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(54) Title: TWO COMPONENT POLYOXYMETHYLENE BASED SYSTEMS

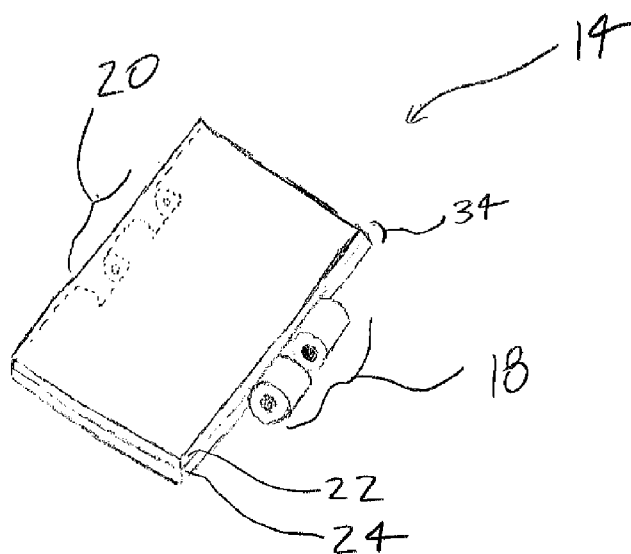


Figure 2

(57) Abstract: A two component polyoxymethylen based system is disclosed. The two component system is comprised of a first polymer layer and a second polymer layer. The first polymer layer is comprised of a polyoxymethylen polymer composition comprising a polyoxymethylen polymer and optionally a tribological modifier. The second polymer layer is comprised of a second polymer composition comprising a liquid crystalline polymer, a polyarylene sulfide polymer, or a combination thereof and at least one tribological modifier. The compositions provide polymer articles, such as conveyor components, with improved tribological properties.



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TWO COMPONENT POLYOXYMETHYLENE BASED SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Application Serial No. 61/893,480 having a filing date of October 21, 2013, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Polyacetal polymers, which are commonly referred to as polyoxymethylene polymers, have become established as exceptionally useful engineering materials in a variety of applications. For instance, because polyoxymethylene polymers have excellent mechanical properties, fatigue resistance, abrasion resistance, chemical resistance, and moldability, they are widely used in constructing polymer articles, such as articles for use in the automotive industry and the electrical industry.

[0003] Polyoxymethylene polymers are often provided with additives to adapt the properties for a specific application, for example by using reinforcing fibers or tribological modifiers. For instance, polyoxymethylene polymers have been combined with a tribological modifier for producing polymer compositions well suited for use in tribological applications where the polymer article is in moving contact with other articles, such as metal articles, plastic articles, and the like. These tribological applications can include embodiments where the polymer composition is formed into gear wheels, pulleys, sliding elements, and the like. The addition of a tribological modifier can provide a composition with a reduced coefficient of friction, little frictional noise, and low wear.

[0004] In the past, conveyor components such as chain links in conveying systems for packaging operations have been produced using various polymers such as polyoxymethylenes and polyamide-imides. However, in order to convey packages and containers on the conveyor chain links, lubricants and coatings are often applied to the conveyor chain links to reduce the coefficient of friction. EP Patent No. 0831038 to Kasai et al. discloses conveyor chains that are coated with an external lubricant such as water or soapy water in order to reduce the

coefficient of friction between the conveyor chain and an opposing surface. In addition, U.S. Patent Nos. 6,485,794 and 7,067,182 to Li et al. disclose the application of a thermal or radiation curable coating composition to a plastic beverage container and a conveying surface in order to reduce the coefficient of friction. Additionally, U.S. Patent Nos. 4,436,200 to Hodlewsky et al. and 5,559,180 to Takahashi et al. disclose the use of polytetrafluoroethylene for modifying the tribological properties of a polyacetal to reduce the coefficient of friction.

[0005] Although modified polyoxymethylene compositions have been found to be well suited in tribological applications, further improvements are still necessary. For instance, a need exists for providing a polyoxymethylene based system with improved tribological properties. In particular, a need exists for providing a polyoxymethylene based system with a reduced coefficient of friction when in contact with other moving articles such as metal articles or plastic articles such as polyethylene terephthalate. In addition, a need exists for providing a polyoxymethylene based system with improved tribological properties suitable for conveyor chain applications.

SUMMARY

[0006] In general, the present disclosure is directed to a polymer article comprising a first polymer layer and a second polymer layer. The first polymer layer is comprised of a polyoxymethylene polymer composition comprising a polyoxymethylene polymer and optionally, at least one tribological modifier. The second polymer layer is comprised of a second polymer composition comprising a liquid crystalline polymer, a polyarylene sulfide polymer, or a combination thereof. The second polymer composition further comprises at least one tribological modifier. In one embodiment, the tribological modifier in the second polymer composition may comprise a polytetrafluoroethylene. In one embodiment, the second polymer composition may further comprise a reinforcing fiber.

[0007] The second polymer layer may be connected to the first polymer layer. In one embodiment, the second polymer layer may be connected to the first polymer layer via overmolding. In another embodiment, the second polymer layer

may be connected to the first polymer layer using an interlocking mechanism. In another embodiment, the second polymer layer may be connected to the first polymer layer using a fastener.

[0008] Other features and aspects of the present disclosure are discussed in greater detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A full and enabling disclosure of the present disclosure is set forth more particularly in the remainder of the specification, including reference to the accompanying figures, in which:

[00010] Figure 1 is a conveyor belt assembly comprising conveyor components according to one embodiment of the present disclosure;

[00011] Figure 2 is a two-component conveyor component according to one embodiment of the present disclosure;

[00012] Figure 3a is a two-component conveyor component demonstrating an interlocking mechanism according to one embodiment of the present disclosure;

[00013] Figure 3b is a two-component conveyor component demonstrating an interlocking mechanism according to another embodiment of the present disclosure;

[00014] Figure 4 is a two-component conveyor component demonstrating a fastening mechanism according to one embodiment of the present disclosure;

[00015] Figure 5a is a two-component conveyor component produced using an overmolding process according to one embodiment of the present disclosure; and

[00016] Figure 5b is a two-component conveyor component produced using an overmolding process according to another embodiment of the present disclosure.

[00017] Repeat use of the reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the present invention.

DETAILED DESCRIPTION

[00018] Reference now will be made in detail to the embodiments of the invention, one or more examples of which are set forth below. Each example is

provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment, can be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention cover such modifications and variations.

[00019] In general, the present disclosure is directed to a polyoxymethylene based system with improved tribological properties such as a reduced coefficient of friction. The tribological properties of the polyoxymethylene based system can be improved by utilizing tribological modifiers.

[00020] The polyoxymethylene based system may comprise a two-component system. In general, a two-component system is comprised of a first polymer layer and a second polymer layer wherein the second polymer layer may be connected to the first polymer layer. The first polymer layer is comprised of a polyoxymethylene polymer composition comprising a polyoxymethylene polymer and optionally, at least one tribological modifier. The second polymer layer is comprised of a second polymer composition comprising a liquid crystalline polymer, a polyarylene sulfide polymer, or a combination thereof. The second polymer composition may further comprise at least one tribological modifier, a reinforcing fiber, or a combination thereof.

[00021] The present inventors have discovered that by utilizing the polyoxymethylene based system of the present invention, improved sliding properties and a reduced coefficient of friction against other surfaces can be obtained. In particular, the system can exhibit a reduced coefficient of friction against other surfaces, such as a polyethylene terephthalate surface, while still exhibiting desirable mechanical properties. In addition, these systems also generate little frictional noise and experience low wear.

[00022] Polyoxymethylene Polymer

[00023] According to the present disclosure, the polyoxymethylene polymer composition of the two-component system is comprised of a polyoxymethylene polymer.

[00024] The preparation of the polyoxymethylene polymer can be carried out by polymerization of polyoxymethylene-forming monomers, such as trioxane or a mixture of trioxane and a cyclic acetal such as dioxolane in the presence of ethylene glycol as a molecular weight regulator. The polyoxymethylene polymer used in the polymer composition may comprise a homopolymer or a copolymer. According to one embodiment, the polyoxymethylene is a homo- or copolymer which comprises at least 50 mol.%, such as at least 75 mol.%, such as at least 90 mol.% and such as even at least 97 mol.% of $-\text{CH}_2\text{O}-$ repeat units.

[00025] In one embodiment, a polyoxymethylene copolymer is used. The copolymer can contain from about 0.1 mol.% to about 20 mol.% and in particular from about 0.5 mol.% to about 10 mol.% of repeat units that comprise a saturated or ethylenically unsaturated alkylene group having at least 2 carbon atoms, or a cycloalkylene group, which has sulfur atoms or oxygen atoms in the chain and may include one or more substituents selected from the group consisting of alkyl cycloalkyl, aryl, aralkyl, heteroaryl, halogen or alkoxy. In one embodiment, a cyclic ether or acetal is used that can be introduced into the copolymer via a ring-opening reaction.

[00026] Preferred cyclic ethers or acetals are those of the formula:



in which x is 0 or 1 and R^2 is a $\text{C}_2 - \text{C}_4$ -alkylene group which, if appropriate, has one or more substituents which are $\text{C}_1 - \text{C}_4$ -alkyl groups, or are $\text{C}_1 - \text{C}_4$ -alkoxy groups, and/or are halogen atoms, preferably chlorine atoms. Merely by way of example, mention may be made of ethylene oxide, propylene 1,2-oxide, butylene 1,2-oxide, butylene 1,3-oxide, 1,3-dioxane, 1,3-dioxolane, and 1,3-dioxepan as cyclic ethers, and also of linear oligo- or polyformals, such as polydioxolane or polydioxepan, as comonomers.

[00027] It is particularly advantageous to use copolymers composed of from 99.5 to 95 mol.% of trioxane and of from 0.5 to 5 mol.% of one of the above-mentioned comonomers.

[00028] The polymerization can be effected as precipitation polymerization or in the melt. By a suitable choice of the polymerization parameters, such as duration of polymerization or amount of molecular weight regulator, the molecular weight and hence the MVR value of the resulting polymer can be adjusted.

[00029] In one embodiment, a polyoxymethylene polymer with hydroxyl terminal groups can be produced using a cationic polymerization process followed by solution hydrolysis to remove any unstable end groups. During cationic polymerization, a glycol, such as ethylene glycol can be used as a chain terminating agent. The cationic polymerization results in a bimodal molecular weight distribution containing low molecular weight constituents. In one particular embodiment, the low molecular weight constituents can be significantly reduced by conducting the polymerization using a heteropoly acid such as phosphotungstic acid as the catalyst. When using a heteropoly acid as the catalyst, for instance, the amount of low molecular weight constituents can be less than about 2 wt. %.

[00030] A heteropoly acid refers to polyacids formed by the condensation of different kinds of oxo acids through dehydration and contains a mono- or poly-nuclear complex ion wherein a hetero element is present in the center and the oxo acid residues are condensed through oxygen atoms. Such a heteropoly acid is represented by the formula:



wherein

M represents an element selected from the group consisting of P, Si, Ge, Sn, As, Sb, U, Mn, Re, Cu, Ni, Ti, Co, Fe, Cr, Th or Ce,

M' represents an element selected from the group consisting of W, Mo, V or Nb,

m is 1 to 10,

n is 6 to 40,

z is 10 to 100,

x is an integer of 1 or above, and

y is 0 to 50.

[00031] The central element (M) in the formula described above may be composed of one or more kinds of elements selected from P and Si and the

coordinate element (M') is composed of at least one element selected from W, Mo and V, particularly W or Mo.

