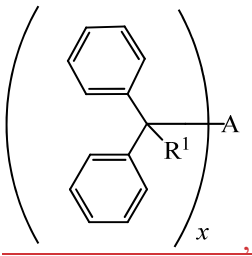
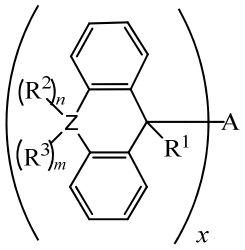
effectively operate as sealing components, seal connectors and similar parts. The cross-linking compounds must be useful for operation at high service temperatures associated with oilfield and other harsh conditions and industrial uses, while still maintaining good mechanical performance, resisting extrusion of the seal or connector material into a gap between two surfaces to be sealed or along the pin, and resisting creep when in use without becoming brittle and significantly losing its ductility.

BRIEF SUMMARY ~~OF THE INVENTION~~

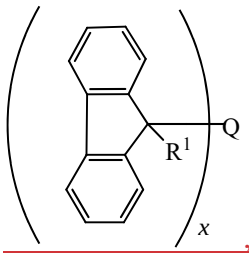
[0048a] In one aspect of the present disclosure, there is provided a cross-linking composition comprising a cross-linking compound for cross-linking an organic polymer, wherein the cross-linking compound is selected from the group consisting of:



, (II)



, and (I)



, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-

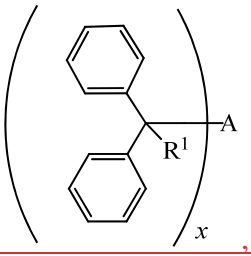
NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0.

[0048b] In another aspect of the present disclosure, there is provided a molded article formed from the cross-linking composition disclosed herein.

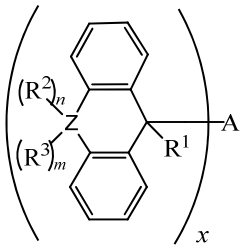
[0048c] In a further aspect of the present disclosure, there is provided an article of manufacture formed from the composition disclosed herein, wherein the article of manufacture is selected from acid-resistant coatings, chemical-casted films, extruded films, solvent-casted films, blown films, encapsulated products, insulation, packaging, composite cells, connectors, and sealing assemblies in the shape of O-rings, V-rings, U-cups, gaskets, bearings, valve seats, adapters, wiper rings, chevron back-up rings, and tubing.

[0048d] In another aspect of the present disclosure, there is provided a method of controlling the cross-linking reaction rate of a cross-linking compound for use in cross-linking an organic polymer, comprising:

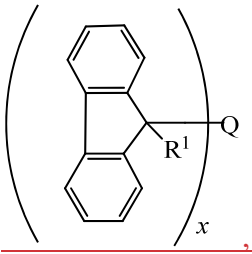
(a) providing a cross-linking composition comprising at least one cross-linking compound and a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking compound has one or more of the following structures:



, (II)



, and (I)



, (III)

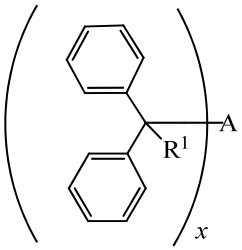
wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0; and

(b) heating the cross-linking composition such that oligomerization of the cross-linking compound occurs.

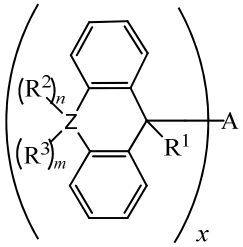
[0048e] In a further aspect of the present disclosure, there is provided an organic polymer composition for use in forming a cross-linked organic polymer, comprising:

a dehalogenated organic polymer, and

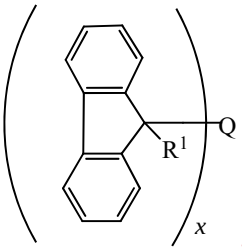
at least one cross-linking compound having a structure selected from the group consisting of:



, (II)



, and (I)



, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0; and

wherein the dehalogenated organic polymer is formed by a process comprising reacting an organic polymer having at least one halogen-containing reactive group with an alkali metal compound to break a bond between the organic polymer having the at least one halogen-containing reactive group and a halogen atom in the at least one halogen containing reactive group to form an intermediate.

[0048f] In another aspect of the present disclosure, there is provided a molded article formed using the organic polymer composition disclosed herein.

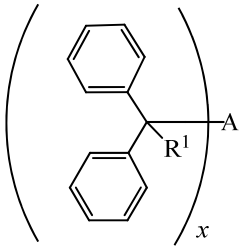
[0048g] In a further aspect of the present disclosure, there is provided an article of manufacture formed from the composition disclosed herein, wherein the article of manufacture is selected from acid-resistant coatings; chemical-casted films; extruded films; solvent-casted films; blown films; encapsulated products; insulation; packaging; composite cells; connectors; sealing assemblies, including O-rings, V-rings, U-cups, gaskets; bearings; valve seats; adapters; wiper rings; chevron back-up rings; and tubing.

[0048h] In another aspect of the present disclosure, there is provided a method of controlling the cross-linking reaction rate of an organic polymer having at least one halogen-containing reactive group during a cross-linking reaction, comprising:

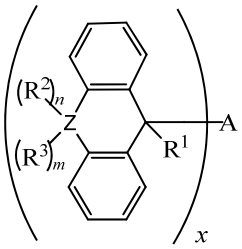
(a) reacting the organic polymer having at least one halogen-containing reactive group with an alkali metal compound to break a bond between the organic polymer having the at least one halogen-containing reactive group and a halogen atom in the at least one halogen-containing reactive group, and to form an intermediate having a carbocation;

(b) reacting the intermediate having the carbocation with acetic acid to form a dehalogenated organic polymer; and

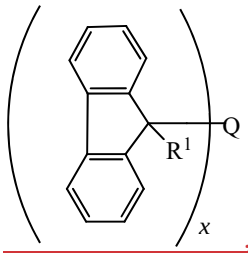
(c) cross-linking the dehalogenated organic polymer using a cross-linking reaction comprising a cross-linking compound selected from the group of:



, (II)



, and (I)



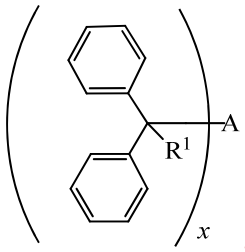
, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0.

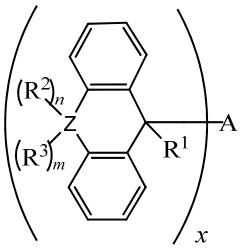
[0048i] In a further aspect of the present disclosure, there is provided a method of preparing an elastomeric material, comprising

(a) providing an aromatic polymer which is nonelastomeric at room temperature;

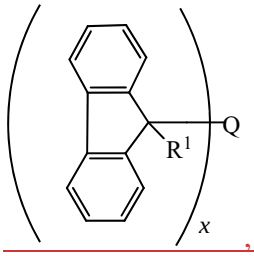
(b) cross-linking the aromatic polymer using a cross-linking compound to form a cross-linked aromatic polymer that is substantially cured, wherein the cross-linking compound has a structure selected from the group consisting of:



, (II)



, and (I)



, (III)

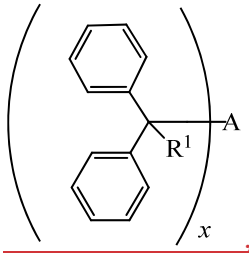
wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0; and

(c) heating the cross-linked aromatic polymer to a temperature at or above a glass transition temperature of the cross-linked aromatic polymer.

