	3196
Ultimate Elongation, % TD	931	790	708
Ultimate Elongation, % MD	829	756	656
50% Modulus, psi TD	118	103	96
50% Modulus, psi MD	271	119	104
100% Modulus, psi TD	148	138	129
100% Modulus, psi MD	341	165	148
200% Modulus, psi TD	210	210	200
200% Modulus, psi MD	480	271	257
300% Modulus, psi TD	291	327	324
300% Modulus, psi MD	630	447	458
500% Modulus, psi TD	593	913	1030
500% Modulus, psi MD	1080	1270	1393
100% TD Hysteresis (75 F) (10 in/min)			
Stress @ 100% extension, psi	136.4	212.5	144.8
Recoverable energy @ cycle 1, %	79.4	89.1	88.6
Hysteresis set @ cycle 1, %	4.9	4.7	4.9
100% MD Hysteresis (75 F) (10 in/min)			
Stress @ 100% extension, psi	379.5	144.7	175.5
Recoverable energy @ cycle 1, %	46.3	86.4	85.5
Hysteresis set @ cycle 1, %	8.7	4.9	4.8

[0057]

TABLE 4B

	Compound Number		
	4-1 %	4-2 %	4-3 %
200% TD Hysteresis (75 F) (10 in/min)			
Stress @ 200% extension, psi	231.7	225.2	166.9
Recoverable energy @ cycle 1, %	73.3	88.9	87.3
Hysteresis set @ cycle 1, %	8.6	7.4	8.9
200% MD Hysteresis (75 F) (10 in/min)			
Stress @ 200% extension, psi	610.8	301.5	223.7
Recoverable energy @ cycle 1, %	40.3	82.8	81.3
Hysteresis set @ cycle 1, %	16.4	7.5	8.7
300% TD Hysteresis (75 F) (10 in/min)			
Stress @ 200% extension, psi	278.6	298.3	347.2
Recoverable energy @ cycle 1, %	68.2	87.3	85
Hysteresis set @ cycle 1, %	13.2	9.1	11.1
300% MD Hysteresis (75 F) (10 in/min)			
Stress @ 200% extension, psi	609.6	436.7	541.7
Recoverable energy @ cycle 1, %	36.5	78	75.2
Hysteresis set @ cycle 1, %	25.4	9.6	11.3
Stress Relaxation @ 150%, TD (20 in/min) @ 100 F for 60 min			
Max Stress, psi	196.4	152.8	140.62
Stress @ 1 hr, psi	152.7	128	115.2
% Relaxation, %	22	16.2	18.1
Stress Relaxation @ 150%, MD (20 in/min) @ 100 F for 60 min.			
Max Stress, psi	395	175	183
Stress @ 1 hr, psi	269	142	122
% Relaxation, %	32	18.9	33.44

Example 5

[0058] In this example two different controlled distribution block copolymers (#13 and #3) were compounded with two different ethylene styrene interpolymers, which interpolymers were made with a metallocene catalyst and had a random structure. These interpolymers were Dow 2900TE having a styrene content of 34.2% w and Dow 2901 TE, having a styrene content of 72.7% w. The various components were mixed in a Brabender mixer and then formed into compression-molded films. The various formulations and results are shown below in Table 5. As shown in Table 5 the addition of 2900TE to Polymer #3 increases strength across the complete composition range from 90/10 to 10/90 while retaining high elongation. Surprisingly, Examples 5-2 through 5-4 are transparent with excellent hysteresis recovery and low permanent set. The higher styrene content of 2901 TE produces opaque compounds (examples 5-8 through 5-13) that still retain high strength and elongation across the range. The addition of polymer #13 to 2900TE, examples 5-15 to 5-17, decreases permanent set and improves hysteresis recovery and elongation without loss of tensile strength. Examples 5-2 through 5-6 have the unexpected benefit of having higher tensile strength than the two polymers of which they are composed.