[00032] Specific examples of heteropoly acids are phosphomolybdic acid, phosphotungstic acid, phosphomolybdotungstic acid, phosphomolybdovanadic acid, phosphomolybdotungstovanadic acid, phosphotungstovanadic acid, silicotungstic acid, silicomolybdic acid, silicomolybdotungstic acid, silicomolybdotungstovanadic acid and acid salts thereof. Excellent results have been achieved with heteropoly acids selected from 12-molybdophosphoric acid ($\text{H}_3\text{PMo}_{12}\text{O}_{40}$) and 12-tungstophosphoric acid ($\text{H}_3\text{PW}_{12}\text{O}_{40}$) and mixtures thereof.

[00033] The heteropoly acid may be dissolved in an alkyl ester of a polybasic carboxylic acid. It has been found that alkyl esters of polybasic carboxylic acid are effective to dissolve the heteropoly acids or salts thereof at room temperature (25°C).

[00034] The alkyl ester of the polybasic carboxylic acid can easily be separated from the production stream since no azeotropic mixtures are formed. Additionally, the alkyl ester of the polybasic carboxylic acid used to dissolve the heteropoly acid or an acid salt thereof fulfills the safety aspects and environmental aspects and, moreover, is inert under the conditions for the manufacturing of oxymethylene polymers.

[00035] Preferably the alkyl ester of a polybasic carboxylic acid is an alkyl ester of an aliphatic dicarboxylic acid of the formula:



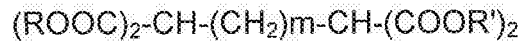
wherein

n is an integer from 2 to 12, preferably 3 to 6 and

R and R' represent independently from each other an alkyl group having 1 to 4 carbon atoms, preferably selected from the group consisting of methyl, ethyl, n-propyl, iso-propyl, n-butyl, iso-butyl and tert.-butyl.

[00036] In one embodiment, the polybasic carboxylic acid comprises the dimethyl or diethyl ester of the above-mentioned formula, such as a dimethyl adipate (DMA).

[00037] The alkyl ester of the polybasic carboxylic acid may also be represented by the following formula:



wherein

m is an integer from 0 to 10, preferably from 2 to 4 and

R and R' are independently from each other alkyl groups having 1 to 4 carbon atoms, preferably selected from the group consisting of methyl, ethyl, n-propyl, iso-propyl, n-butyl, iso-butyl and tert.-butyl.

[00038] Particularly preferred components which can be used to dissolve the heteropoly acid according to the above formula are butantetracarboxylic acid tetraethyl ester or butantetracarboxylic acid tetramethyl ester.

[00039] Specific examples of the alkyl ester of a polybasic carboxylic acid are dimethyl glutaric acid, dimethyl adipic acid, dimethyl pimelic acid, dimethyl suberic acid, diethyl glutaric acid, diethyl adipic acid, diethyl pimelic acid, diethyl suberic acid, diethyl phthalic acid, dimethyl isophthalic acid, dimethyl terephthalic acid, diethyl phthalic acid, diethyl isophthalic acid, diethyl terephthalic acid, butantetracarboxylic acid tetramethylester and butantetracarboxylic acid tetraethylester as well as mixtures thereof. Other examples include dimethylisophthalate, diethylisophthalate, dimethylterephthalate or diethylterephthalate.

[00040] Preferably, the heteropoly acid is dissolved in the alkyl ester of the polybasic carboxylic acid in an amount lower than 5 wt.%, preferably in an amount ranging from 0.01 to 5 wt.%, wherein the weight is based on the entire solution.

[00041] In some embodiments, the polymer composition of the present disclosure may contain other polyoxymethylene homopolymers and/or polyoxymethylene copolymers. Such polymers, for instance, are generally unbranched linear polymers which contain at least 80%, such as at least 90%, oxymethylene units.

[00042] The polyoxymethylene polymer can have any suitable molecular weight. The molecular weight of the polymer, for instance, can be from about 4,000 grams per mole to about 20,000 g/mol. In other embodiments, however, the molecular weight can be well above 20,000 g/mol, such as from about 20,000 g/mol to about 100,000 g/mol.

[00043] The polyoxymethylene polymer present in the composition can generally melt flow index (MFI) ranging from about 1 to about 50 g/10 min, as determined according to ISO 1133 at 190 °C and 2.16 kg, though polyoxymethylenes having a higher or lower melt flow index are also encompassed herein. For example, the polyoxymethylene polymer may be a low or mid-molecular weight polyoxymethylene that has a melt flow index of greater than about 5 g/10 min, greater than about 10 g/10 min, or greater than about 15 g/10 min. The melt flow index of the polyoxymethylene polymer can be less than about 25 g/10 min, less than about 20 g/10 min, less than about 18 g/10 min, less than about 15 g/10 min, less than about 13 g/10 min, or less than about 12 g/10 min. The polyoxymethylene polymer may for instance be a high molecular weight polyoxymethylene that has a melt flow index of less than about 5 g/10min, less than about 3 g/10min, or less than about 2 g/10min.

[00044] The polyoxymethylene polymer may contain a relatively high amount of functional groups, such as hydroxyl groups in the terminal positions. More particularly, the polyoxymethylene polymer can have terminal hydroxyl groups, for example hydroxyethylene groups and/or hydroxyl side groups, in at least more than about 50% of all the terminal sites on the polymer. It should be understood that the total number of terminal groups present includes all side terminal groups. In addition to the terminal hydroxyl groups, the polyoxymethylene polymer may also have other terminal groups usual for these polymers such as alkoxy groups, formate groups, acetate groups or hemiacetal groups.

[00045] The polyoxymethylene polymer may also optionally have a relatively low amount of low molecular weight constituents. As used herein, low molecular weight constituents (or fractions) refer to constituents having molecular weights below 10,000 dalton. In this regard, the polyoxymethylene polymer can contain low molecular weight constituents in an amount less than about 10 wt.%, based on the total weight of the polyoxymethylene. In certain embodiments, for instance, the polyoxymethylene polymer may contain low molecular weight constituents in an amount less than about 5 wt.%, such as in an amount less than about 3 wt.%, such as even in an amount less than about 2 wt.%.

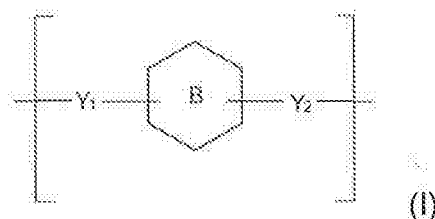
[00046] The polyoxymethylene polymer may be present in the polyoxymethylene polymer composition in an amount of at least 60 wt.%, such as at least 70 wt.%, such as at least 80 wt.%, such as at least 90 wt.%, such as at least 95 wt.%. In general, the polyoxymethylene polymer is present in an amount of less than about 100 wt.%, such as less than about 99 wt.%, such as less than about 97 wt.%, wherein the weight is based on the total weight of the polyoxymethylene polymer composition.

[00047] Liquid Crystalline Polymer

[00048] According to the present disclosure, the second polymer composition of the two-component system may comprise a liquid crystalline polymer.

[00049] Suitable thermotropic liquid crystalline polymers may include aromatic polyesters, aromatic poly(esteramides), aromatic poly(estercarbonates), aromatic polyamides, etc., and may likewise contain repeating units formed from one or more aromatic hydroxycarboxylic acids, aromatic dicarboxylic acids, aromatic diols, aromatic aminocarboxylic acids, aromatic amines, aromatic diamines, etc., as well as combinations thereof.

[00050] Liquid crystalline polymers are generally classified as "thermotropic" to the extent that they can possess a rod-like structure and exhibit a crystalline behavior in its molten state (e.g., thermotropic nematic state). Such polymers may be formed from one or more types of repeating units as is known in the art. The liquid crystalline polymer may, for example, contain one or more aromatic ester repeating units, typically in an amount of from about 60 mol.% to about 99.9 mol.%, in some embodiments from about 70 mol.% to about 99.5 mol.%, and in some embodiments, from about 80 mol.% to about 99 mol.% of the polymer. The aromatic ester repeating units may be generally represented by the following Formula (I):



wherein,

ring B is a substituted or unsubstituted 6-membered aryl group (e.g., 1,4-phenylene or 1,3-phenylene), a substituted or unsubstituted 6-membered aryl group fused to a substituted or unsubstituted 5- or 6-membered aryl group (e.g., 2,6-naphthalene), or a substituted or unsubstituted 6-membered aryl group linked to a substituted or unsubstituted 5- or 6-membered aryl group (e.g., 4,4-biphenylene); and

Y_1 and Y_2 are independently O, C(O), NH, C(O)HN, or NHC(O).

[00051] Typically, at least one of Y_1 and Y_2 are C(O). Examples of such aromatic ester repeating units may include, for instance, aromatic dicarboxylic repeating units (Y_1 and Y_2 in Formula I are C(O)), aromatic hydroxycarboxylic repeating units (Y_1 is O and Y_2 is C(O) in Formula I), as well as various combinations thereof.

[00052] Aromatic dicarboxylic repeating units, for instance, may be employed that are derived from aromatic dicarboxylic acids, such as terephthalic acid, isophthalic acid, 2,6-naphthalenedicarboxylic acid, diphenyl ether-4,4'-dicarboxylic acid, 1,6-naphthalenedicarboxylic acid, 2,7-naphthalenedicarboxylic acid, 4,4'-dicarboxybiphenyl, bis(4-carboxyphenyl)ether, bis(4-carboxyphenyl)butane, bis(4-carboxyphenyl)ethane, bis(3-carboxyphenyl)ether, bis(3-carboxyphenyl)ethane, etc., as well as alkyl, alkoxy, aryl and halogen substituents thereof, and combinations thereof. Particularly suitable aromatic dicarboxylic acids may include, for instance, terephthalic acid ("TA"), isophthalic acid ("IA"), and 2,6-naphthalenedicarboxylic acid ("NDA"). When employed, repeating units derived from aromatic dicarboxylic acids (e.g., IA, TA, and/or NDA) typically constitute from about 5 mol.% to about 60 mol.%, in some embodiments from about 10 mol.% to about 55 mol.%, and in some embodiments, from about 15 mol.% to about 50 mol.% of the polymer.

[00053] Aromatic hydroxycarboxylic repeating units may also be employed that are derived from aromatic hydroxycarboxylic acids, such as, 4-hydroxybenzoic acid; 4-hydroxy-4'-biphenylcarboxylic acid; 2-hydroxy-6-naphthoic acid; 2-hydroxy-5-naphthoic acid; 3-hydroxy-2-naphthoic acid; 2-hydroxy-3-naphthoic acid; 4'-hydroxyphenyl-4-benzoic acid; 3'-hydroxyphenyl-4-benzoic acid; 4'-hydroxyphenyl-3-benzoic acid, etc., as well as alkyl, alkoxy, aryl and halogen substituents thereof,

and combination thereof. Particularly suitable aromatic hydroxycarboxylic acids are 4-hydroxybenzoic acid ("HBA") and 6-hydroxy-2-naphthoic acid ("HNA").

When employed, repeating units derived from hydroxycarboxylic acids (e.g., HBA and/or HNA) typically constitute from about 10 mol.% to about 85 mol.%, in some embodiments from about 20 mol.% to about 80 mol.%, and in some embodiments, from about 25 mol.% to about 75 mol.% of the polymer.