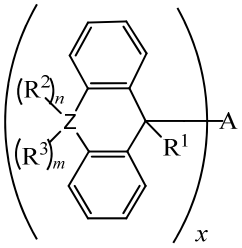
[0048j] In another aspect of the present disclosure, there is provided an elastomeric article formed by the method disclosed herein.

[0048k] In a further aspect of the present disclosure, there is provided a method of using an organic polymer that is not elastomeric at room temperature in an elastomeric application, comprising

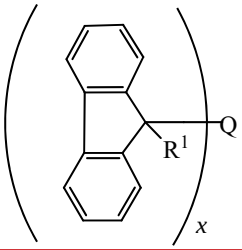
cross-linking the organic polymer using a cross-linking compound to form a cross-linked organic polymer to substantially cure the aromatic polymer, wherein the cross-linking compound has a structure selected from the group consisting of:



, (II)



, and (I)



, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is

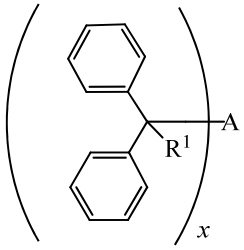
from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0; and

heating the cross-linked polymer in use at or above a glass transition temperature of the cross-linked polymer such that it becomes elastomeric.

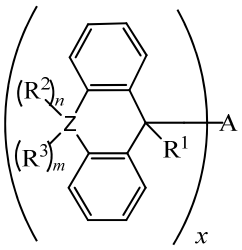
[0048l] In another aspect of the present disclosure, there is provided a method of preparing an elastomeric material, comprising:

(a) providing an aromatic polymer which is non-elastomeric at room temperature;

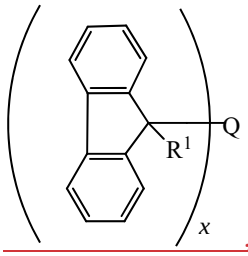
(b) cross-linking the aromatic polymer using a cross-linking compound to form a cross-linked aromatic polymer, wherein the cross-linking compound has a structure selected from the group consisting of:



, (II)



, and (I)



, (III)

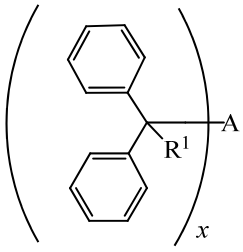
wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or

different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0;

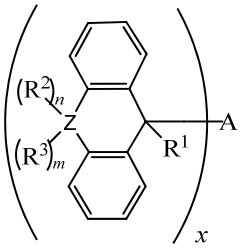
(c) heating the cross-linked aromatic polymer to a temperature at or above a glass transition temperature of the cross-linked aromatic polymer.

[0048m] In a further aspect of the present disclosure, there is provided a method of improving extrusion- and creep-resistance of a component for use in a high temperature sealing element or seal connector, comprising,

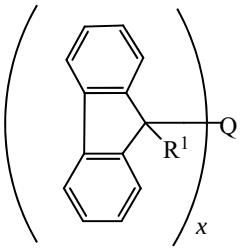
providing a composition comprising an aromatic polymer and a cross-linking compound, wherein the cross-linking compound has a structure selected from the group consisting of:



, (II)



, and (I)



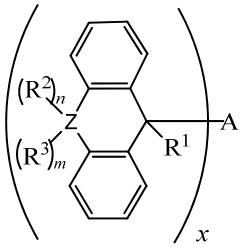
, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0;

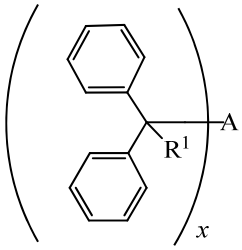
subjecting the composition to a heat molding process to form the component and cross-link the aromatic polymer.

[0048n] In another aspect of the present disclosure, there is provided a sealing component formed by the method disclosed herein.

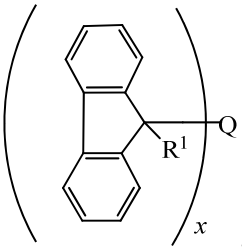
[0049] The present ~~invention~~disclosure provides a cross-linking composition for cross-linking an organic polymer, comprising a cross-linking compound having a structure according to one or more of the following formulas:



, (I)



, and (II)



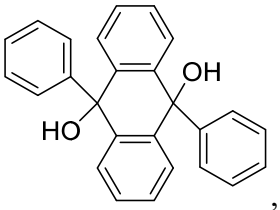
, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine (-NH_2), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein

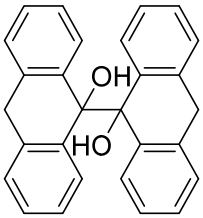
Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0.

[0050] In some ~~embodiment~~examples, the cross-linking composition may comprise a blend of one or more cross-linking compounds selected from formulas (I), (II), and (III). Further, in other ~~embodiment~~examples, the cross-linking composition may include at least one cross-linking compound selected from formulas (I), (II), and (III), and also including at least one additional cross-linking compound, such as a cross-linking compound of the type disclosed in U.S. Patent No. 9,006,353. While blends of one or more cross-linking compound may be used, it is preferred that a single cross-linking compound is selected.

[0051] The cross-linking compound in the composition as noted above may have a structure according to formula (I) and selected from the group consisting of:

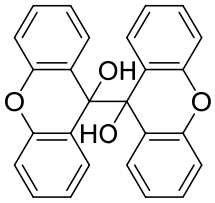


, (IV)

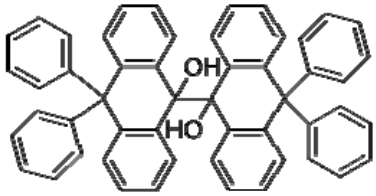


,

(V)



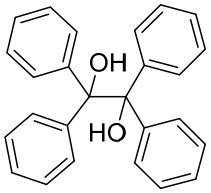
, and (VI)



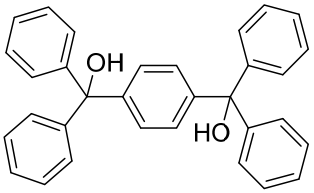
.

(VII)

[0052] The cross-linking compound in the composition as noted above may have a structure according to formula (II) and is selected from the group consisting of:

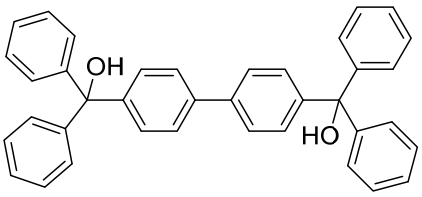


, (VIII)



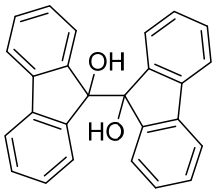
, and

(IX)



. (X)

[0053] The cross linking compound in the composition as noted above may also have a structure according to formula (III) and also as follows:



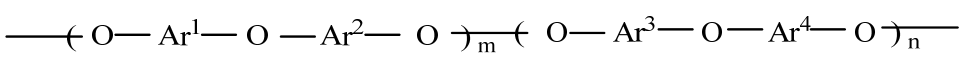
. (XI)

[0054] The arene, alkyl, or aryl moiety A of the cross-linking compounds according to formula (I) or (II) as noted above preferably has a molecular weight of about 1,000 g/mol to about 9,000 g/mol, and more preferably about 2,000 g/mol to about 7,000 g/mol.