TABLE 5A

FORMULATION(% weight):	Molded Films						
	5-1	5-2	5-3	5-4	5-5	5-6	5-7
Polymer #13							
Polymer #3	100	90	80	50	30	20	10
2900 TE		10	20	50	70	80	90
2901 TE							
AO 330	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Properties:							
<u>Stress-Strain</u>							
Max. Stress, psi	4106.0	6118	6088	8014	6494	6647	5901
Ultimate Elongation, %	789	840	829	794	739	741	695
50% Modulus, psi	236	285	395	314	454	485	466
100% Modulus, psi	308	346	464	408	566	604	599
200% Modulus, psi	459	480	624	599	785	849	862
300% Modulus, psi	680	672	848	891	1159	1254	1302
500% Modulus, psi	1402	1501	1898	2192	2816	2793	3071
100% Hysteresis:							
Max. stress, psi	372.9	271.3	346.2	363.9	452	491.9	515.7
Perm. Set, %	7.5	7.4	8.6	9.7	10.3	10.3	10.4
1st Cycle Recovery, %	67.7	74	67.7	66.4	63.1	62.5	60.7
Load Stress 50% ext., psi	297	228	284	286	356	387	408
Unload Stress 50% ext., psi	197	168	187	177	204	218	221
Stress @ 50% Ext.2nd load, psi	214	186	215	222	265	287	298
Stress @ 50% Ext.2nd Unload, psi	190	163	180	170	195	208	210
2nd Cycle Recovery, %	90.5	89.7	87.2	82.3	80.4	79.8	78.6
300% Hysteresis:							
Max. stress, psi	500.4	533.6	537.6	711.8	864.3	914.4	968.2
Perm. Set, %	15.4	20.1	26.6	53.8	79.1	89.4	102
1st Cycle Recovery, %	69.4	65.1	58.8	43.7	34.8	32.7	29.9
Load Stress 50% ext., psi	215.4	234.3	240.4	290.7	379.7	404.6	429.8
Unload Stress 50% ext., psi	97.4	81.7	60.2	n/a	n/a	n/a	n/a
100% Cyc-1 Load Stress, psi	267.7	282.7	289.5	366.1	473.9	506.3	533.4
100% Stress Cyc-1 Unload, psi	161.6	152.6	129.9	78.8	39.8	22.2	n/a

[0059]

TABLE 5B

FORMULATION(% weight):	Molded Films					
	5-8	5-9	5-10	5-11	5-12	5-13
Polymer #13						
Polymer #3	90	80	50	30	20	10
2900 TE						
2901 TE	10	20	50	70	80	90
AO 330	0.2	0.2	0.2	0.2	0.2	0.2
Properties:						
<u>Stress-Strain</u>						
Max. Stress, psi	4721	5450	4089	4121	4581	4820
Ultimate Elongation, %	749	689	443	398	396	376
50% Modulus, psi	328	282	252	329	364	371
100% Modulus, psi	392	350	357	458	531	592
200% Modulus, psi	550	534	719	968	1218	1534
300% Modulus, psi	790	862	1748	2569	3056	3349
500% Modulus, psi	1842	2584	n/a	N/A	N/A	N/A
100% Hysteresis:						
Max. stress, psi	317.3	292.6	355.5	359	426.6	555.6
Perm. Set, %	11.4	15.2	24.7	31.8	33.3	40
1st Cycle Recovery, %	66.6	62.1	50.4	42.7	37.9	30
Load Stress 50% ext., psi	256	240	254	243	289	371
Unload Stress 50% ext., psi	168	144	115	83	81	60
Stress @50% Ext.2nd load, psi	196	186	223	222	247	281
Stress @50% Ext.2nd Unload, psi	160	135	100	59	54	31
2nd Cycle Recovery, %	85.5	79	57.8	46.1	43.1	38.5

TABLE 5B-continued

FORMULATION(% weight):	Molded Films					
	5-8	5-9	5-10	5-11	5-12	5-13
300% Hysteresis:						
Max. stress, psi	648.4	788.3	2073.7	2315.6	2849.1	2735.3
Perm. Set, %	26.4	32.9	53	69.2	78.2	95.2
1st Cycle Recovery, %	60.1	55.7	35.5	30.4	26.8	22.7
Load Stress 50% ext., psi	260.5	274	269.8	281.7	337.7	360.2
Unload Stress 50% ext., psi	71.1	53.4	n/a	n/a	n/a	n/a
100% Cyc-1 Load Stress, psi	321.6	330.7	366.7	398	487.2	528.5
100% Stress Cyc-1 Unload, psi	154.9	144	112.7	73.8	59.9	14.2

[0060]