[00054] Other repeating units may also be employed in the polymer. In certain embodiments, for instance, repeating units may be employed that are derived from aromatic diols, such as hydroquinone, resorcinol, 2,6-dihydroxynaphthalene, 2,7-dihydroxynaphthalene, 1,6-dihydroxynaphthalene, 4,4'-dihydroxybiphenyl (or 4,4'-biphenol), 3,3'-dihydroxybiphenyl, 3,4'-dihydroxybiphenyl, 4,4'-dihydroxybiphenyl ether, bis(4-hydroxyphenyl)ethane, etc., as well as alkyl, alkoxy, aryl and halogen substituents thereof, and combinations thereof. Particularly suitable aromatic diols may include, for instance, hydroquinone ("HQ") and 4,4'-biphenol ("BP"). When employed, repeating units derived from aromatic diols (e.g., HQ and/or BP) typically constitute from about 1 mol.% to about 30 mol.%, in some embodiments from about 2 mol.% to about 25 mol.%, and in some embodiments, from about 5 mol.% to about 20% of the polymer. Repeating units may also be employed, such as those derived from aromatic amides (e.g., acetaminophen ("APAP")) and/or aromatic amines (e.g., 4-aminophenol ("AP"), 3-aminophenol, 1,4-phenylenediamine, 1,3-phenylenediamine, etc.). When employed, repeating units derived from aromatic amides (e.g., APAP) and/or aromatic amines (e.g., AP) typically constitute from about 0.1 mol.% to about 20 mol.%, in some embodiments from about 0.5 mol.% to about 15 mol.%, and in some embodiments, from about 1 mol.% to about 10 mol.% of the polymer. It should also be understood that various other monomeric repeating units may be incorporated into the polymer. For instance, in certain embodiments, the polymer may contain one or more repeating units derived from non-aromatic monomers, such as aliphatic or cycloaliphatic hydroxycarboxylic acids, dicarboxylic acids, diols, amides, amines, etc. Of course, in other embodiments, the polymer may be "wholly aromatic" in that it lacks repeating units derived from non-aromatic (e.g., aliphatic or cycloaliphatic) monomers.

[00055] Although not necessarily required, the liquid crystalline polymer may be a "low naphthenic" polymer to the extent that it contains a minimal content of repeating units derived from naphthenic hydroxycarboxylic acids and naphthenic dicarboxylic acids, such as naphthalene-2,6-dicarboxylic acid ("NDA"), 6-hydroxy-2-naphthoic acid ("HNA"), or combinations thereof. That is, the total amount of repeating units derived from naphthenic hydroxycarboxylic and/or dicarboxylic acids (e.g., NDA, HNA, or a combination of HNA and NDA) may typically be no more than 30 mol.%, in some embodiments no more than about 15 mol.%, in some embodiments no more than about 10 mol.%, in some embodiments no more than about 8 mol.%, and in some embodiments, from 0 mol.% to about 5 mol.% of the polymer (e.g., 0 mol.%). Despite the absence of a high level of conventional naphthenic acids, it is believed that the resulting "low naphthenic" polymers are still capable of exhibiting good thermal and mechanical properties.

[00056] In one particular embodiment, the liquid crystalline polymer may be formed from repeating units derived from 4-hydroxybenzoic acid ("HBA") and terephthalic acid ("TA") and/or isophthalic acid ("IA"), as well as various other optional constituents. The repeating units derived from 4-hydroxybenzoic acid ("HBA") may constitute from about 10 mol.% to about 80 mol.%, in some embodiments from about 30 mol.% to about 75 mol.%, and in some embodiments, from about 45 mol.% to about 70 mol.% of the polymer. The repeating units derived from terephthalic acid ("TA") and/or isophthalic acid ("IA") may likewise constitute from about 5 mol.% to about 40 mol.%, in some embodiments from about 10 mol.% to about 35 mol.%, and in some embodiments, from about 15 mol.% to about 35 mol.% of the polymer. Repeating units may also be employed that are derived from 4,4'-biphenol ("BP") and/or hydroquinone ("HQ") in an amount from about 1 mol.% to about 30 mol.%, in some embodiments from about 2 mol.% to about 25 mol.%, and in some embodiments, from about 5 mol.% to about 20 mol.% of the polymer. Other possible repeating units may include those derived from 6-hydroxy-2-naphthoic acid ("HNA"), 2,6-naphthalenedicarboxylic acid ("NDA"), and/or acetaminophen ("APAP"). In certain embodiments, for example, repeating units derived from HNA, NDA, and/or APAP may each constitute from about 1 mol.% to about 35 mol.%, in some embodiments from

about 2 mol.% to about 30 mol.%, and in some embodiments, from about 3 mol.% to about 25 mol.% when employed.

[00057] Regardless of the particular constituents and nature of the polymer, the liquid crystalline polymer may be prepared by initially introducing the aromatic monomer(s) used to form ester repeating units (e.g., aromatic hydroxycarboxylic acid, aromatic dicarboxylic acid, etc.) and/or other repeating units (e.g., aromatic diol, aromatic amide, aromatic amine, etc.) into a reactor vessel to initiate a polycondensation reaction. The particular conditions and steps employed in such reactions are well known, and may be described in more detail in U.S. Patent No. 4,161,470 to Calundann; U.S. Patent No. 5,616,680 to Linstid, III, et al.; U.S. Patent No. 6,114,492 to Linstid, III, et al.; U.S. Patent No. 6,514,611 to Shepherd, et al.; and WO 2004/058851 to Waggoner. The vessel employed for the reaction is not especially limited, although it is typically desired to employ one that is commonly used in reactions of high viscosity fluids. Examples of such a reaction vessel may include a stirring tank-type apparatus that has an agitator with a variably-shaped stirring blade, such as an anchor type, multistage type, spiral-ribbon type, screw shaft type, etc., or a modified shape thereof. Further examples of such a reaction vessel may include a mixing apparatus commonly used in resin kneading, such as a kneader, a roll mill, a Banbury mixer, etc.

[00058] If desired, the reaction may proceed through the acetylation of the monomers as known the art. This may be accomplished by adding an acetylating agent (e.g., acetic anhydride) to the monomers. Acetylation is generally initiated at temperatures of about 90°C. During the initial stage of the acetylation, reflux may be employed to maintain vapor phase temperature below the point at which acetic acid byproduct and anhydride begin to distill. Temperatures during acetylation typically range from between 90°C to 150°C, and in some embodiments, from about 110°C to about 150°C. If reflux is used, the vapor phase temperature typically exceeds the boiling point of acetic acid, but remains low enough to retain residual acetic anhydride. For example, acetic anhydride vaporizes at temperatures of about 140°C. Thus, providing the reactor with a vapor phase reflux at a temperature of from about 110°C to about 130°C is particularly desirable. To ensure substantially complete reaction, an excess

amount of acetic anhydride may be employed. The amount of excess anhydride will vary depending upon the particular acetylation conditions employed, including the presence or absence of reflux. The use of an excess of from about 1 to about 10 mole percent of acetic anhydride, based on the total moles of reactant hydroxyl groups present is not uncommon.

[00059] Acetylation may occur in in a separate reactor vessel, or it may occur *in situ* within the polymerization reactor vessel. When separate reactor vessels are employed, one or more of the monomers may be introduced to the acetylation reactor and subsequently transferred to the polymerization reactor. Likewise, one or more of the monomers may also be directly introduced to the reactor vessel without undergoing pre-acetylation.

[00060] In addition to the monomers and optional acetylating agents, other components may also be included within the reaction mixture to help facilitate polymerization. For instance, a catalyst may be optionally employed, such as metal salt catalysts (e.g., magnesium acetate, tin(II) acetate, tetrabutyl titanate, lead acetate, sodium acetate, potassium acetate, etc.) and organic compound catalysts (e.g., N-methylimidazole). Such catalysts are typically used in amounts of from about 50 to about 500 parts per million based on the total weight of the recurring unit precursors. When separate reactors are employed, it is typically desired to apply the catalyst to the acetylation reactor rather than the polymerization reactor, although this is by no means a requirement.

[00061] The reaction mixture is generally heated to an elevated temperature within the polymerization reactor vessel to initiate melt polycondensation of the reactants. Polycondensation may occur, for instance, within a temperature range of from about 250°C to about 400°C, in some embodiments from about 280°C to about 395°C, and in some embodiments, from about 300°C to about 380°C. For instance, one suitable technique for forming the liquid crystalline polymer may include charging precursor monomers and acetic anhydride into the reactor, heating the mixture to a temperature of from about 90°C to about 150°C to acetylate a hydroxyl group of the monomers (e.g., forming acetoxy), and then increasing the temperature to from about 250°C to about 400°C to carry out melt polycondensation. As the final polymerization temperatures are approached,

volatile byproducts of the reaction (e.g., acetic acid) may also be removed so that the desired molecular weight may be readily achieved. The reaction mixture is generally subjected to agitation during polymerization to ensure good heat and mass transfer, and in turn, good material homogeneity. The rotational velocity of the agitator may vary during the course of the reaction, but typically ranges from about 10 to about 100 revolutions per minute ("rpm"), and in some embodiments, from about 20 to about 80 rpm. To build molecular weight in the melt, the polymerization reaction may also be conducted under vacuum, the application of which facilitates the removal of volatiles formed during the final stages of polycondensation. The vacuum may be created by the application of a suctional pressure, such as within the range of from about 5 to about 30 pounds per square inch ("psi"), and in some embodiments, from about 10 to about 20 psi.

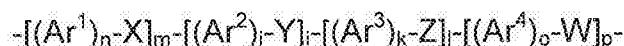
[00062] Following melt polymerization, the molten polymer may be discharged from the reactor, typically through an extrusion orifice fitted with a die of desired configuration, cooled, and collected. Commonly, the melt is discharged through a perforated die to form strands that are taken up in a water bath, pelletized and dried. In some embodiments, the melt polymerized polymer may also be subjected to a subsequent solid-state polymerization method to further increase its molecular weight. Solid-state polymerization may be conducted in the presence of a gas (e.g., air, inert gas, etc.). Suitable inert gases may include, for instance, include nitrogen, helium, argon, neon, krypton, xenon, etc., as well as combinations thereof. The solid-state polymerization reactor vessel can be of virtually any design that will allow the polymer to be maintained at the desired solid-state polymerization temperature for the desired residence time. Examples of such vessels can be those that have a fixed bed, static bed, moving bed, fluidized bed, etc. The temperature at which solid-state polymerization is performed may vary, but is typically within a range of from about 250°C to about 350°C. The polymerization time will of course vary based on the temperature and target molecular weight. In most cases, however, the solid-state polymerization time will be from about 2 to about 12 hours, and in some embodiments, from about 4 to about 10 hours.

[00063] The liquid crystalline polymer may be present in the second polymer composition in an amount of at least 40 wt.%, such as at least 50 wt.%, such as at least 60 wt.%, such as at least 70 wt.%, such as at least 80 wt.%, such as at least 90 wt.%. In general, the liquid crystalline polymer is present in an amount of less than about 100 wt.%, such as less than about 90 wt.%, such as less than about 80 wt.%, such as less than about 70 wt.%, such as less than about 60 wt.%, wherein the weight is based on the total weight of the second polymer composition.

[00064] Polyarylene Sulfide

[00065] According to the present disclosure, the second polymer composition of the two-component system may comprise a polyarylene sulfide polymer.

[00066] Polyarylene sulfide polymers are generally able to withstand relatively high temperatures without melting. Polyarylene sulfide polymers generally have repeating units of the formula:



wherein,

Ar^1 , Ar^2 , Ar^3 , and Ar^4 are independently arylene units of 6 to 18 carbon atoms;

W, X, Y, and Z are independently bivalent linking groups selected from $-SO_2-$, $-S-$, $-SO-$, $-CO-$, $-O-$, $-C(O)O-$ or alkylene or alkylidene groups of 1 to 6 carbon atoms, wherein at least one of the linking groups is $-S-$; and

n, m, i, j, k, l, o, and p are independently 0, 1, 2, 3, or 4, subject to the proviso that their sum total is not less than 2.