[0055] In another ~~embodiment~~example, the ~~invention~~present disclosure includes an organic polymer composition for use in forming a cross-linked organic polymer, comprising an organic polymer and at least one cross-linking compound having a structure selected from formula (I), formula (II), and formula (III) as shown above.

[0056] The organic polymer is preferably a polymer selected from poly(arylene ether)s, polysulfones, polyethersulfones, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s, and polyaramids.

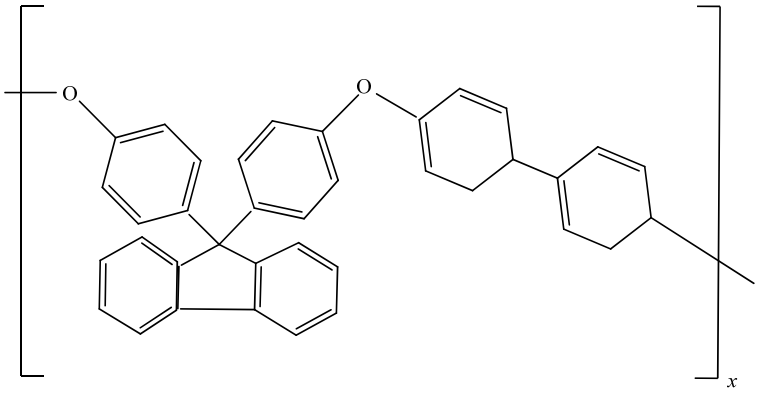
[0057] The organic polymer may also be a polymer in one ~~embodiment~~example herein that is a poly(arylene ether) including polymer repeating units along its backbone having the structure according to formula (XIII):



(XIII)

wherein Ar^1, Ar^2, Ar^3 and Ar^4 are identical or different aryl radicals, m = 0 to 1.0, and n = 1-m.

[0058] In a further preferred ~~embodiment~~example, the organic polymer is a polymer having an aromatic group in the backbone, preferably a poly(arylene ether), m is 1 and n is 0 and the polymer has repeating units along its backbone having the structure of formula (XIV):



(XIV)

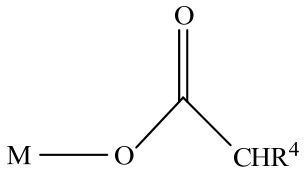
[0059] The organic polymer composition may further comprise one or more additives. Preferably, the additive(s) is/are selected from one or more of continuous or discontinuous, long or short, reinforcing fibers selected from one or more of carbon fibers, glass fibers, woven glass fibers, woven carbon fibers, aramid fibers, boron fibers, polytetrafluorethylene (PTFE) fibers, ceramic fibers, polyamide fibers, and/or one or more filler(s) selected from carbon black, silicate, fiberglass, calcium sulfate, boron, ceramic, polyamide, asbestos, fluorographite, aluminum hydroxide, barium sulfate, calcium carbonate, magnesium carbonate, silica, alumina, aluminum nitride, borax (sodium borate), activated carbon, pearlite, zinc terephthalate, graphite, talc, mica, silicon carbide whiskers or platelets, nanofillers, molybdenum disulfide, fluoropolymer fillers, carbon nanotubes and fullerene tubes.

[0060] The additive preferably includes a reinforcing fiber which is a continuous or discontinuous, long or short fiber, that is carbon fiber, polytetrafluoroethylene (PTFE) fiber, and/or glass fiber. Most preferably, the additive is a reinforcing fiber and is a continuous long fiber. The organic polymer composition in preferred ~~embodiment~~example~~s~~ comprises about 0.5% to about 65% by weight of additive(s) in the composition and more preferably about 5.0% to about 40% by weight of additive(s) in the composition. The organic polymer composition may further comprise one or more of stabilizers, flame retardants, pigments, colorants, plasticizers, surfactants, and/or dispersants.

[0061] In another ~~embodiment~~example according to the present ~~invention~~disclosure, the cross-linking composition comprises a cross-linking compound having a structure as described above and a cross-linking reaction additive. The cross-linking reaction additive is selected from an organic acid and/or an acetate compound and is capable of forming a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking

an organic polymer. The cross-linking reaction additive may be an organic acid, such as glacial acetic acid, formic acid, and/or benzoic acid.

[0062] The cross-linking reaction additive may be an acetate compound that has a structure according to formula (XII):



(XII)

wherein M is a Group I or a Group II metal; and R^4 is an alkyl, aryl, or aralkyl group, wherein the alkyl group is a hydrocarbon group of 1 to about 30 carbon atoms, preferably about 1 to about 15 carbon atoms having 0 to about 10 ester or ether groups along or in the chain of the hydrocarbon group, preferably about 0 to about 5 ester or ether groups, wherein R^4 may have 0 to about 10, preferably about 0 to about 5, functional groups that may be one or more of sulfate, phosphate, hydroxyl, carbonyl, ester, halide, mercapto or potassium. More preferably, the acetate compound may be lithium acetate hydrate, sodium acetate and/or potassium acetate, and salts and derivatives thereof.

[0063] The weight percentage ratio of the cross-linking compound to the cross-linking reaction additive may be about 10:1 to about 10,000:1, and more preferably about 20:1 to about 1000:1.

[0064] In another ~~embodiment~~example, the ~~invention~~present disclosure includes an organic polymer composition for use in forming a cross-linked organic polymer, comprising a cross-linking compound having a structure selected from formula (I), formula (II), and formula (III) as described above; a cross-linking reaction additive selected from an organic acid and/or an acetate compound; and at least one organic polymer, wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the organic polymer.

[0065] In a further ~~embodiment~~example, the ~~invention~~present disclosure includes an organic polymer composition for use in forming a cross-linked organic polymer, comprising an organic polymer and a reactive cross-linking oligomer which is a reaction product of a cross-linking compound having a structure selected from the group of formula (I), formula (II), and formula (III) as described above and a cross-linking reaction additive selected from an organic acid and/or an acetate compound. Preferably, the weight percentage ratio of the organic polymer to the

combined weight of the cross-linking compound and the cross-linking reaction additive is about 1:1 to about 100:1.

[0066] The organic polymer is selected from any of the organic polymers as discussed above. Further, when the organic polymer is a polyarylene ether it may have repeating units according to the structure of formula (XIII), and may have a structure of formula (XIV).

[0067] The cross-linking composition may further comprise at least one additive as discussed above, wherein the composition comprises 0.5% to about 65% by weight of the at least one additive. The cross-linking composition may further comprises one or more of a stabilizer, a flame retardant, a pigment, a plasticizer, a surfactant, and a dispersant.

[0068] The cross-linking composition may be used to form a molded article. The molded article is molded using extrusion, injection molding, blow molding, blown film molding, compression molding, or injection/compression molding. The article of manufactured is selected from acid-resistant coatings, chemical-casted films, extruded films, solvent-casted films, blown films, encapsulated products, insulation, packaging, composite cells, connectors, and sealing assemblies in the shape of O-rings, V-rings, U-cups, gaskets, bearings, valve seats, adapters, wiper rings, chevron back-up rings, and tubing.