TABLE 5C

FORMULATION(% weight):	Molded Films					
	5-14	5-15	5-16	5-17	5-18	5-19
Polymer #13	100	30	20	10		
Polymer #3						
2900 TE		70	80	90	100	
2901 TE						100
AO 330		0.2	0.2	0.2		
Properties:						
Stress-Strain						
Max. Stress, psi	5260.5	6232	6379	5487	5916	4209
Ultimate Elongation, %	714.5	722.5	703	675	662	302
50% Modulus, psi	497.5	495.5	522	534	438	372
100% Modulus, psi	543	607.5	649	659.5	582	626
200% Modulus, psi	772.5	851.5	916	927.5	876	1851
300% Modulus, psi	1170	1254	1379	1364	1344	n/a
500% Modulus, psi	2611	2727	3010	2872	2932	n/a
100% Hysteresis:						
Max. stress, psi	490.4	468.2	489	532.3	543.6	613.8
Perm. Set, %	20.4	15	14.1	14.5	13	40.9
1st Cycle Recovery, %	39.4	54.6	55.2	53.6	55.3	30.5
Load Stress 50% ext., psi	456	373	389	423	424	366
Unload Stress 50% ext., psi	162	178	187	195	201	54
Stress @ 50% Ext.2nd load, psi	263	265	280	298	295	278
Stress @ 50% Ext.2nd Unload, psi	152	167	178	186	191	29
2nd Cycle Recovery, %	67	73.7	73.8	73	75.1	39.3
300% Hysteresis:						
Max. stress, psi	921	933.1	943.8	1046.2	1013.2	*samples broke, exceeded limits
Perm. Set, %	42.3	93.5	102.2	108.3	113.6	
1st Cycle Recovery, %	38.9	30	29.5	28.3	28.3	
Load Stress 50% ext., psi	452.1	408	413.5	460.7	409.7	
Unload Stress 50% ext., psi	25.2	n/a	n/a	n/a	n/a	
100% Cyc-1 Load Stress, psi	487	500.1	511.1	569.1	526.3	
100% Stress Cyc-1 Unload, psi	119.5	13.9	6.5	n/a	n/a	

Example 6

[0061] In this example one controlled distribution block copolymer (#9) was compared against a selectively hydrogenated SBS block copolymer (KRATON G 1651) in various compounds with extending oil and polypropylene homopolymer. The various formulations and results are shown below in Table 6. As shown in Table 6, compositions made with polymer #9 have much improved melt flows compared with compositions made with G-1651. Surpris-

ingly, the tensile strengths of compositions made with polymer #9 are almost the same in the machine and transverse directions in the mold when compared to G-1651 compositions. This means that parts formed by injection molding or extrusion will fill the mold better, have much less tendency to warp when exposed to heat, and will have more uniform properties when Polymer #9 is substituted for G-1651. This stability means they will have opportunities for use in medical applications.

TABLE 6

		Compound #					
		6-1	6-2	6-3	6-4	6-5	6-6
		Polymer Type					
Formulation		#9	G-1651	#9	G-1651	#9	G-1651
Polymer	phr	100	100	100	100	100	100
PP Pm6100	phr	25	25	50	50	75	75
Oil	phr	90	90	140	140	90	90
<u>Properties</u>							
MFR 200° C./5 kg	g/10 min	5.6	0.1	120	26	30	7
Hardness Shore A	30 sec	43	55	53	61	82	85
Resilience	%	52	55	47	46	46	43
Din Abrasion	mm ³	285	110	244	95	146	65
<u>Tensile properties</u>							
Mod 300%	MD MPa	2.5	4	2.5	4	5.9	7
Mod 300%	PMD MPa	2.2	3	2.4	3	5.2	5
Tensile Strength	MD MPa	6.6	4	3	5	8.5	10
Tensile Strength	PMD MPa	8.1	13	2.9	12	9.6	21
Elongation at Break	MD %	700	330	450	510	520	500
Elongation at Break	PMD %	805	780	470	790	615	805
Trouser tear	MD kN/m	9.6	7	6.9	9	17.5	18
Trouser tear	PMD kN/m	8.9	8	7.8	10	23	21

Example 7

[0062] In this example two different controlled distribution block copolymers (#11 and #9) were compared against two different selectively hydrogenated SBS block copolymers (KRATON G 1651 and 1654) in oiled compounds. The extending oil used was Primol 352. To the oil and polymer were added various other components including polypropylene, poly(phenylene oxide) (Blendex HPP857), polysty-

rene, syndiotactic polystyrene (MA405), cyclic olefin copolymer (Topas 6017) and ABS (Terluran 967 K). The various formulations and results are shown below in Table 7. As shown in Table 7 compositions based on polymers #9 and 11 are more isotropic than the comparison polymer while maintaining a good balance of properties. They can also be blended with a variety of engineering thermoplastics to yield a good balance of isotropic properties.