[00067] The arylene units Ar^1 , Ar^2 , Ar^3 , and Ar^4 may be selectively substituted or unsubstituted. Advantageous arylene units are phenylene, biphenylene, naphthylene, anthracene and phenanthrene. The polyarylene sulfide typically includes more than about 30 mol.%, more than about 50 mol.%, or more than about 70 mol.% arylene sulfide ($-S-$) units. For example, the polyarylene sulfide may include at least 85 mol.% sulfide linkages attached directly to two aromatic rings. In one particular embodiment, the polyarylene sulfide is a polyphenylene sulfide, defined herein as containing the phenylene sulfide structure $-(C_6H_4-S)_n-$ (wherein n is an integer of 1 or more) as a component thereof.

[00068] Synthesis techniques that may be used in making a polyarylene sulfide are generally known in the art. By way of example, a process for producing a polyarylene sulfide can include reacting a material that provides a hydrosulfide ion (e.g., an alkali metal sulfide) with a dihaloaromatic compound in an organic amide solvent. The alkali metal sulfide can be, for example, lithium sulfide, sodium sulfide, potassium sulfide, rubidium sulfide, cesium sulfide or a mixture thereof. When the alkali metal sulfide is a hydrate or an aqueous mixture, the alkali metal sulfide can be processed according to a dehydrating operation in advance of the polymerization reaction. An alkali metal sulfide can also be generated *in situ*. In addition, a small amount of an alkali metal hydroxide can be included in the reaction to remove or react impurities (e.g., to change such impurities to harmless materials) such as an alkali metal polysulfide or an alkali metal thiosulfate, which may be present in a very small amount with the alkali metal sulfide.

[00069] The dihaloaromatic compound can be, without limitation, an o-dihalobenzene, m-dihalobenzene, p-dihalobenzene, dihalotoluene, dihalonaphthalene, methoxy-dihalobenzene, dihalobiphenyl, dihalobenzoic acid, dihalodiphenyl ether, dihalodiphenyl sulfone, dihalodiphenyl sulfoxide or dihalodiphenyl ketone. Dihaloaromatic compounds may be used either singly or in any combination thereof. Specific exemplary dihaloaromatic compounds can include, without limitation, p-dichlorobenzene; m-dichlorobenzene; o-dichlorobenzene; 2,5-dichlorotoluene; 1,4-dibromobenzene; 1,4-dichloronaphthalene; 1-methoxy-2,5-dichlorobenzene; 4,4'-dichlorobiphenyl; 3,5-dichlorobenzoic acid; 4,4'-dichlorodiphenyl ether; 4,4'-dichlorodiphenylsulfone; 4,4'-dichlorodiphenylsulfoxide; and 4,4'-dichlorodiphenyl ketone. The halogen atom can be fluorine, chlorine, bromine or iodine, and two halogen atoms in the same dihalo-aromatic compound may be the same or different from each other. In one embodiment, o-dichlorobenzene, m-dichlorobenzene, p-dichlorobenzene or a mixture of two or more compounds thereof is used as the dihalo-aromatic compound. As is known in the art, it is also possible to use a monohalo compound (not necessarily an aromatic compound) in combination with the dihaloaromatic compound in order to form end groups of the polyarylene sulfide

or to regulate the polymerization reaction and/or the molecular weight of the polyarylene sulfide.

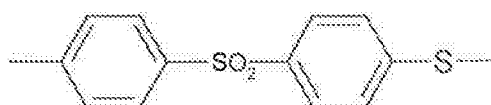
[00070] The polyarylene sulfide(s) may be homopolymers or copolymers. For instance, selective combination of dihaloaromatic compounds can result in a polyarylene sulfide copolymer containing not less than two different units. For instance, when p-dichlorobenzene is used in combination with m-dichlorobenzene or 4,4'-dichlorodiphenylsulfone, a polyarylene sulfide copolymer can be formed containing segments having the structure of formula:



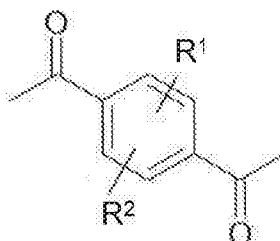
and segments having the structure of formula:



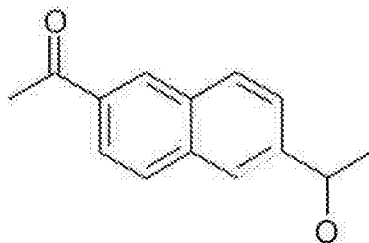
or segments having the structure of formula:



[00071] In another embodiment, a polyarylene sulfide copolymer may be formed that includes a first segment with a number-average molar mass M_n of from 1000 to 20,000 g/mol. The first segment may include first units that have been derived from structures of the formula:



where the radicals R^1 and R^2 , independently of one another, are a hydrogen, fluorine, chlorine or bromine atom or a branched or unbranched alkyl or alkoxy radical having from 1 to 6 carbon atoms; and/or second units that are derived from structures of the formula:



[00072] The first unit may be p-hydroxybenzoic acid or one of its derivatives, and the second unit may be composed of 2-hydroxynaphthalene-6-carboxylic acid. The second segment may be derived from a polyarylene sulfide structure of the formula:



where Ar is an aromatic radical, or more than one condensed aromatic radical, and q is a number from 2 to 100, in particular from 5 to 20. The radical Ar may be a phenylene or naphthylene radical. In one embodiment, the second segment may be derived from poly(m-thiophenylene), from poly(o-thiophenylene), or from poly(p-thiophenylene).

[00073] The polyarylene sulfide(s) may be linear, semi-linear, branched or crosslinked. Linear polyarylene sulfides typically contain 80 mol.% or more of the repeating unit $-(Ar-S)-$. Such linear polymers may also include a small amount of a branching unit or a cross-linking unit, but the amount of branching or cross-linking units is typically less than about 1 mol.% of the total monomer units of the polyarylene sulfide. A linear polyarylene sulfide polymer may be a random copolymer or a block copolymer containing the above-mentioned repeating unit. Semi-linear polyarylene sulfides may likewise have a cross-linking structure or a branched structure introduced into the polymer a small amount of one or more monomers having three or more reactive functional groups. By way of example, monomer components used in forming a semi-linear polyarylene sulfide can include an amount of polyhaloaromatic compounds having two or more halogen substituents per molecule which can be utilized in preparing branched polymers. Such monomers can be represented by the formula $R'X_n$, where each X is selected from chlorine, bromine, and iodine, n is an integer of 3 to 6, and R' is a polyvalent aromatic radical of valence n which can have up to about 4 methyl substituents, the total number of carbon atoms in R' being within the range of 6 to

about 16. Examples of some polyhaloaromatic compounds having more than two halogens substituted per molecule that can be employed in forming a semi-linear polyarylene sulfide include 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, 1,3-dichloro-5-bromobenzene, 1,2,4-triiodobenzene, 1,2,3,5-tetrabromobenzene, hexachlorobenzene, 1,3,5-trichloro-2,4,6-trimethylbenzene, 2,2',4,4'-tetrachlorobiphenyl, 2,2',5,5'-tetra-iodobiphenyl, 2,2',6,6'-tetrabromo-3,3',5,5'-tetramethylbiphenyl, 1,2,3,4-tetrachloronaphthalene, 1,2,4-tribromo-6-methylnaphthalene, etc., and mixtures thereof.

[00074] Regardless of the particular structure, the number average molecular weight of the polyarylene sulfide is typically about 15,000 g/mol or more, and in some embodiments, about 30,000 g/mol or more. In certain cases, a small amount of chlorine may be employed during formation of the polyarylene sulfide. Nevertheless, the polyarylene sulfide will still have a low chlorine content, such as about 1000 ppm or less, in some embodiments about 900 ppm or less, in some embodiments from about 1 to about 800 ppm, and in some embodiments, from about 2 to about 700 ppm. In certain embodiments, however, the polyarylene sulfide is generally free of chlorine or other halogens.

[00075] The polyarylene sulfide polymer may be present in the second polymer composition in an amount of at least 40 wt.%, such as at least 50 wt.%, such as at least 60 wt.%, such as at least 70 wt.%, such as at least 80 wt.%, such as at least 90 wt.%. In general, the polyarylene sulfide polymer is present in an amount of less than about 100 wt.%, such as less than about 90 wt.%, such as less than about 80 wt.%, such as less than about 70 wt.%, such as less than about 60 wt.%, wherein the weight is based on the total weight of the second polymer composition.

[00076] Tribological Modifiers

[00077] According to the present disclosure, the polyoxymethylene polymer composition of the two-component system may further comprise at least one tribological modifier. Additionally, according to the present disclosure, the second polymer composition of the two-component system may further comprise at least one tribological modifier.

[00078] According to the present disclosure, the polyoxymethylene polymer composition of the two-component system may comprise boron nitride, ultra-high molecular weight silicone, or a combination thereof.

[00079] In one embodiment, boron nitride may be used to modify the polyoxymethylene polymer. Boron nitride can be particularly beneficial in improving the tribological properties and reducing the coefficient of friction of polyoxymethylene. Boron nitride exists in a variety of different crystalline forms (e.g., h-BN – hexagonal, c-BN – cubic or sphalerite, and w-BN – wurtzite). In one embodiment, hexagonal boron nitride may be used in the composition. Not to be limited by theory, the h-BN may promote lubricity due to its layered structure and weak secondary forces between adjacent layers allowing or easy sliding of the layers. The boron nitride may have an average particle size ranging from about 0.5 μm to about 10 μm , such as from about 1 μm to about 6 μm , such as about 1.5 μm or 5 μm . The boron nitride may be present in the polyoxymethylene polymer composition in an amount of at least about 0.1 wt.%, such as at least about 0.5 wt.%, such as at least about 0.75 wt.%, such as at least about 1 wt.%, such as at least about 2 wt.% and generally less than about 10 wt.%, such as less than about 5 wt.%, such as less than about 2.5 wt.%, such as less than about 2 wt.%, wherein the weight is based on the total weight of the polyoxymethylene polymer composition. In one embodiment, the composition may be substantially free of the boron nitride such that it is present in an amount of 0 wt.%.

[00080] In another embodiment, ultra-high molecular weight silicone (UHMW-Si) may be used to modify the polyoxymethylene polymer. In general, the UHMW-Si can have an average molecular weight of greater than 100,000 g/mol, such as greater than about 200,000 g/mol, such as greater than about 300,000 g/mol, such as greater than about 500,000 g/mol and less than about 3,000,000 g/mol, such as less than about 2,000,000 g/mol, such as less than about 1,000,000 g/mol, such as less than about 500,000 g/mol, such as less than about 300,000 g/mol. Generally, the UHMW-Si can have a kinematic viscosity at 40°C measured according to DIN 51562 of greater than 100,000 mm^2s^{-1} , such as greater than about 200,000 mm^2s^{-1} , such as greater than about 1,000,000 mm^2s^{-1} , such as greater than about 5,000,000 mm^2s^{-1} , such as greater than about 10,000,000

mm^2s^{-1} , such as greater than about $15,000,000 \text{ mm}^2\text{s}^{-1}$ and less than about $50,000,000 \text{ mm}^2\text{s}^{-1}$, such as less than about $25,000,000 \text{ mm}^2\text{s}^{-1}$, such as less than about $10,000,000 \text{ mm}^2\text{s}^{-1}$, such as less than about $1,000,000 \text{ mm}^2\text{s}^{-1}$, such as less than about $500,000 \text{ mm}^2\text{s}^{-1}$, such as less than about $200,000 \text{ mm}^2\text{s}^{-1}$.