[0069] A method is also provided herein for controlling the cross-linking reaction rate of a cross-linking compound of the type described herein for use in cross-linking an organic polymer. The method comprises providing a cross-linking composition comprising a cross-linking compound and a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking compound has a structure selected from the group consisting of formula (I), formula (II), and formula (III) as shown above, and heating the cross-linking composition such that oligomerization of the cross-linking compound occurs. In some ~~embodiment~~examples, the cross-linking composition comprises one or more additional cross-linking compounds.

[0070] In one ~~embodiment~~example, the method further comprises heating the cross-linking composition before heat molding. In an alternative ~~embodiment~~example, the method further comprises heating the cross-linking composition during heat molding.

[0071] The cross-linking compound used in the method for controlling the cross-linking reaction rate may have any of the various structures as noted above. In one ~~embodiment~~example, the cross-linking reaction additive is an organic acid selected from glacial acetic acid, formic acid, and/or benzoic acid, and/or an acetate compound selected from lithium acetate hydrate, sodium acetate, and/or potassium acetate, and salts and derivatives thereof.

[0072] In one ~~embodiment~~example, the method for controlling the cross-linking reaction rate further comprises combining the cross-linking compound and the cross-linking reaction additive in a solvent and reacting the cross-linking compound and the cross-linking reaction additive to form a reactive oligomerized cross-linking compound. In an alternative ~~embodiment~~example, the method for controlling the cross-linking reaction rate further comprises combining the cross-linking compound and the cross-linking reaction additive in solid form.

[0073] The method for controlling the cross-linking reaction rate may comprise adding the reactive oligomerized cross-linking compound to an organic polymer to form a cross-linkable composition, and cross-linking the organic polymer composition to form a cross-linked organic polymer.

[0074] In the method for controlling the cross-linking reaction rate, the organic polymer can be any of the organic polymers as discussed above. The organic polymer may be a polyarylene ether including polymer repeating units according to the structure of formula (XIII).

[0075] As observed by Applicant in U.S. Patent No. 9,109,080, incorporated herein by reference in relevant part, as viscosity increases in aromatic group-containing organic polymers, the degree of inhibition which can be achieved from using such cross-linking reaction additives for rate control may not always be sufficient such that in some ~~embodiment~~examples, additional modification is desirable to improve end effects by reducing and/or controlling the curing and cross-linking rate. While U.S. Patent No. 9,109,080 identified debrominated organic polymers for cross-linking, this patent provided limited cross-linking compounds, wherein such compounds may be difficult and/or expensive to produce.

[0076] The present ~~invention~~disclosure provides debrominated organic polymers for cross-linking, particularly useful for those organic polymers having an aromatic group in the backbone and/or that are in the category of high glass transition temperature polymers, as well as compositions including such dehalogenated organic polymers and methods for preparing and cross-linking the same using the cross-linking compounds of formula (I), formula (II), and formula (III), discussed above. The resulting articles are formed using controlled cross-linking reaction rates enabling use of traditional molding techniques during cross-linking of such polymers due to the enhanced processability of the dehalogenated organic polymers. As previously observed by the Applicant, this allows for creation of a variety of unique and readily moldable cross-linked organic polymer articles of manufacture providing the

beneficial properties of such materials, including chemical resistance, high-temperature and high-pressure performance and strength for a variety of end applications.

[0077] Included herein is an organic polymer composition for use in forming a cross-linked aromatic polymer, comprising a dehalogenated organic polymer and at least one cross-linking compound having a structure selected from the group of formula (I), formula (II), and formula (III) and described in detail above. The dehalogenated organic polymer is formed by a process comprising reacting an organic polymer having at least one halogen-containing reactive group with an alkali metal compound to break a bond between the organic polymer having the at least one halogen-containing reactive group and a halogen atom in the at least one halogen containing reactive group to form an intermediate.

[0078] In one ~~embodiment~~example, the dehalogenated organic polymer is a debrominated organic polymer, wherein the organic polymer may be any of the types of polymers discussed above, and may be a polyarylene ether having polymer repeating units according to formula (XIII). Further, the organic polymer composition may further comprise a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the dehalogenated organic polymer.

[0079] The dehalogenated organic polymer can be formed by reacting an organic polymer having at least one halogen-containing reactive group with an alkali metal compound to break the bond between the organic polymer having the at least one halogen-containing reactive group and the halogen atom in the at least one halogen-containing reactive group to form an intermediate having a carbocation as described in U.S. Patent No. 9,109,080, assigned to Applicant and incorporated herein in relevant part. The intermediate having the carbocation is reacted with acetic acid to form the debrominated organic polymer. In one ~~embodiment~~example, the halogen-containing reactive group is a bromine-containing reactive group.

[0080] The alkali metal compound useful in such a dehalogenation reaction is preferably one having the structure R^5-M', wherein M' is an alkali metal and R^5 is H or a branched or straight chain organic group selected from alkyl, alkenyl, aryl and aralkyl groups of from 1 to about 30 carbon atoms having from 0 to about 10 ester or ether groups along or in a chain or structure of the group, and wherein R^5 may be substituted or unsubstituted.

[0081] The alkali metal compound may in one preferred ~~embodiment~~example herein be *t*-butyllithium. The organic polymer having at least one halogen-containing end group, such as a bromine-containing reactive group, is preferably reacted with the alkali metal compound in a solvent, and the organic polymer having at least one halogen-containing end group is also preferably dried prior to reacting in the solvent. The reaction occurs at low temperatures until a majority of halogen atoms are removed from the organic polymer.

[0082] The organic polymer composition can be used to form a molded article. The molded article may be formed using extrusion, injection molding, blow molding, blown film molding, compression molding, or injection/compression molding. The article of manufacture being selected from acid-resistant coatings; chemical-casted films; extruded films; solvent-casted films; blown films; encapsulated products; insulation; packaging; composite cells; connectors; sealing assemblies; including O-rings, V-rings, U-cups, gaskets; bearings; valve seats; adapters; wiper rings; chevron back-up rings; and tubing.

[0083] After dehalogenation of the organic polymer, the polymer can be introduced into a cross-linking reaction to provide enhanced performance to such a reaction. Thus, the present ~~invention~~disclosure includes a method of controlling the cross-linking reaction rate of an organic polymer having at least one halogen-containing reactive group during a cross-linking reaction, preferably organic polymers having an aromatic group in the backbone chain of the polymer. The method comprises: (a) reacting the organic polymer having at least one halogen-containing reactive group with an alkali metal compound to break the bond between the organic polymer having the at least one halogen-containing reactive group and the halogen atom in the at least one halogen-containing reactive group and thereby forming an intermediate having a carbocation; (b) reacting the intermediate having the carbocation with acetic acid to form a dehalogenated organic polymer; and (c) cross-linking the dehalogenated organic polymer using a cross-linking reaction utilizing a cross-linking compound according to formula (I), (II), or (III) as described herein.

[0084] The at least one halogen-containing reactive group is generally a terminal group and the organic polymer may be any of those noted above, such as poly(arylene ether)s, polysulfones, polyethersulfones, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s and polyaramids, and is preferably one having an aromatic group in the backbone chain of the polymer.