TABLE 7A

	Compound									
	7-1	7-2	7-3	7-4	7-5	7-6	7-7	7-8	7-9	
Polymer #11	100	100	100	100	100		100			
Polymer #9						100				
G1651								100		
G1654									100	
Primol 352	80	80	80	80	80	110	110	110	110	
PP (MFR = 5.5)						45	45	45	45	
PPO (Blendex HPP857)	40									
PS 144C		40								
Syndiotactic PS (MA 405)			40							
COC (Topas 6017)				40						
ABS (Terluran 967 K)					40					
Presence of IPN	no	no	no	yes	no	yes	yes	yes	yes	
Hardness, Shore A	74	50	40	52	50	59	61	64	63	
30 sec										
<u>Compression set, %</u>										
70° C./24 hrs	65	73	84	82	83	54/56	56/65	42	48/50	
100° C./24 hrs	97	100	100	100	100	84	97	62	81	

[0063]

TABLE 7B

	Compound								
	7-1	7-2	7-3	7-4	7-5	7-6	7-7	7-8	7-9
Stress strain properties MD									
300% Modulus, MPa	4.9	5.3	4.7	3	4.8	3.3	3.8	3.9	4.2
Ts at break MPa	5.2	6.5	7.8	7.4	5.5	4.8	5.5	5.7	5.3
Elongation at break	350	400	470	650	550	560	580	570	460
Delamination	no	no	no	no	yes	no	no	no	no
PMD									
300% Modulus, MPa	5.3	2.9	3.1	2.2	3.2	2.7	2.9	2.7	3
Ts at break MPa	6.5	14.2	11	9.3	6.7	4.5	4.8	13.3	13
Elongation at break	445	740	670	750	750	650	640	900	900
Delamination	no	no	no	no	yes	no	no	no	no
Anisotropy (TS _{pmd} /TS _{md})	1.2	2.2	1.4	1.3	1.2	0.94	0.9	2.3	2.5
Angle Tear Strength, kN/m									
Md	nm	27	24	26	28	22	25	30	30
Delamination	—	no	minor	no	yes	no	no	no	no
Pmd	nm	37	32	26	32	22	25	35	35
Delamination	—	no	minor	no	yes	no	no	no	no

Example 8

[0064] In this example three different controlled distribution block copolymers (#3, #4 and #5) were compared against a selectively hydrogenated SBS block copolymer (KRATON G 1651) in formulations comprising polymer, polypropylene (PP 5A15H), extending oil (Drakeol 34) and silica. These formulations are intended for use as cap seals for screwed containers. The compounds mentioned in Table 8 were prepared by preblending the raw materials then mixing under heat and shear until a uniform blend was achieved. Blending viscosity for compounds with polymers 3, 4 and 5 was lower than for G1651 compound. Each compound was then molded under heat and pressure to make a plaque of uniform thickness. Samples from these plaques were tested on a mechanical properties instrument, the results being found in Table 8.

[0065] Polymers 3, 4 and 5 show isotropic behavior for mechanical properties, but G 1651 does not. Polymer 5 molecular weight is less than G 1651 by 50,000, yet exhibits

the same tensile and elongation properties. Modulus for polymers 3,4 and 5 are slightly higher than that of G 1651, indicating that the compound is slightly stiffer. Coefficient of friction shows that increasing the amount of styrene in the midblock lowers the surface friction of the molded part.

[0066] The advantages of compounds made with polymers 3, 4 and 5 include:

- [0067] 1. Lower blending viscosity results in easier mold processing
- [0068] 2. Isotropic behavior allows dimensional stability in molded parts
- [0069] 3. Increase in tensile, elongation and modulus allows for use of less polymer in compounds
- [0070] 4. Decrease in coefficient of friction allows for use in applications where low friction surfaces are desirable, such as bottle cap seals.