[00081] The UHMW-Si may comprise a siloxane such as a polysiloxane or polyorganosiloxane. In one embodiment, the UHMW-Si may comprise a dialkylpolysiloxane such as a dimethylsiloxane, an alkylarylsiloxane such as a phenylmethylsiloxane, or a diarylsiloxane such as a diphenylsiloxane, or a homopolymer thereof such as a polydimethylsiloxane or a polymethylphenylsiloxane, or a copolymer thereof with the above molecular weight and/or kinematic viscosity requirements. The polysiloxane or polyorganosiloxane may also be modified with a substituent such as an epoxy group, a hydroxyl group, a carboxyl group, an amino group or a substituted amino group, an ether group, or a meth(acryloyl) group in the end or main chain of the molecule. The UHMW-Si compounds may be used singly or in combination. Any of the above UHMW-Si compounds may be used with the above molecular weight and/or kinematic viscosity requirements.

[00082] The UHMW-Si may be added to the polyoxymethylene polymer composition as a masterbatch wherein the UHMW-Si is dispersed in a polyoxymethylene polymer and the masterbatch is thereafter added to another polyoxymethylene polymer. The masterbatch may comprise from about 10 wt.% to about 50 wt.%, such as from about 25 wt.% to about 50 wt.%, such as from about 35 wt.% to about 45 wt.% of an UHMW-Si.

[00083] The UHMW-Si may be present in the polyoxymethylene polymer composition in an amount of at least about 0.1 wt.%, such as at least about 0.5 wt.%, such as at least about 0.75 wt.%, such as at least about 1 wt.%, such as at least about 2 wt.% and generally less than about 10 wt.%, such as less than about 6 wt.%, such as less than about 5 wt.%, such as less than about 4 wt.%, such as less than about 3.5 wt.%, such as less than about 3 wt.%, wherein the weight is based on the total weight of the polyoxymethylene polymer composition. In one embodiment, the composition may be substantially free of the UHMW-Si such that it is present in an amount of 0 wt.%.

[00084] According to another embodiment, boron nitride, such as hexagonal-boron nitride, and UHMW-Si may be utilized in combination to modify the polyoxymethylene polymer. The present inventors have discovered that when both tribological modifiers are used simultaneously, the combination provides a synergistic effect with a resulting polymer composition that exhibits improved tribological properties while maintaining or even improving the mechanical properties. In such embodiment, the boron nitride and UHMW-Si may be utilized in the polyoxymethylene polymer composition in the amounts disclosed above.

[00085] According to the present disclosure, the second polymer composition of the two-component system may comprise a polytetrafluoroethylene (PTFE). In one embodiment, the PTFE may be in the form of a powder. In another embodiment, the PTFE may be in the form of a fiber. The PTFE may be present in an amount of at least 0.1 wt.%, such as at least 1 wt.%, such as at least 5 wt.%, such as at least 10 wt.%, such as at least 15 wt.% and generally less than about 50 wt.%, such as less than about 40 wt.%, such as less than about 30 wt.%, such as less than about 25 wt.%, such as less than about 15 wt.%.

[00086] In another embodiment, the polyoxymethylene polymer composition of the two-component system may also comprise PTFE as described above. In still another embodiment, the second polymer composition may also comprise boron nitride, UHMW-Si, or a combination thereof as described above.

[00087] According to the present disclosure, various other tribological modifiers may be incorporated into the polyoxymethylene polymer composition or the second polymer composition. These tribological modifiers may include, for instance, calcium carbonate particles, ultrahigh-molecular weight polyethylene (UHMW-PE) particles, stearyl stearate particles, silicone oil, a polyethylene wax, an amide wax, wax particles comprising an aliphatic ester wax comprised of a fatty acid and a monohydric alcohol, a graft copolymer with an olefin polymer as a graft base, or a combination thereof. These tribological modifiers include the following:

[00088] (1) From 0.1-50 wt.%, such as from 1-25 wt.%, of a calcium carbonate particle such as a calcium carbonate (chalk) powder.

[00089] (2) From 0.1-50 wt.%, such as from 1-25 wt.%, such as from 2.5-20 wt.%, such as from 5 to 15 wt.%, of an ultrahigh-molecular weight polyethylene

(UHMW-PE) powder. UHMW-PE can be employed as a powder, in particular as a micro-powder. The UHMW-PE generally has a mean particle diameter D_{50} (volume based and determined by light scattering) in the range of 1 to 5000 μm , preferably from 10 to 500 μm , and particularly preferably from 10 to 150 μm such as from 30 to 130 μm , such as from 80 to 150 μm , such as from 30 to 90 μm .

[00090] The UHMW-PE can have an average molecular weight of higher than $1.0 \cdot 10^6$ g/mol, such as higher than $2.0 \cdot 10^6$ g/mol, such as higher than $4.0 \cdot 10^6$ g/mol, such as ranging from $1.0 \cdot 10^6$ g/mol to $15.0 \cdot 10^6$ g/mol, such as from $3.0 \cdot 10^6$ g/mol to $12.0 \cdot 10^6$ g/mol, determined by viscosimetry. Preferably, the viscosity number of the UHMW-PE is higher than 1000 ml/g, such as higher than 1500 ml/g, such as ranging from 1800 ml/g to 5000 ml/g, such as ranging from 2000 ml/g to 4300 ml/g (determined according to ISO 1628, part 3; concentration in decahydronaphthalin: 0.0002 g/ml).

[00091] (3) From 0.1-10 wt.%, such as from 0.1-5 wt.%, such as from 0.5-3 wt.%, of stearyl stearate.

[00092] (4) From 0.1-10 wt.%, such as from 0.5-5 wt.%, such as from 0.8-2 wt.%, of a silicone oil. Alternatively, in one embodiment, the composition may be substantially free of silicone oil, such as less than about 0.2 wt.%, such as less than about 0.1 wt.%, such as less than about 0.05 wt.%, such as less than about 0.01 wt.%, such as about 0 wt.%. . In another embodiment, the composition may not comprise a combination of silicone oil and UHMW-Si alone. In such embodiments, the composition may comprise UHMW-Si, silicone oil, and another tribological modifier, such as hexagonal boron nitride or PTFE.

[00093] When silicone oil is present in the composition, the silicone oil can have an average molecular weight of at least about 5,000 g/mol, such as at least about 20,000 g/mol, such as at least about 50,000 g/mol and generally less than 100,000 g/mol, such as less than about 75,000 g/mol, such as less than about 50,000 g/mol. The silicone oil can have a kinematic viscosity at 40°C measured according to DIN 51562 of greater than about $100 \text{ mm}^2\text{s}^{-1}$, such as greater than about $5,000 \text{ mm}^2\text{s}^{-1}$, such as greater than about $15,000 \text{ mm}^2\text{s}^{-1}$ and generally less than $100,000 \text{ mm}^2\text{s}^{-1}$, such as less than about $50,000 \text{ mm}^2\text{s}^{-1}$, such as less than about $25,000 \text{ mm}^2\text{s}^{-1}$, such as less than about $15,000 \text{ mm}^2\text{s}^{-1}$. The silicone oil may

comprise a liquid polysiloxane such as a polydimethylsiloxane at a room temperature of 25°C with the above molecular weight and/or kinematic viscosity specifications.

[00094] (5) From 0.1-5 wt.%, such as from 0.5-3 wt.%, of a polyethylene wax, such as an oxidized polyethylene wax.

[00095] (6) From 0.1-5 wt.%, such as from 0.2-2 wt.%, of an amide wax.

[00096] (7) From 0.1-5 wt.%, such as from 0.5-3 wt.%, of an aliphatic ester wax composed of a fatty acid and of a monohydric alcohol.

[00097] (8) From 0.1-50 wt.%, such as from 1-25 wt.%, such as from 2-10 wt.% by weight of a graft copolymer which has an olefin polymer as a graft base and, grafted on this, at least one vinyl polymer or one ether polymer, and/or a graft copolymer which has an elastomeric core based on polydienes and a hard graft envelope composed of (meth)acrylates and/or of (meth)acrylonitriles. A suitable graft base can be any olefin homopolymer (e.g., polyethylene or polypropylene) or copolymer or copolymers derived from copolymerizable ethylenically unsaturated monomers (e.g., ethylenepropylene copolymers, ethylene-1-butene copolymers, ethylene/glycidyl (meth)acrylate copolymers). Suitable graft monomers are any of the ethylenically unsaturated monomers having a polar group or other graftable monomers having polar groups that modify the polarity of the essentially non-polar graft base (e.g., ethylenically unsaturated carboxylic acids such as (meth)acrylic acid and derivatives thereof in combination with acrylonitrile or styrene/acrylonitrile, if appropriate). In one embodiment, the graft copolymer may comprise a polyethylene or polypropylene graft base grafted with acrylonitrile or with styrene/acrylonitrile.

[00098] In general, the tribological modifiers improve the tribological properties of the polyoxymethylene polymer composition and second polymer composition of the polyoxymethylene based system such as by reducing the coefficient of friction and wear when contacted with another surface, such as a polyethylene terephthalate surface. In addition, in some instances, the tribological modifiers may even improve upon the mechanical properties of the polyoxymethylene polymer composition and/or the second polymer composition.

[00099] According to the present disclosure, tribological modifiers improve the tribological properties of the compositions and the polyoxymethylene based systems without the need for an external lubricant, such as water-based or PTFE-based external lubricants, when utilized in tribological applications. An external lubricant may be a lubricant that is applied to a polymer article or polyoxymethylene based system of the present disclosure. In one embodiment, an external lubricant may not be associated with the polyoxymethylene based system or polymer article such that the external lubricant is not present on a surface of the polyoxymethylene based system or polymer article. In another embodiment, an external lubricant may be utilized with the polyoxymethylene based system and polymer article of the present disclosure.

[000100] Fiber Reinforcements

[000101] According to the present disclosure, the polyoxymethylene polymer composition of the two-component system may further comprise at least one reinforcing fiber. Additionally, according to the present disclosure, the second polymer composition of the two-component system may further comprise at least one reinforcing fiber.

[000102] The reinforcing fibers which may be used according to the present invention include mineral fibers, glass fibers, polymer fibers such as aramid fibers, metal fibers such as steel fibers, carbon fibers, or natural fibers. These fibers may be unmodified or modified, e.g. provided with a sizing or chemically treated, in order to improve adhesion to the polymer.

[000103] According to one embodiment, the reinforcing fibers comprise glass fibers. Glass fibers may be provided with a sizing to protect the glass fiber, to smooth the glass fiber, and to improve the adhesion between the glass fiber and the polymer matrix material. A sizing usually comprises silanes, film forming agents, lubricants, wetting agents, adhesives, optionally antistatic agents and plasticizers, emulsifiers and optionally further additives. Specific examples of silanes are aminosilanes. Film forming agents are, for example, polyvinylacetates, polyesters, and polyurethanes. Particularly suitable glass fibers are E-glass, A-glass, C-glass, D-glass, AR-glass, R-glass, S1-glass, S2-glass, etc., and

mixtures thereof. In one embodiment, the glass fibers may be chopped glass fibers or glass fiber rovings (tows).

[000104] The reinforcing fibers may be compounded into the polymer matrix, for example in an extruder or kneader. However, the reinforcing fibers may also advantageously take the form of continuous-filament fibers sheathed or impregnated with the polymer composition in a process suitable for this purpose, and then processed or wound up in the form of a continuous strand, or cut to a desired pellet length so that the fiber lengths and pellet lengths are identical. An example of a process particularly suitable for this purpose is the pultrusion process.

[000105] Fiber diameters can vary depending upon the particular fiber used and whether the fiber is in either a chopped or a continuous form. The fibers, for instance, can have a diameter of less than about 100 μm , such as less than about 50 μm . For instance, the fibers can be chopped or continuous fibers and can have a fiber diameter of from about 5 μm to about 100 μm , such as from about 5 μm to about 50 μm , such as from about 5 μm to about 15 μm . The fibers may also have a relatively high aspect ratio (average length divided by nominal diameter) to help improve the mechanical properties of the resulting polymer composition. For example, the fibers may have an aspect ratio of from about 2 to about 50, in some embodiments from about 4 to about 40, and in some embodiments, from about 5 to about 20.