[0085] The at least one halogen-containing reactive group is preferably represented by $-R^6-(X)_p$, wherein R^6 is carbon or a branched or straight chain organic group selected from

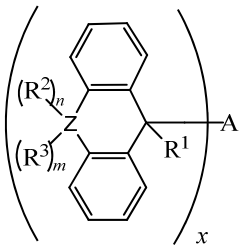
alkyl, alkenyl, aryl and aralkyl groups of from 1 to about 30 carbon atoms having from 0 to about 10 ester or ether groups along or in a chain or structure of the group, preferably from 0 to about 5 of such groups, and wherein R^6 may be substituted or unsubstituted; and wherein X is a halogen atom and *p* is an integer that is 1 or 2.

[0086] In one ~~embodiment~~example herein, the alkali metal compound is selected from the group consisting of R^5-M', wherein M' is an alkali metal and R^5 is H or a branched or straight chain organic group selected from alkyl, alkenyl, aryl and aralkyl groups of from 1 to about 30 carbon atoms having from 0 to about 10 ester or ether groups, preferably 0 to about 5 such groups, along or in a chain or structure of the group, and wherein R^5 may be substituted or unsubstituted.

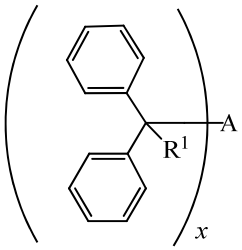
[0087] The organic polymer having the at least one halogen-containing end group is preferably reacted with the alkali metal compound in a solvent according to an ~~embodiment~~example of the method described herein. The solvent is preferably one which is capable of dissolving the organic polymer having the at least one halogen-containing reactive group and is free of functional groups that react with the halogen in the halogen-containing reacting group under reaction conditions in step (a) noted above. Suitable solvents include a heptane, a hexane, tetrahydrofuran, and a diphenyl ether. The organic polymer having the at least one halogen-containing end group is also preferably dried prior to reacting with the alkali metal compound in the solvent.

[0088] The first reaction step of a dehalogenation treatment preferably occurs at a temperature of less than about -20°C, and more preferably about -70°C for a period of about 2 hours.

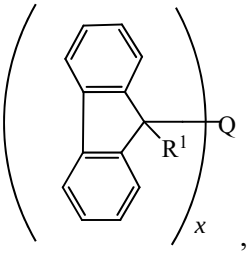
[0089] Step (c) of the method of controlling the cross-linking reaction rate of an organic polymer as noted above, comprises reacting the dehalogenated organic polymer with a cross-linking compound having a structure selected from:



, (I)



, and (II)



, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 have a molecular weight less than about 10,000 g/mol and are the same or different and are selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight, saturated or unsaturated alkyl chain of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0.

[0090] Step (c) may also further comprise providing a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the dehalogenated organic polymer.

[0091] Step (c) noted above may also include heating the cross-linking compound of the type described above and the cross-linking reaction additive in a separate composition such that oligomerization of the cross-linking compound occurs to form the reactive intermediate oligomer. The method may also comprise adding the reactive intermediate oligomer to the dehalogenated organic polymer to form a cross-linkable composition and then cross-linking the cross-linkable composition to form a cross-linked organic polymer.

[0092] In another ~~embodiment~~example described herein, the ~~invention~~present disclosure relates to a method of preparing an elastomeric material, comprising the steps of (a) providing an aromatic polymer which is nonelastomeric at room temperature; (b) cross-linking the aromatic

polymer using a cross-linking compound having a structure selected from the group of formula (I), formula (II), and formula (III) to form a cross-linked aromatic polymer that is substantially cured; and (c) heating the cross-linked aromatic polymer to a temperature at or above a glass transition temperature of the cross-linked aromatic polymer.

[0093] In one ~~embodiment~~example of the method of preparing an elastomeric material, in step (b), the aromatic polymer is at least about 80% cured, preferably at least about 90% cured, and more preferably fully cured.

[0094] The aromatic polymer used in the method may be selected from the group consisting of poly(arylene ether)s, polysulfones, polyethersulfones, polyarylene sulfides, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s, polyarylates, liquid crystalline polymers (LCPs) and polyaramids. In one ~~embodiment~~example, the aromatic polymer is a poly(arylene ether) including polymer repeating units having the structure of formula (XIII) as discussed above. Further, in some ~~embodiment~~examples the organic polymer is a poly(arylene ether) including polymer repeating units having the structure of formula (XIV).

[0095] In one ~~embodiment~~example, in step (b) of the method of preparing an elastomeric material further comprises cross-linking the organic polymer with the cross-linking compound and a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the organic polymer.

[0096] The method of preparing an elastomeric material may further include forming a composition comprising the cross-linked organic polymer and heating the composition to form a molded article, wherein step (c) further comprises placing the molded article in use at a temperature at or above the glass transition temperature of the cross-linked organic polymer.

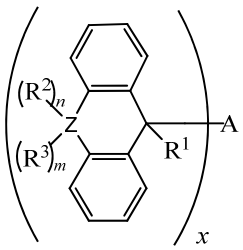
[0097] The present ~~invention~~disclosure further includes an elastomeric material formed by heating a cross-linked aromatic polymer that is substantially cured at or above a glass transition temperature of the cross-linked aromatic polymer, wherein the aromatic polymer is not elastomeric at room temperature prior to cross-linking, and wherein the aromatic polymer is cross-linked by reaction with a cross-linking compound or by thermally induced cross-linking of an aromatic polymer having a graft bonded to the aromatic polymer.

[0098] The ~~invention~~present disclosure includes an elastomeric article formed by heat molding a composition comprising a cross-linked aromatic polymer to form a molded article, wherein the aromatic polymer is not elastomeric at room temperature prior to cross-linking, and wherein the cross-linked aromatic polymer is substantially cured, and heating the molded article at or above a glass transition temperature of the cross-linked aromatic polymer, wherein the aromatic polymer is cross-linked by reaction with a cross-linking compound or by thermally induced cross-linking of an aromatic polymer having a graft bonded to the aromatic polymer. The elastomeric article is selected from the group consisting of an O-ring, a V-cup, a U-cup, a gasket, at least one component of a seal stack, a packer element, a diaphragm, a thee seal, a bearing, a valve seat, an adapter, a wiper ring, a chevron seal back-up ring, and tubing.

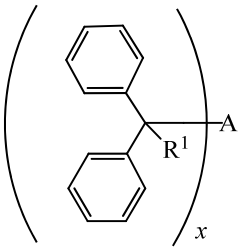
[0099] The ~~invention~~present disclosure also includes a method of using an organic polymer that is not elastomeric at room temperature in an elastomeric application, comprising cross-linking the organic polymer using a cross-linking compound selected from formula (I), (II), or (III) to form a cross-linked organic polymer to substantially cure the aromatic polymer; and heating the cross-linked polymer in use at or above a glass transition temperature of the cross-linked polymer such that it becomes elastomeric.

[0100] The method may further comprise forming a composition comprising the cross-linked organic polymer, molding the composition into a molded article, placing the molded article in use and heating the molded article in use so as to heat the cross-linked polymer at or above the glass transition temperature of the cross-linked polymer.