TABLE 8

Formulation (parts by weight)	Unit	Direction	Compound #			
			8-1	8-2	8-3	8-4
			Polymer Type			
			G-1651	#3	#4	#5
Polymer			100	100	100	100
Drakeol 34			100	100	100	100
PP5A15H			34	34	34	34
Silica			41	41	41	41
Property						
Tensile Properties						
Tensile	psi	MD	810	629	673	1378
		TD	1343	619	636	1440
Ultimate elongation	%	MD	616	646	686	858
		TD	872	740	599	883

TABLE 8-continued

Formulation (parts by weight)	Unit	Direction	Compound #			
			8-1	8-2	8-3	8-4
			Polymer Type			
			G-1651	#3	#4	#5
100% modulus	psi	MD	207	297	232	228
		TD	195	230	266	228
300% modulus	psi	MD	404	453	363	452
		TD	384	381	421	456
COF		Static	2.05	1.59	1.05	0.823
		Dynamic	2.03	1.15	1.15	0.698

Example 9

[0071] In this example two different controlled distribution block copolymers (#15 and #16) were compared with KRATON FG-1901 in blends with Nylon 6,6 (Zytel 101) at 15 and 20% by weight in a twin screw extruder. Polymer #16 was prepared by maleating Polymer #15 to a level of 1.7% weight bound maleic anhydride in a Bergstroff twin screw extruder. KRATON FG 1901 is an S-EB-S block copolymer that was maleated to a similar level of 1.7% weight. The blends were injection molded and the impact strength was measured using an Izod impact tester. Samples were taken both from the blind end of the mold and the gate end of the mold to minimize molding effects.

[0072] As shown in Table 9, the addition of maleic anhydride dramatically improves the ability of Polymer #15 to toughen Nylon 6,6. The greater toughness presented by the maleated Polymer #15 might allow less modifier to be used to achieve the same toughness compared to available materials.

TABLE 9

Formulation (% weight)	9-1	9-2	9-3	9-4	9-5
Polymer # 15	20				
Polymer # 16		15	20		
KRATON FG 1901				15	20
Nylon 6,6	80	85	80	85	80
	Notched Izod Impact Test (foot pounds per inch)				
Gate end	2.05	20.7	25.1	13.2	21.2
Blind end	2.08	23.6	25.9	13.5	23.1

Example 10

[0073] In this example we compared a controlled distribution copolymers (#14) with KRATON G 1650 in an experiment to prepare dipped articles. The method employed was as follows: first the polymer was dissolved in toluene. If needed, plasticizer was added to control viscosity. The solution was filtered through 100 mesh metal filter. Then a glass tube (diameter 25 mm, L=25 cm) was immersed in the solution. The glass tube was removed from the solution at an appropriate speed to obtain a homogeneous film on the tube. The solvent was allowed to evaporate. The typical evaporation time for toluene at 45-50° C. is 5 minutes. Next the glass tube was cooled to room temperature. The dipping sequence was repeated as needed. After the last dip, the solvent was allowed to evaporate completely

(1-2 hours at 45-50° C.). The tube was cooled down and the film removed carefully from the glass tube. Tensile Testing was conducted according to ISO 4074-9 after cutting circular test-samples from the samples.

[0074] As shown in Table 10, Polymer #14 exhibits an advantaged combination of tensile strength and set at break.

TABLE 10

	Sample ID				
	10-1	10-2	10-3	10-4	10-5
	Polymer				
	14	14	G1650	G1650	G1650
Concentration % w	13	10	15	15	15
Brookfield viscosity	250	150	375	370	365
Oil content phr	0	25	0	25	50
PS MW k	10	10	10	10	10
PSC eff. % w	20	16	30	24	20
Number of dips	2-3	3	2	2	2
Thickness micro-m	50	50	100	75	80
Stress 100% MPa	1.8	1.0	1.6	1.5	1.3
Stress 300% MPa	3.8	1.9	3.1	2.6	2.2
Elongation %	500	550	450	650	810
Force N	30	25	35	60	65
Tensile strength MPa	24	18	12	30	27
Set after break %	3	5	6	8	15

Example 11

[0075] In this example we compared two different controlled distribution block copolymers (#2 and #3) with KRATON G-1730, a selectively hydrogenated S-I-S-I tetra block copolymer in various compounds useful in personal hygiene articles. Some compounds only contained the controlled distribution polymer or G-1730 plus polyethylene (PE NA601), while other compounds also contained a resin (Regalrez 1126).