[000106] When employed in the polymer composition, the reinforcing fibers may also help improve the strength. However, the relative amount of the reinforcing fiber in the polymer compositions may also be selectively controlled to help achieve the desired mechanical properties without adversely impacting other properties of the composition, such as its flowability. For example, when present, the respective composition may contain reinforcing fibers in an amount of at least 1 wt.%, such as at least 5 wt.%, such as at least 7 wt.%, such as at least 10 wt.%, such as at least 15 wt.% and generally less than about 50 wt.%, such as less than about 45 wt.%, such as less than about 40 wt.%, such as less than about 30 wt.%, such as less than about 20 wt.%, wherein the weight is based on the total weight of the respective polyoxymethylene or second polymer composition.

[000107] Other Additives

[000108] The polymer compositions of the present disclosure may also contain other known additives such as, for example, antioxidants, formaldehyde scavengers, acid scavengers, UV stabilizers or heat stabilizers. In addition, the compositions can contain processing auxiliaries, for example adhesion promoters, lubricants, nucleants, demolding agents, fillers, or antistatic agents and additives which impart a desired property to the compositions and articles or parts produced therefrom.

[000109] In one embodiment, an ultraviolet light stabilizer may be present. The ultraviolet light stabilizer may comprise a benzophenone, a benzotriazole, or a benzoate. The UV light absorber, when present, may be present in the polymer composition in an amount of at least about 0.01 wt.%, such as at least about 0.05 wt.%, such as at least about 0.075 wt.% and less than about 1 wt.%, such as less than about 0.75 wt.%, such as less than about 0.5 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000110] In one embodiment, a formaldehyde scavenger, such as a nitrogen-containing compound, may be present. Mainly, of these are heterocyclic compounds having at least one nitrogen atom as hetero atom which is either adjacent to an amino-substituted carbon atom or to a carbonyl group, for example pyridine, pyrimidine, pyrazine, pyrrolidone, aminopyridine and compounds derived therefrom. Other particularly advantageous compounds are triamino-1,3,5-triazine (melamine) and its derivatives, such as melamine-formaldehyde condensates and methylol melamine. Oligomeric polyamides are also suitable in principle for use as formaldehyde scavengers. The formaldehyde scavenger may be used individually or in combination.

[000111] Further, the formaldehyde scavenger can be a guanamine compound which can include an aliphatic guanamine-based compound, an alicyclic guanamine-based compound, an aromatic guanamine-based compound, a hetero atom-containing guanamine-based compound, or the like. The formaldehyde scavenger may be present in the polymer composition in an amount of at least about 0.01 wt.%, such as at least about 0.05 wt.%, such as at least about 0.075 wt.% and less than about 1 wt.%, such as less than about 0.75 wt.%, such as less

than about 0.5 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000112] In one embodiment, an acid scavenger may be present. The acid scavenger may comprise, for instance, an alkaline earth metal salt. For instance, the acid scavenger may comprise a calcium salt, such as a calcium citrate. The acid scavenger may be present in an amount of at least about 0.001 wt.%, such as at least about 0.005 wt.%, such as at least about 0.0075 wt.% and less than about 1 wt.%, such as less than about 0.75 wt.%, such as less than about 0.5 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000113] In one embodiment, a nucleant may be present. The nucleant may increase crystallinity and may comprise an oxymethylene terpolymer. In one particular embodiment, for instance, the nucleant may comprise a terpolymer of butanediol diglycidyl ether, ethylene oxide, and trioxane. The nucleant may be present in the composition in an amount of at least about 0.01 wt.%, such as at least about 0.05 wt.%, such as at least about 0.1 wt.% and less than about 2 wt.%, such as less than about 1.5 wt.%, such as less than about 1 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000114] In one embodiment, an antioxidant, such as a sterically hindered phenol, may be present. Examples which are available commercially, are pentaerythrityl tetrakis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate], triethylene glycol bis[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propionate], 3,3'-bis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionohydrazide], and hexamethylene glycol bis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate]. The antioxidant may be present in the polymer composition in an amount of at least about 0.01 wt.%, such as at least about 0.05 wt.%, such as at least about 0.075 wt.% and less than about 1 wt.%, such as less than about 0.75 wt.%, such as less than about 0.5 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000115] In one embodiment, a light stabilizer, such as a sterically hindered amine, may be present in addition to the ultraviolet light stabilizer. Hindered amine light stabilizers that may be used include oligomeric hindered amine compounds that are N-methylated. For instance, hindered amine light stabilizer may comprise

a high molecular weight hindered amine stabilizer. The light stabilizers, when present, may be present in the polymer composition in an amount of at least about 0.01 wt.%, such as at least about 0.05 wt.%, such as at least about 0.075 wt.% and less than about 1 wt.%, such as less than about 0.75 wt.%, such as less than about 0.5 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000116] In one embodiment, a lubricant, not including the tribological modifiers mentioned above, may be present. The lubricant may comprise a polymer wax composition. Further, in one embodiment, a polyethylene glycol polymer (processing aid) may be present in the composition. The polyethylene glycol, for instance, may have a molecular weight of from about 1000 to about 5000, such as from about 3000 to about 4000. In one embodiment, for instance, PEG-75 may be present. Lubricants may generally be present in the polymer composition in an amount of at least about 0.01 wt.%, such as at least about 0.05 wt.%, such as at least about 0.075 wt.% and less than about 1 wt.%, such as less than about 0.75 wt.%, such as less than about 0.5 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000117] In one embodiment, a compatibilizer, such as a phenoxy resin, may be present. Generally, the phenoxy resin may be present in the composition in an amount of at least about 0.01 wt.%, such as at least about 0.05 wt.%, such as at least about 0.075 wt.% and less than about 1 wt.%, such as less than about 0.75 wt.%, such as less than about 0.5 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000118] In one embodiment, a colorant may be present. Colorants that may be used include any desired inorganic pigments, such as titanium dioxide, ultramarine blue, cobalt blue, and other organic pigments and dyes, such as phthalocyanines, anthraquinones, and the like. Other colorants include carbon black or various other polymer-soluble dyes. The colorant may be present in the composition in an amount of at least about 0.01 wt.%, such as at least about 0.05 wt.%, such as at least about 0.1 wt.% and less than about 5 wt.%, such as less than about 2.5 wt.%, such as less than about 1 wt.%, wherein the weight is based on the total weight of the respective polymer composition.

[000119] Polymer Articles

[000120] The compositions of the present disclosure can be compounded and formed into a polymer article using any technique known in the art. For instance, the respective composition can be intensively mixed to form a substantially homogeneous blend. The blend can be melt kneaded at an elevated temperature, such as a temperature that is higher than the melting point of the polymer utilized in the polymer composition but lower than the degradation temperature.

Alternatively, the respective composition can be melted and mixed together in a conventional single or twin screw extruder. Preferably, the melt mixing is carried out at a temperature ranging from 100 to 280°C, such as from 120 to 260°C, such as from 140 to 240°C or 180 to 220°C. However, such processing should be conducted for each respective composition at a desired temperature to minimize any polymer degradation.

[000121] After extrusion, the compositions may be formed into pellets. The pellets can be molded into polymer articles by techniques known in the art such as injection molding, thermoforming, blow molding, rotational molding and the like. According to the present disclosure, the polymer articles demonstrate excellent tribological behavior and mechanical properties. Consequently, the polymer articles can be used for several applications where low wear and excellent gliding properties are desired.

[000122] Polymer articles include any moving articles or moldings that are in contact with another surface and may require high tribological requirements. For instance, polymer articles include articles for the automotive industry, especially housings, latches such as rotary latches, window winding systems, wiper systems, pulleys, sun roof systems, seat adjustments, levers, bushes, gears, gear boxes, claws, pivot housings, wiper arms, brackets or seat rail bearings, zippers, switches, cams, rollers or rolling guides, sliding elements or glides such as sliding plates, conveyor belt parts such as chain elements and links, castors, fasteners, levers, conveyor system wear strips and guard rails. An almost limitless variety of polymer articles may be formed from the polymer compositions of the present disclosure.

[000123] According to the present disclosure, the polyoxymethylene based system can be used to produce a polymer article comprising two layers to provide at least a two-component system. In such system, the second polymer layer is connected to the first polymer layer.

[000124] The first polymer layer is comprised of a polyoxymethylene polymer composition comprising a polyoxymethylene polymer and optionally at least one tribological modifier. In general, the first polymer layer provides a support or base for the second polymer layer. The second polymer layer is comprised of a second polymer composition comprising a liquid crystalline polymer, a polyarylene sulfide polymer, or a combination thereof and at least one tribological modifier. In general, the second polymer layer provides a surface for contacting and/or conveying against another body to provide a tribological effect. The second polymer layer may contact a sliding body such as a bottle or a container.

[000125] The first polymer layer and/or the second polymer layer may contain engaging mechanisms allowing one article to be connected to an adjacent article. Such mechanisms include but are not limited to a pin or the like. It should be noted that any engaging mechanisms in the art may be utilized to engage adjacent articles.

[000126] Further, the first polymer layer can be connected to the second polymer layer using any method known in the art. For instance, the polymer layers may be connected to one another such that they are directly or indirectly connected or linked. The layers may be fixedly or removably attached to one another and/or an intermediate layer. The layers may be connected using any method known in the art. The polymer layers may be connected by interlocking mechanisms, fasteners, co-molding, overmolding, intermediate layers, adhesives, etc.

[000127] The interlocking mechanism may include a male member and a female member for accepting the male member, such as grooves and plugs. The male member or groove and/or female member or plug may be located on either the first or second polymer layer. It should also be understood that these members may be of any shape or configuration as long as they provide an interlocking mechanism. It should also be understood that more than one interlocking mechanism may be utilized. The members may be formed into the respective

layers and subsequently combined to form the polymer article. On the other hand, a member may be created in one layer and the other layer may be injection molded to provide the corresponding interlocking part comprising a member. For instance, in one embodiment, the first polymer layer can be connected to the second polymer layer during a two-component injection molding process.

[000128] In another embodiment, the first polymer layer may be connected to the second polymer layer using a fastener, such as a mechanical fastener. Fasteners include screws, nails, rivets, snaps, and the like and others generally known in the art. The fastener can be inserted through either the first polymer layer or the second polymer layer in order to attach or connect the polymer layers together. It should also be understood that any number of fasteners may be utilized for connecting the polymer layers.

[000129] In one embodiment, the first polymer layer is in direct contact and connected to the second polymer layer. In another embodiment, the first polymer layer is in indirect contact and connected to the second polymer layer. For instance, an intermediate layer may also be utilized to connect the polymer layers. For instance, an intermediate layer may be utilized individually or in conjunction with an interlocking mechanism or a fastener as described above.

[000130] In another embodiment, the second polymer layer may be overmolded onto the first polymer layer. The second polymer layer may entirely overmold or partially overmold the first polymer layer. However, it should be understood that any overmolding configuration may be utilized as long as the second polymer layer generally provides a surface for contacting and conveying against another body to provide a tribological effect. In addition, when overmolding, it should be understood that either the first polymer layer or second polymer layer may employ engaging mechanisms. It should be understood that any method of overmolding known in the art may be utilized to connect the second polymer layer with the first polymer layer.

[000131] In one embodiment, the second polymer layer overlays or covers at least 50%, such as at least 75%, such as at least 85%, such as at least 90%, such as at least 95% of at least one surface of the first polymer layer. In one embodiment,

the second polymer overlays or covers 100% of at least one surface of the first polymer layer.

[000132] In general, the second polymer may have a thickness of at least about 0.01 mm, such as at least about 0.02 mm, such as at least about 0.1 mm, such as at least about 0.5 mm, such as at least about 0.75 mm, such as at least about 1 mm and generally less than about 10 mm, such as less than about 7.5 mm, such as less than about 5 mm, such as less than about 3 mm.