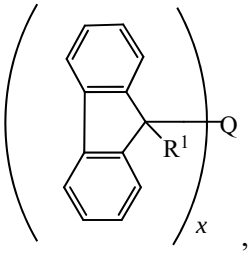
[0101] The ~~invention~~present disclosure further has an ~~embodiment~~example including a method of preparing an elastomeric material. The method comprises (a) providing an aromatic polymer which is non-elastomeric at room temperature; (b) cross-linking the aromatic polymer using a cross-linking compound to form a cross-linked aromatic polymer, wherein the cross-linking compound has a structure selected from one or more of the group of



, (I)



, and (II)



, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 have a molecular weight less than about 10,000 g/mol and are the same or different and are selected from the group consisting of hydrogen, hydroxide (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight, saturated or unsaturated alkyl chain of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0; and (c) heating the cross-liked aromatic polymer to a temperature at or above a glass transition temperature of the cross-linked aromatic polymer.

[0102] In the method of preparing an elastomeric material, in step (b), the aromatic polymer is preferably at least about 80% cured, more preferably at least about 90% cured and most preferably, it is fully cured. The aromatic polymer in the method may be one or more of poly(arylene ether)s, polysulfones, polyethersulfones, polyarylene sulfides, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s, polyarylates, liquid crstalline polymers (LCPs) and polyaramids.

[0103] In one ~~embodiment~~example, the aromatic polymer is a poly(arylene ether) including polymer repeating units having the structure of formula (XIII) as discussed above. In some ~~embodiment~~examples, the organic polymer is a polyarylene ether according to formula (XIV).

[0104] In this method, step (b) may further comprise cross-linking the organic polymer with the cross-linking compound and a cross-linking reaction additive selected from an organic acid and/or an acetate compound as discussed above, wherein the cross-linking

reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the organic polymer.

[0105] In another ~~embodiment~~example according to the present ~~invention~~disclosure, the present ~~invention~~disclosure relates to a method of improving extrusion- and creep-resistance of a component for use in a high temperature sealing element or seal connector, comprising: providing a composition comprising aromatic polymer and a cross-linking compound of a structure according to formula (I), formula (II), and/or formula (III), and subjecting the composition to a heat molding process to form the component and cross-link the aromatic polymer.

[0106] The aromatic polymer may be one or more of a polyarylene polymer, a polysulfone, a polyphenylene sulfide, a polyimide, a polyamide, a polyurea, a polyurethane, a polyphthalamide, a polyamide-imide, an aramid, a polybenzimidazole, and blends, copolymers and derivatives thereof. Preferably, the aromatic polymer is a polyarylene polymer and/or a polysulfone polymer, and blends, copolymers and derivatives thereof.

[0107] When the aromatic polymer is a polyarylene ether polymer, it may have repeating having units of the structure according to formula (XIV).

[0108] If the aromatic polymer is a polyarylene-type polymer, it is preferably at least one of polyetheretherketone, polyetherketone, polyetherketoneetherketoneketone, polyetherketoneketone, polysulfone, polyphenylene sulfide, polyethersulfone, polyarylsulfone, and blends, copolymers and derivatives thereof.

[0109] The composition for formation of an extrusion-resistant sealing member may also include a cross-linking reaction additive capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking an organic polymer. The cross-linking reaction additive may be an organic acid which may be glacial acetic acid, formic acid, and/or benzoic acid. In another ~~embodiment~~example, the cross-linking reaction additive may be an acetate compound that has a structure according to formula (XII).

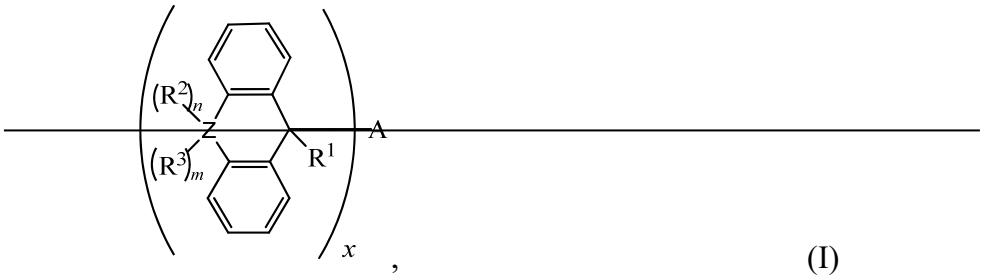
[0110] The compositions for forming extrusion resistant sealing members may be unfilled compositions providing enhanced ductility in use, or they may be filled if the user desires to modify the properties of the composition.

[0111] The ~~invention~~present disclosure also includes sealing components of a sealing assembly formed by a method comprising the step of cross-linking a composition as described herein. A sealing

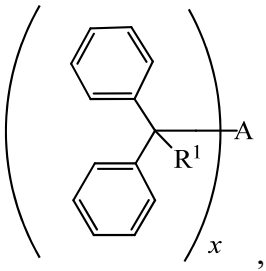
CLAIMS

We claim:

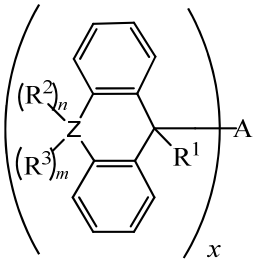
1. A cross-linking composition comprising a cross-linking compound for cross-linking an organic polymer, wherein the cross-linking compound is selected from the group consisting of:



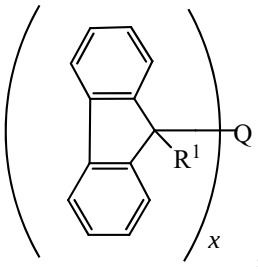
, (I)



, ~~and~~ (II)



, and (I)



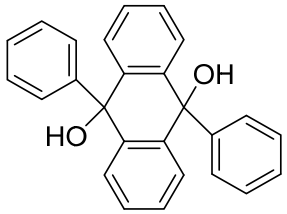
, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six

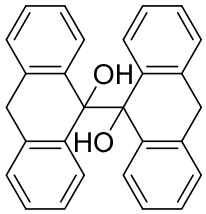
carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0.

2. The cross-linking composition according to claim 1, wherein the cross-linking compound ~~has a structure according to formula (I) and~~ is selected from a group consisting of:

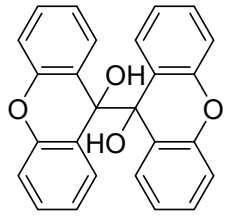
(a) a compound having a structure according to formula (I) that is selected from the group consisting of formulae (IV), (V), (VI), and (VII):



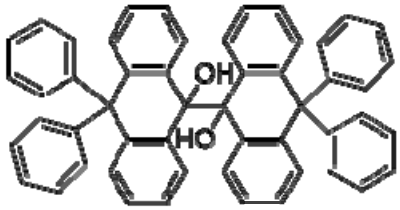
, (IV)



, (V)

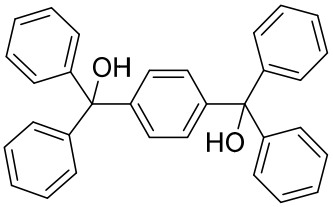


, and (VI)

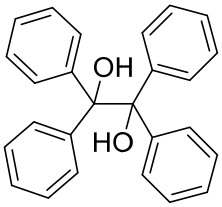


~~;~~ (VII)