[0076] The first set of compounds (numbers 1 to 6) were prepared in the brabender mixing head on small scale. Following that larger amounts of the control formulation containing G-1730 and one other controlled distribution copolymer compound (compound #7 and 8) were compounded on a twin screw extruder. The pellets were then transformed into film on a cast film line. The properties of those films were measured in the machine (MD) and transverse (TD) directions. The examples shown in Table 11 reveal that the polymers of the present invention give much higher modulus values while retaining the other good prop-

erties of the control compound. Those higher modulus values are a result of the stiffer stretch of the inventive polymers and allow elastic laminate constructions having higher force or allow the same laminate to be made more efficiently with less elastomer. The films made form the present invention surprisingly have much greater tear strength than the control films.

TABLE 11A

	Compounds:					
	1	2	3	4	5	6
	Polymer					
	G-1730	#2	#3	G-1730	#2	#3
Polymer	68%	68%	68%	84.80%	84.80%	84.80%
Regalrez 1126	20%	20%	20%			
PE NA601	11.80%	11.80%	11.80%	15%	15%	15%
AO 330	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%
Properties (from plaques):						
<u>Stress-Strain</u>						
Max. Stress at Break, psi	2090	3169	3255	1620	2859	2683
Strain at Break, %	1083	1057	895	927	1050	690
100% Modulus, psi	141	159	165	231	300	314
200% Modulus, psi	189	201	236	295	361	428
300% Modulus, psi	250	256	321	382	440	580
500% Modulus, psi	427	443	605	651	663	1165
<u>Hysteresis</u>						
Perm. Set, %	8.2	8.9	7.4	10.9	13.9	13.7
1st Cycle Recovery, %	79.4	76.9	83.3	68.8	60.5	61.9

[0077]

TABLE 11B

	Compounds			
	7	8		
	Polymer			
	#3	G-1730		
Polymer	68%	68%		
Regalrez 1126	20%	20%		
PE NA601	11.80%	11.80%		
AO 330	0.20%	0.20%		
Properties (from films):				
	MD	TD	MD	TD
<u>Stress-Strain</u>				
Max. Stress at Break, psi	3635	3124	3213	1924
Strain at Break, %	769	773	888	787
100% Modulus, psi	168	137	122	106
200% Modulus, psi	212	175	158	139

TABLE 11B-continued

300% Modulus, psi	273	243	211	189
500% Modulus, psi	357	336	281	255
	689	661	535	498
<u>100% Hysteresis</u>				
Perm. Set, %	8.7	6.6	6.5	7.2
1st Cycle Recovery, %	69.4	78.7	78.8	78.8
	98	103	84	58
<u>300% Hysteresis:</u>				
Perm. Set, %	31.1		16.9	
1st Cycle Recovery, %	56.8		71.3	
100% Stress Cyc-1	85.2		80.5	
Unload, psi				
Stress Relaxation @ 150% Strain				
Max. Stress, psi	196		153	
Stress @ End of Test, psi	162		116	
% Relax @ 30', %	18		25	
Elmendorff tear:				
Tear strength(g/mils)	105.7	112.4	85	77

Example #12

[0078] This example is similar to Example #6, in that one controlled distribution block copolymer (#9) was compared against a selectively hydrogenated SBS block copolymer (KRATON G 1654) in a compound with extending oil and polypropylene homopolymer. The results are shown in Table 12. As shown in Table 12, the composition with Polymer #9 has much improved melt flows compared to compositions made with G-1654. Surprisingly, the compression set of the two compounds are nearly the same. This means that the compound made with Polymer #9 can be much more easily molded than the compound containing G-1654 while retaining approximately the same properties.

TABLE 12

Formulation (parts by weight)		
100 pbw Block Copolymer		
110 pbw Plasticiser (Primol 352)		
45 pbw Polypropylene (MFR = 5.5)		
0.2 pbw Irganox 1010		
0.8 pbw Irganox PS 800		
Extrusion conditions (W&Pfl ZSK 25) Werner Pfleiderer ZSK 25		
Spiral flows conditions: Temperature of melt = 190° C./mould = 30° C., Injection time: 3 sec		
Polymer	G1654	#9
<u>Spiral Flow, degrees</u>		
500 bars	450	670
750 bars	670	890
900 bars	790	980
<u>MFR, (g/10 min)</u>		
230° C./2.16 kg	1	25
200° C./5 kg	4	60
<u>IPN test in toluene</u>		
PP content (% w)	25	20