[000133] According to one embodiment of the present disclosure, the polymer article can be a conveyor component, such as a conveyor chain component. Generally, conveyor chains are made from a series of links having generally flat surfaces wherein the links may be connected to each other by pins. General examples of such conveyor components are disclosed in U.S. Patent No. 5,309,705 to Takahashi et al., U.S. Patent No. 6,161,685 to Stebnicki, and U.S. Patent No. 4,436,200 to Hodlewsky et al., which are all incorporated herein by reference in their entirety.

[000134] In one embodiment, the conveyor component may be a conveyor chain link. As shown in Figure 1, a conveying system **10** is comprised of a conveyor belt **12**. The conveyor belt **12** is comprised of conveyor components **14**. The conveyor belt **12** and conveyor components **14** are used to transport items **16** such as packages, containers, and the like. According to the present disclosure, the conveyor components **14** may exist as a two-component system.

[000135] For instance, as shown in Figure 2, the polymer article may be a conveyor component **14** that exists as a two-component system **34**. Figure 2 exhibits a general characterization of a two-component system. According to the two-component system, the second polymer layer **22** is connected to the first polymer layer **24**. In Figure 2, a second polymer layer **22** overlays a first polymer layer **24** such that the second polymer layer **22** covers an entire surface of the first polymer layer **24**. However, the second polymer layer **22** may partially overlay the first polymer layer **24** such that the second polymer layer **22** only partially covers a surface of the first polymer layer **24**.

[000136] The first polymer layer **24** is comprised of a polyoxymethylene polymer composition comprising a polyoxymethylene polymer and optionally at least one

tribological modifier. In general, the first polymer layer **24** provides a support or base for the second polymer layer **22**. The second polymer layer **22** is comprised of a second polymer composition comprising a liquid crystalline polymer or a polyarylene sulfide polymer and at least one tribological modifier. In general, the second polymer layer **22** provides a surface for contacting and conveying a sliding body or container such as a plastic or glass bottle.

[000137] According to Figure 2, the engaging mechanisms **18** and **20** are located on the first polymer layer **24**. However, it should be understood that engaging mechanisms **18** and **20** may be located on second polymer layer **22** or on both polymer layers **22** and **24**. Engaging mechanisms **18** and **20** of adjacent components **14** can be connected using a pin (not shown) or the like to create a conveyor belt as shown in Figure 1. It should be understood that any engaging mechanisms **18** and **20** known in the art can be utilized to engage adjacent conveyor components **14**.

[000138] According to Figures 3a and 3b, first polymer layer **24** can be connected to the second polymer layer **22** using an interlocking mechanism **26** such as a male member **28** or a groove **28** and a female member **30** or a plug **30**. As shown in Figure 3a, the first polymer layer **24** may comprise a male member/groove **28** while the second polymer layer comprises a female member **30**. However, as shown in Figure 3b, the first polymer layer **24** may comprise a female member **30** while the second polymer layer **22** comprises a male member **28**. It should also be understood that the male member and female member may be of any shape or configuration as long as they provide an interlocking mechanism **26**. It should also be understood that more than one interlocking mechanism may be utilized.

[000139] When an interlocking mechanism **26** is used to connect the first polymer layer **24** with second polymer layer **22**, the male member **28** or female member **30** may be formed into the respective layers and subsequently combined to form a conveyor component **14**. On the other hand, a male member **28** or female member **30** may be created in one layer and the other layer may be injection molded to provide the corresponding interlocking part comprising a male member **28** or female member **30**. For instance, in one embodiment, the first polymer layer

24 can be connected to the second polymer layer **22** during a two-component injection molding process.

[000140] In another embodiment, as shown in Figure 4, the first polymer layer **24** may be connected to the second polymer layer **22** using a fastener **36**. Fasteners include screws, nails, snaps, and the like. According to Figure 4, the fastener **36** is inserted through the second polymer layer **22** and into the first polymer layer **24**. However, the fastener **36** may also be inserted through the first polymer layer **24** and into the second polymer layer **22**. It should also be understood that any number of fasteners **36** may be utilized for connecting the polymer layers.

[000141] In another embodiment, as shown in Figures 5a and 5b, the second polymer layer **22** may be overmolded onto the first polymer layer **24**. As shown in Figure 5a, the second polymer layer **22** entirely overmolds the first polymer layer **24**. As shown in Figure 5b, the second polymer layer **22** partially overmolds the first polymer layer **24**. However, it should be understood that any overmolding configuration may be utilized as long as the second polymer layer **24** generally provides a surface for contacting and conveying a sliding body or container such as a plastic or glass bottle. In addition, when overmolding, it should be understood that either the first polymer layer **24** or second polymer layer **22** may employ engaging mechanisms **18** and **20**. It should be understood that any method of overmolding known in the art may be utilized to connect the second polymer layer **22** with the first polymer layer **24**.

[000142] Properties

[000143] Utilizing the polyoxymethylene based system according to the present disclosure provides compositions and articles with improved tribological properties. According to the present disclosure, the tribological properties are generally measured by the coefficient of friction.

[000144] In general, static friction is the friction between two or more surfaces that are not moving relative to each other (ie., both objects are stationary). In general, dynamic friction occurs when two objects are moving relative to each other (ie., at least one object is in motion). In addition, stick-slip is generally known as a phenomenon caused by continuous alternating between static and dynamic friction.

[000145] According to the present disclosure, the polymer article of the two-component system may exhibit a static coefficient of friction against another surface, as determined according to VDA 230-206, of greater than about 0.01, such as greater than about 0.03, such as greater than about 0.05, such as greater than about 0.08, such as greater than about 0.1 but generally less than about 0.18, such as less than about 0.15, such as less than about 0.12, such as less than about 0.1. In one embodiment in particular, the second polymer layer of the polymer article may exhibit the aforementioned static coefficient of friction.

[000146] According to the present disclosure, the polymer article of the two-component system may exhibit a dynamic coefficient of friction against another surface, as determined according to VDA 230-206, of greater than about 0.01, such as greater than about 0.03, such as greater than about 0.05, such as greater than about 0.08, such as greater than about 0.1 but generally less than about 0.18, such as less than about 0.15, such as less than about 0.12, such as less than about 0.1. In one embodiment in particular, the second polymer layer of the polymer article may exhibit the aforementioned dynamic coefficient of friction.

[000147] In one embodiment, the above static coefficient of friction and dynamic coefficient of friction values are exhibited between the polymer article, such as the second polymer layer, of the two-component system and various counter-materials. For instance, the above values can be exhibited between the polymer article, such as the second polymer layer, of the two-component system and a polyester surface such as a polyethylene terephthalate surface. In another embodiment, the above values are exhibited between the polymer article, such as the second polymer layer, of the two-component system and a polyacetal surface, a metal surface such as a steel surface, or a polyolefin surface such as a polypropylene surface or a polyethylene surface such as an ultra-high molecular weight polyethylene surface.

[000148] The present disclosure may be better understood with reference to the following example.

EXAMPLES

[000149] The examples of the invention are given below by way of illustration and not by way of limitation. The following experiments were conducted in order to show some of the benefits and advantages of the present invention.

[000150] The compositions comprise either a liquid crystalline polymer or a polyphenylene sulfide polymer and at least one tribological modifier such as polytetrafluoroethylene. In addition, glass fibers were also utilized in the compositions. The formulations are disclosed in the table below.

[000151] The components of each respective polymer composition were substantially and homogeneously blended and compounded using a co-rotating intermeshing twin screw extruder. When glass fibers were utilized, they were added to the twin-screw extruder at a suitable downstream feeding position. The respective compositions were extruded, pelletized, and then molded using an injection molding machine.

[000152] The molded compositions were then tested to determine the tribological properties against a polyethylene terephthalate surface. Stick-slip tests were conducted to determine the dynamic coefficient of friction and the static coefficient of friction. Stick-slip tests were conducted according to VDA 230-206. A ball-on-plate configuration was utilized with a load of 10 N, sliding speed of 8 mm/s, and a test duration of 8-45 minutes.

[000153] New polymer layers or molds were tested after injection molding. Used polymer layers or molds were produced by abrading a new polymer mold with sand paper in order to simulate a used mold or article.

		Sample 1	Sample 2	Sample 3	Comparative Sample 1
POM (wt. %) (HF C9021)		0	0	0	100
LCP (wt. %)		75	65	0	0
PPS (wt. %)		0	0	52.5	0
PTFE (wt. %)		25	20	7.5	0
Glass fibers (wt. %)		0	15	40	0
Used Mold	Dynamic CoF	0.070	0.067	0.082	0.107
	Static CoF	0.076	0.079	0.094	0.116
New Mold	Dynamic CoF	0.075	0.088	0.094	0.134
	Static CoF	0.098	0.101	0.112	0.145

[000154] These and other modifications and variations to the present invention may be practiced by those of ordinary skill in the art, without departing from the spirit and scope of the present invention, which is more particularly set forth in the appended claims. In addition, it should be understood that aspects of the various embodiments may be interchanged both in whole or in part.

[000155] Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only, and is not intended to limit the invention so further described in such appended claims.

CLAIMS

1. A polymer article comprising:
a first polymer layer comprising a polyoxymethylene polymer composition comprising
a polyoxymethylene polymer, and
5 optionally, at least one tribological modifier;
a second polymer layer connected to the first polymer layer, the second polymer layer comprising a second polymer composition, the second polymer composition comprising
a liquid crystalline polymer, a polyarylene sulfide polymer, or a
10 combination thereof, and
at least one tribological modifier.
2. The polymer article according to claim 1, wherein the tribological modifier in the second polymer composition comprises a polytetrafluoroethylene.
3. The polymer article of claim 2, wherein the polytetrafluoroethylene is present in an amount of from about 1 wt.% to about 40 wt.%.
4. The polymer article according to any one of the preceding claims, wherein the second polymer composition further comprises glass fibers.
5. The polymer article according to any one of the preceding claims, wherein the polyoxymethylene polymer composition comprises a tribological modifier selected from the group consisting of boron nitride, ultra-high molecular weight silicone, or a combination thereof.
6. The polymer article according to any one of the preceding claims, wherein the polyoxymethylene polymer composition comprises a tribological modifier selected from the group consisting of calcium carbonate, ultrahigh-molecular weight polyethylene, stearyl stearate, silicone oil, polyethylene wax,
5 amide wax, or a combination thereof.
7. The polymer article according to any one of the preceding claims, wherein the liquid crystalline polymer contains aromatic ester repeating units.
8. The polymer article according to claim 7, wherein the aromatic ester repeating units comprise aromatic dicarboxylic acid repeating units, aromatic hydroxycarboxylic acid repeating units, or a combination thereof.

9. The polymer article according to any one of the preceding claims, wherein the liquid crystalline polymer repeating units comprise units formed from a hydroxycarboxylic acid, a dicarboxylic acid, and an aromatic diol.

10. The polymer article according to any one of the preceding claims, wherein the polyarylene sulfide polymer is a polyphenylene sulfide polymer.

11. The polymer article according to any one of the preceding claims, wherein the first polymer layer and the second polymer layer are connected by an interlocking mechanism.

12. The polymer article according to any one of claims 1 to 10, wherein the first polymer layer and the second polymer layer are connected by overmolding.

13. The polymer article according to any one of claims 1 to 10, wherein the first polymer layer and the second polymer layer are connected by a fastener.

14. The polymer article according to any one of the preceding claims, wherein the first polymer layer is in contact with the second polymer layer.

15. The polymer article according to any one of the preceding claims, wherein the second polymer layer covers at least 85% of the surface area of one surface of the first polymer layer.