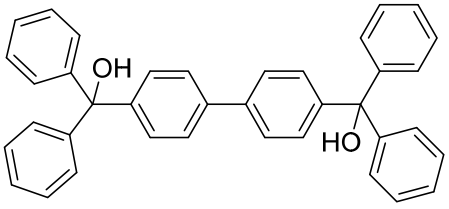
~~3. The cross-linking composition according to claim 1, wherein the cross-linking compound has~~ (b) a compound having a structure according to formula (II) ~~and~~ that is selected from the group consisting of formulae (VIII), (IX), or (X): ~~is selected from the group consisting of:~~



, (VIII)

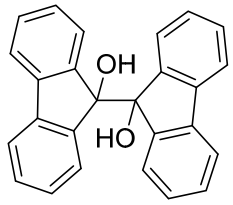


, and (IX)



~~;~~ and (X)

~~4. The cross-linking composition according to claim 1, wherein the cross-linking compound has~~ (c) a compound having a structure according to formula (III) that has formulae (XI): ~~and also as follows~~:

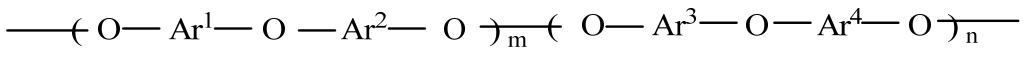


. (XI)

~~5.~~ 3. The cross-linking composition according to claim 1, wherein when A is not Q, A has a molecular weight of about 1,000 g/mol to about 9,000 g/mol.

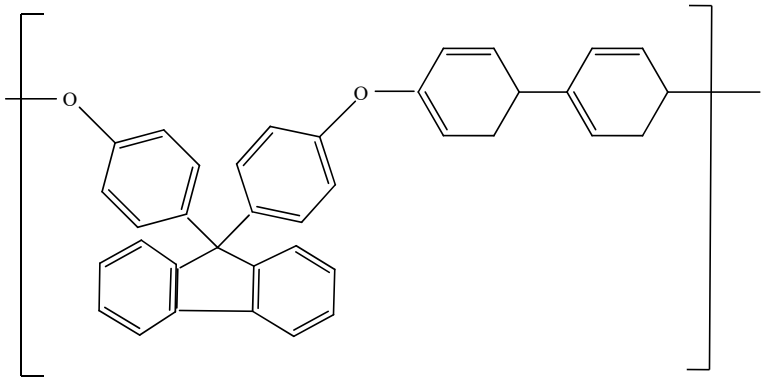
~~6.~~ 4. The cross-linking composition according to claim 1, further comprising at least one organic polymer selected from poly(arylene ether)s, polysulfones, polyethersulfones, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s, and polyaramids.

~~7.~~ 5. The cross-linking composition according to claim ~~6~~ 4, wherein the organic polymer is a poly(arylene ether) including polymer repeating units having the following structure:


(XIII)

wherein Ar^1, Ar^2, Ar^3 and Ar^4 are identical or different aryl radicals, m = 0 to 1.0, and n = 1-m.

~~8.~~ 6. The cross-linking composition according to claim ~~7~~ 5, wherein the organic polymer is a poly(arylene ether), m is 1 and n is 0 and the polymer has repeating units having the structure of formula (XIV):


. (XIV)

~~9.~~ 7. The cross-linking composition according to claim ~~6~~ 4, wherein the cross-linking composition further comprises at least one additive selected from continuous or discontinuous, long or short, reinforcing fibers selected from carbon fibers, glass fibers, woven glass fibers, woven carbon fibers, aramid fibers, boron fibers, polytetrafluorethylene fibers, ceramic fibers, polyamide fibers; and one or more fillers selected from carbon black, silicate, fiberglass, calcium sulfate, boron, ceramic, polyamide, asbestos, fluorographite, aluminum hydroxide, barium sulfate, calcium carbonate, magnesium carbonate, silica, alumina, aluminum nitride,

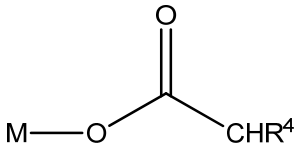
borax (sodium borate), activated carbon, pearlite, zinc terephthalate, graphite, talc, mica, silicon carbide whiskers or platelets, nanofillers, molybdenum disulfide, fluoropolymer, carbon nanotubes and fullerene tubes.

~~10.~~ 8. The cross-linking composition according to claim ~~9~~ 7, wherein the cross-linking composition comprises about 0.5% to about 65% by weight of the at least one additive.

~~11.~~ 9. The cross-linking composition according to claim 1, further comprising a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking an organic polymer.

~~12.~~ 10. The cross-linking composition according to claim ~~11~~ 9, wherein the cross-linking reaction additive is an organic acid selected from glacial acetic acid, formic acid, and/or benzoic acid.

~~13.~~ 11. The cross-linking composition according to claim ~~11~~ 9, wherein the cross-linking reaction additive is an acetate compound having a structure according to formula (XII):



(XII)

wherein M is a Group I or a Group II metal; and R^4 is an alkyl, aryl or aralkyl group, wherein the alkyl group comprises a hydrocarbon group of 1 to about 30 carbon atoms which has from 0 to about 10 ester or ether groups along or in a chain or structure of the group, and wherein R^4 comprises 0 to about 10 functional groups selected from sulfate, phosphate, hydroxyl, carbonyl, ester, halide, mercapto or potassium.

~~14.~~ 12. The cross-linking composition according to claim ~~13~~ 11, wherein the acetate compound is selected from lithium acetate hydrate, sodium acetate, and/or potassium acetate, and salts and derivatives thereof.

~~15.~~ 13. The cross-linking composition according to claim ~~11~~ 9, wherein the weight percentage ratio of the cross-linking compound to the cross-linking reaction additive is about 10:1 to about 10,000:1.

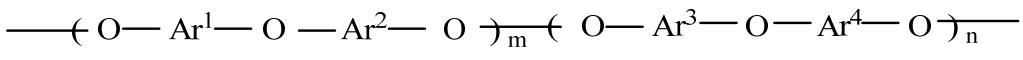
~~16.~~ 14. The cross-linking composition according to claim ~~11~~ 9, further comprising at least one organic polymer, wherein the cross-linking reaction additive is capable of reacting with the

cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the organic polymer.

~~17.~~ 15. The cross-linking composition according to claim ~~16~~ 14, wherein the weight percentage ratio of the organic polymer to the combined weight of the cross-linking compound and the cross-linking reaction additive is about 1:1 to about 100:1.

~~18.~~ 16. The cross-linking composition according to claim ~~16~~ 14, wherein the organic polymer is selected from poly(arylene ether)s, polysulfones, polyethersulfones, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s, and polyaramids.

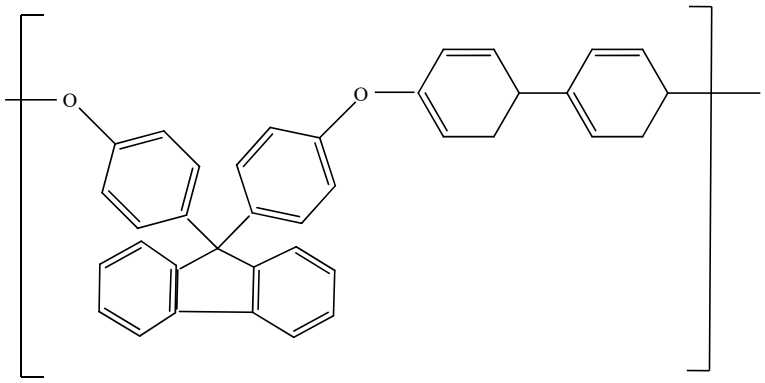
~~19.~~ 17. The cross-linking composition according to claim ~~18~~ 16, wherein the organic polymer is a poly(arylene ether) including polymer repeating units having the following structure:



(XIII)

wherein Ar^1, Ar^2, Ar^3 and Ar^4 are identical or different aryl radicals, m = 0 to 1.0, and n = 1-m.