TABLE 12-continued

Compression set %		
23 C/72 hrs		
70 C/24 hrs	54	48
100 C/24 hrs	81	84
Hardness, Shore A	63	59
DIN Abrasion, mm ³	90	325
Oil bleed-out	No	No
Transparency	3	1

What is claimed is:

1. An elastomeric article comprising at least one hydrogenated block copolymer and, optionally, at least one other polymer selected from the group consisting of olefin polymers, styrene polymers, tackifying resins and engineering thermoplastic resins, wherein said hydrogenated block copolymer has the general configuration:

A-B,
A-B-A,
or
(A-B)_nX,

where n is an integer from 2 to about 30, and X is coupling agent residue and wherein:

- prior to hydrogenation each A block is a mono alkenyl arene homopolymer block and each B block is a controlled distribution copolymer block of at least one conjugated diene and at least one mono alkenyl arene;
- subsequent to hydrogenation about 0-10% of the arene double bonds have been reduced, and at least about 90% of the conjugated diene double bonds have been reduced;
- each A block having an average molecular weight between about 3,000 and about 60,000 and each B block having an average molecular weight between about 30,000 and about 300,000;
- each B block comprises one or more terminal regions adjacent to the A blocks that are rich in conjugated diene units and a region not adjacent to the A blocks that is rich in mono alkenyl arene units;
- the total amount of mono alkenyl arene in the hydrogenated block copolymer is about 15 percent weight to about 75 percent weight; and
- the weight ratio of conjugated diene to mono alkenyl arene in the B block is between about 5:1 and about 1:2.

2. The elastomeric article according to claim 1 wherein said mono alkenyl arene is styrene and said conjugated diene is selected from the group consisting of isoprene and butadiene.

3. The elastomeric article according to claim 2 wherein said conjugated diene is butadiene, and wherein about 20 to about 80 mol percent of the condensed butadiene units in block B have 1,2-configuration.

4. The elastomeric article according to claim 3 wherein in block B there are fewer than 20 consecutive units of any one monomer between that of each different monomer.

5. The elastomeric article according to claim 4 wherein the polymer is an ABA polymer and each block B has a center region with a minimum ratio of butadiene units to styrene units.

6. The elastomeric article according to claim 2 wherein the styrene blockiness index of the block B is less than about 10 percent, said styrene blockiness index being defined to be the proportion of styrene units in the block B having two styrene neighbors on the polymer chain.

7. The elastomeric article according to claim 1 wherein said hydrogenated block copolymer is an (A-B)_nX block copolymer where each A block has an average molecular weight of about 5,000 to about 20,000, each B block has an average molecular weight of about 30,000 to about 100,000, and the total molecular weight is about 80,000 to about 140,000.

8. The elastomeric article according to claim 7 comprising 100 parts by weight of said hydrogenated block copolymer and about 5 to about 50 parts by weight of a polymer extending oil.

9. The elastomeric article according to claim 7 comprising 100 parts by weight of said hydrogenated block copolymer and about 5 to about 50 parts by weight of an olefin polymer selected from the group consisting of ethylene homopolymers, ethylene/alpha olefin copolymers, propylene homopolymers, propylene/alpha olefin copolymers, high impact polypropylene, and ethylene/vinyl acetate copolymers.

10. The elastomeric article according to claim 9 also comprising about 5 to about 50 parts by weight of a tackifying resin.

11. The elastomeric article according to claim 8 also comprising about 5 to about 40 parts by weight of a styrene polymer selected from the group consisting of crystalline polystyrene, high impact polystyrene, syndiotactic polystyrene and acrylonitrile/butadiene/styrene terpolymer.

12. The elastomeric article according to claim 7 comprising 100 parts by weight of said hydrogenated block copolymer and about 5 to about 20 parts by weight of an ethylene/vinyl aromatic interpolymer.

13. The elastomeric article according to claim 12 wherein said ethylene/vinyl aromatic interpolymer is a substantially random ethylene/styrene interpolymer.

14. The elastomeric article according to claim 1 wherein said hydrogenated block copolymer is an (A-B)_nX block copolymer where each A block has an average molecular weight of about 10,000 to about 40,000, each B block has an average molecular weight of about 60,000 to about 140,000, and the total molecular weight is about 140,000 to about 220,000.