16. The polymer article according to any one of the preceding claims, wherein the second polymer layer has a thickness of from about 0.01 mm to about 5 mm.

17. The polymer article according to any one of the preceding claims, wherein the polymer article exhibits a dynamic coefficient of friction against a polyethylene terephthalate surface of from about 0.01 to about 0.18 as determined in accordance with VDA 230-206.

18. The polymer article according to any one of the preceding claims, wherein the polymer article exhibits a dynamic coefficient of friction against a polyacetal surface, a steel surface, a polyethylene surface, or a polypropylene surface of from about 0.01 to about 0.18 as determined in accordance with VDA
5 230-206.

19. The polymer article according to any one of the preceding claims, wherein the polymer article is a conveyor component.

20. The polymer article according to any one of the preceding claims, wherein an external lubricant is not present on a surface of the polymer article.

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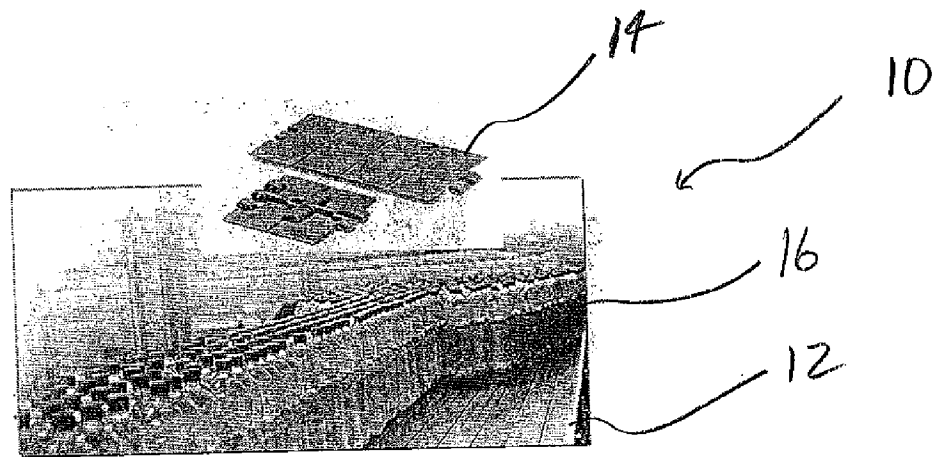


Figure 1

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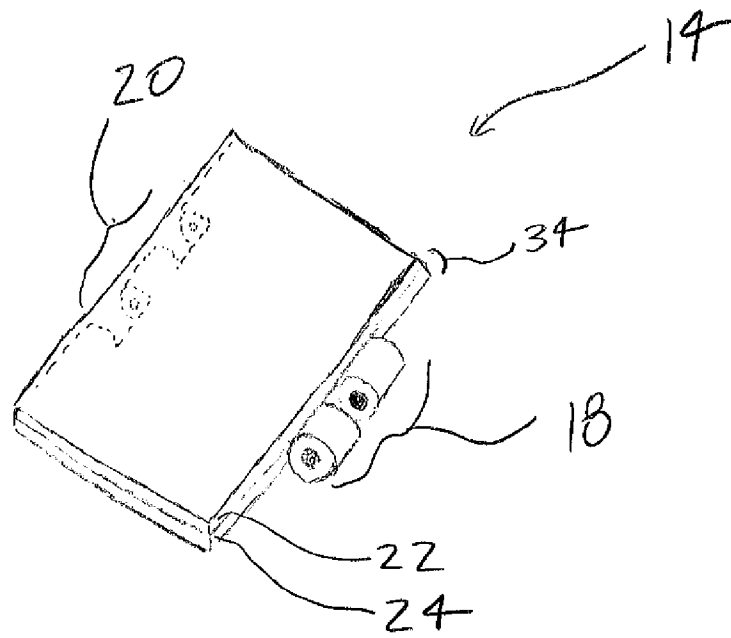


Figure 2

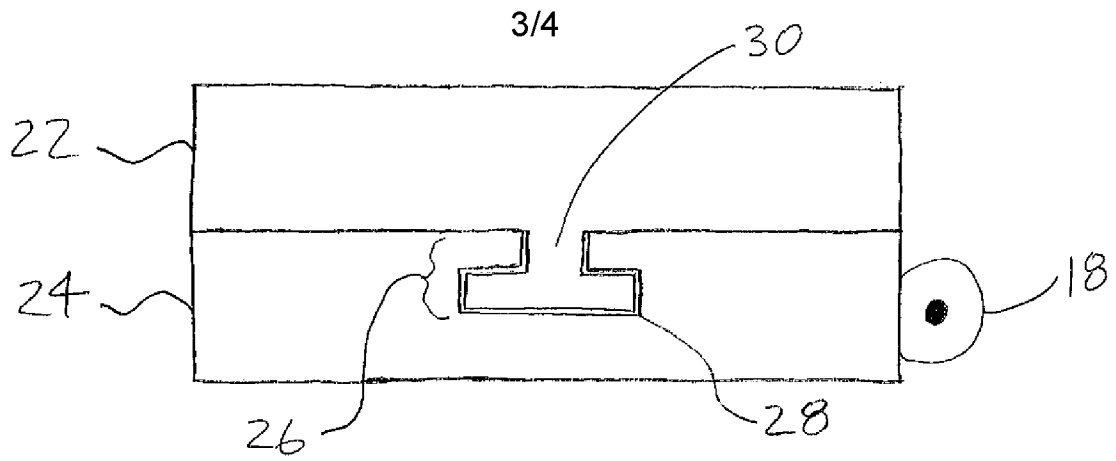


Figure 3a

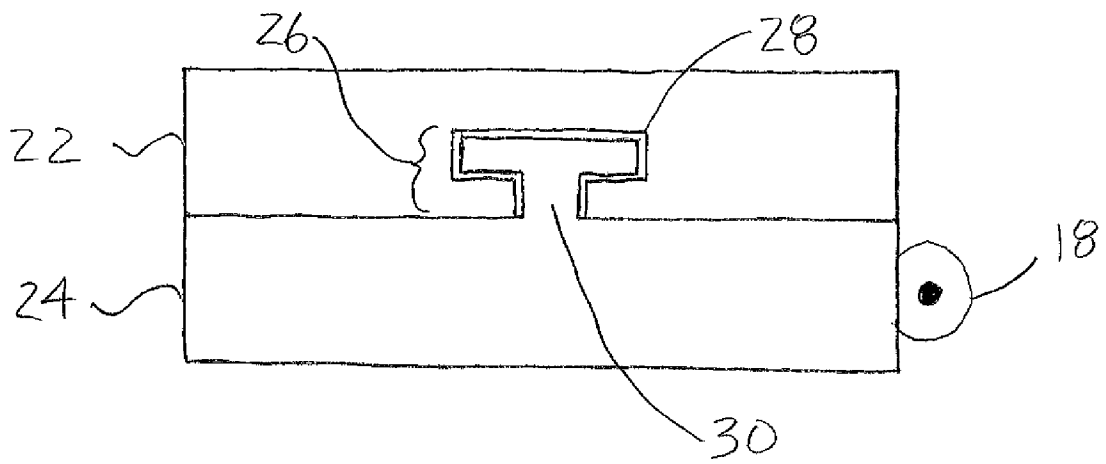


Figure 3b

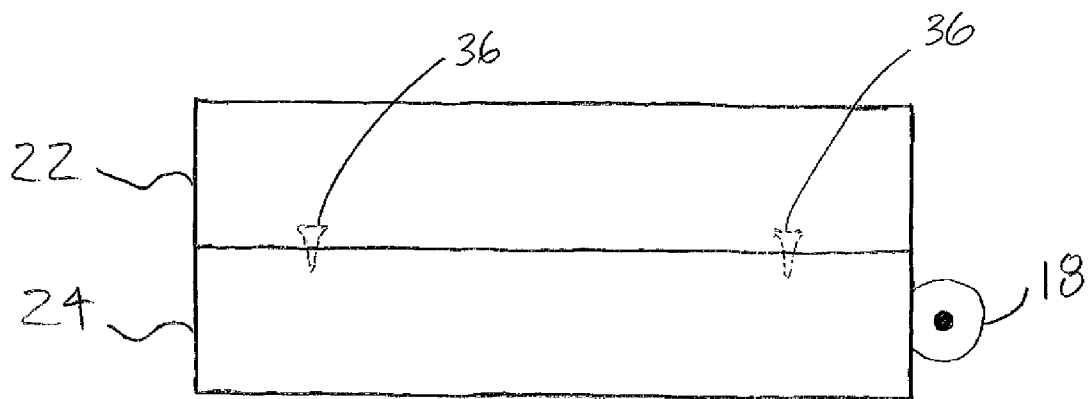


Figure 4

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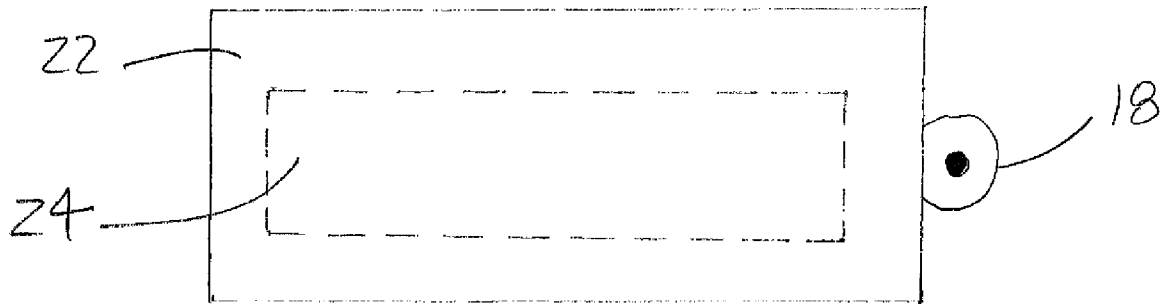


Figure 5a

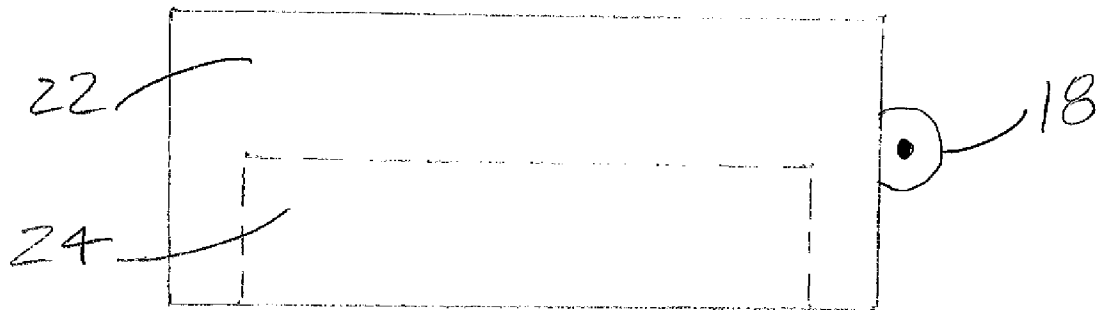


Figure 5b

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2014/065223

A. CLASSIFICATION OF SUBJECT MATTER

INV. B32B27/28 B32B27/42
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B32B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 43 11 634 A1 (RABE THORE [DE]) 14 October 1993 (1993-10-14) claims 1,17	1-20
Y	----- WO 2004/058866 A1 (DU PONT [US]) 15 July 2004 (2004-07-15) page 1, lines 8-12 page 3, lines 8-13 page 5, lines 1-7	1-20
Y	----- DE 10 2004 057190 A1 (FRENZELIT WERKE GMBH & CO KG [DE]) 1 June 2006 (2006-06-01) paragraph [0001] claims 1,6,8,9 paragraph [0020] -----	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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