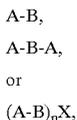
15. The elastomeric article according to claim 14 comprising 100 parts by weight of said hydrogenated block copolymer and about 10 to about 50 parts by weight of an olefin polymer selected from the group consisting of ethylene homopolymers, ethylene/alpha olefin copolymers, propylene homopolymers, propylene/alpha olefin copolymers, high impact polypropylene, and ethylene/vinyl acetate copolymers.

16. The elastomeric article according to claim 15 also comprising about 20 to about 150 parts by weight of a polymer extending oil.

17. The elastomeric article according to claim 14 comprising 100 parts by weight of said hydrogenated block copolymer and about 10 to about 80 parts by weight of at

least one polymer selected from the group consisting of poly(phenylene oxides), syndiotactic polystyrene, cyclic olefin copolymers and acrylonitrile/butadiene/styrene terpolymers.

18. A formulated elastomeric composition comprising at least one hydrogenated block copolymer and at least one component selected from the group consisting of fillers, reinforcements, polymer extending oils and polyolefins, wherein said hydrogenated block copolymer has the general configuration



where n is an integer from 2 to about 30, and X is coupling agent residue and wherein:

- a. prior to hydrogenation each A block is a mono alkenyl arene homopolymer block and each B block is a controlled distribution copolymer block of at least one conjugated diene and at least one mono alkenyl arene;
- b. subsequent to hydrogenation about 0-10% of the arene double bonds have been reduced, and at least about 90% of the conjugated diene double bonds have been reduced;
- c. each A block having an average molecular weight between about 3,000 and about 60,000 and each B block having an average molecular weight between about 30,000 and about 300,000;
- d. each B block comprises one or more terminal regions adjacent to the A blocks that are rich in conjugated diene units and a region not adjacent to the A blocks that is rich in mono alkenyl arene units;
- e. the total amount of mono alkenyl arene in the hydrogenated block copolymer is about 15 percent weight to about 75 percent weight; and
- f. the weight ratio of conjugated diene to mono alkenyl arene in the B block is between about 5:1 and about 1:2.

19. A cap seal formed from the formulated elastomeric composition of claim 18.

20. The cap seal of claim 19 wherein said formulated elastomeric composition comprises 100 parts by weight of said hydrogenated block copolymer and about 50 to about

125 parts by weight of a process extender oil, to 50 parts by weight of polypropylene and optionally 10 to 60 parts by weight silica.

21. The elastomeric article according to claim 1 wherein the article is in the form of a film, sheet, coating, band, strip, profile, molding, foam, tape, fabric, thread, filament, ribbon, fiber, plurality of fibers or, fibrous web.

22. The elastomeric article according to claim 1 wherein said article is formed in a process selected from the group consisting of injection molding, over molding, dipping, extrusion, roto molding, slush molding, fiber spinning, film making or foaming.

23. The elastomeric article according to claim 1 comprising about 5 to 20 percent weight of said hydrogenated block copolymer and about 80 to about 95 percent weight of an engineering thermoplastic resin.

24. The elastomeric article according to claim 23 wherein said engineering thermoplastic resin is selected from the group consisting of thermoplastic polyester, thermoplastic polyurethane, poly(arylether), poly(aryl sulfone), polycarbonate, acrylic resins, acetal resin, polyamide, halogenated thermoplastic and nitrile barrier resin.

25. The elastomeric article according to claim 1 wherein said hydrogenated block copolymer is a functionalized block copolymer.

26. The elastomeric article according to claim 25 wherein said hydrogenated block copolymer has been grafted with an acid compound or its derivative.

27. The elastomeric article according to claim 26 wherein said acid compound or its derivative is selected from the group consisting of maleic anhydride, maleic acid, fumaric acid, and its derivatives.

28. The elastomeric article according to claim 26 wherein said acid compound or its derivative is maleic anhydride or maleic acid.

29. The elastomeric article according to claim 28 containing 75 to 95 weight percent of an engineering thermoplastic selected from the group consisting of polyamides and polyurethanes and 5 to 25 weight percent of the functionalized block polymer.

30. The elastomeric article according to claim 1 comprising about 5 to 40 percent weight of said hydrogenated block copolymer and about 60 to about 95 percent weight of a polystyrene homopolymer or copolymer.

* * * * *