~~20.~~ 18.The cross-linking composition according to claim ~~19~~ 17, wherein the organic polymer is a poly(arylene ether), m is 1 and n is 0 and the polymer has repeating units having the structure of formula (XIV):



. (XIV)

~~21.~~ 19. The cross-linking composition according to claim ~~16~~ 14, wherein the cross-linking composition further comprises at least one additive selected from continuous or discontinuous, long or short, reinforcing fibers selected from carbon fibers, glass fibers, woven glass fibers, woven carbon fibers, aramid fibers, boron fibers, polytetrafluorethylene fibers, ceramic fibers, polyamide fibers; and one or more fillers selected from carbon black, silicate, fiberglass, calcium sulfate, boron, ceramic, polyamide, asbestos, fluorographite, aluminum hydroxide, barium sulfate, calcium carbonate, magnesium carbonate, silica, alumina, aluminum nitride, borax (sodium borate), activated carbon, pearlite, zinc terephthalate, graphite, talc, mica, silicon

carbide whiskers or platelets, nanofillers, molybdenum disulfide, fluoropolymer, carbon nanotubes and fullerene tubes.

~~22.~~ 20. The cross-linking composition according to claim ~~21~~ 19, wherein the cross-linking composition comprises about 0.5% to about 65% by weight of the at least one additive.

~~23.~~ 21. The cross-linking composition according to claim ~~16~~ 14, wherein the cross-linking composition further comprises one or more of a stabilizer, a flame retardant, a pigment, a plasticizer, a surfactant, and a dispersant.

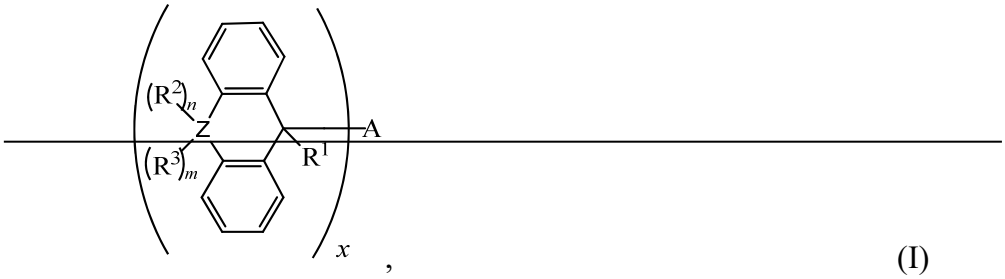
~~24.~~ 22. A molded article formed from the cross-linking composition according to claim ~~16~~ 14.

~~25.~~ 23. The molded article according to claim ~~24~~ 22, wherein the molded article is molded using extrusion, injection molding, blow molding, blown film molding, compression molding, or injection/compression molding.

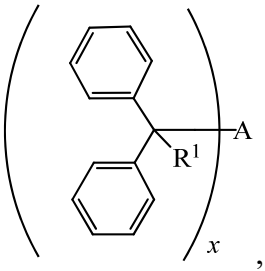
~~26.~~ 24. An article of manufacture formed from the composition according to claim ~~16~~ 14, wherein the article of manufacture is selected from acid-resistant coatings, chemical-casted films, extruded films, solvent-casted films, blown films, encapsulated products, insulation, packaging, composite cells, connectors, and sealing assemblies in the shape of O-rings, V-rings, U-cups, gaskets, bearings, valve seats, adapters, wiper rings, chevron back-up rings, and tubing.

~~27.~~ 25. A method of controlling the cross-linking reaction rate of a cross-linking compound for use in cross-linking an organic polymer, comprising:

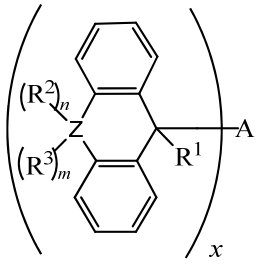
(a) providing a cross-linking composition comprising at least one cross-linking compound and a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking compound has one or more of the following structures:



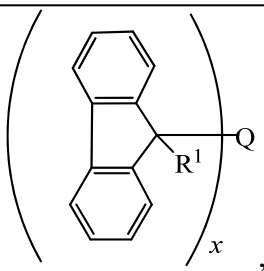
, (I)



, ~~and~~ (II)



, and (I)



, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0; and

(b) heating the cross-linking composition such that oligomerization of the cross-linking compound occurs.

~~28.~~ 26. The method according to claim ~~27~~ 25, wherein the cross-linking composition further comprises one or more additional cross-linking compounds.

~~29.~~ 27. The method according to claim ~~27~~ 25, wherein step (b) further comprises heating the cross-linking composition before heat molding.

~~30.~~ 28. The method according to claim ~~27~~ 25, wherein the cross-linking reaction additive is an organic acid selected from glacial acetic acid, formic acid and/or benzoic acid and/or an acetate compound selected from lithium acetate hydrate, sodium acetate, and/or potassium acetate, and salts and derivatives thereof.

~~31.~~ 29. The method according to claim ~~27~~ 25, further comprising combining the cross-linking compound and the cross-linking reaction additive in a solvent in step (a) and reacting the cross-

linking compound and the cross-linking reaction additive to form a reactive oligomerized cross-linking compound.

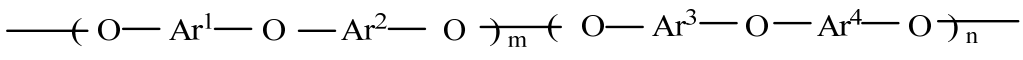
~~32.~~ 30. The method according to claim ~~31~~ 29, further comprising:

(c) adding the reactive oligomerized cross-linking compound to an organic polymer to form a cross-linkable composition, and

(d) cross-linking the organic polymer composition to form a cross-linked organic polymer.

~~33.~~ 31. The method according to claim ~~32~~ 30, wherein the organic polymer is selected from poly(arylene ether)s, polysulfones, polyethersulfones, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s and/or polyaramids.

~~34.~~ 32. The method according to claim ~~33~~ 31, wherein the organic polymer is a poly(arylene ether) including polymer repeating units having the following structure:



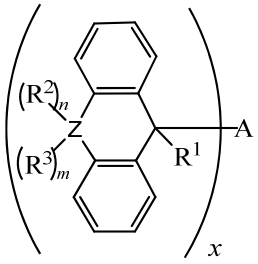
(XIII)

wherein Ar^1, Ar^2, Ar^3 and Ar^4 are identical or different aryl radicals, m = 0 to 1.0, n = 1-m.

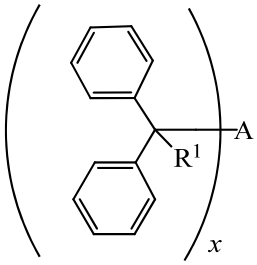
~~35.~~ 33. An organic polymer composition for use in forming a cross-linked organic polymer, comprising:

a dehalogenated organic polymer, and

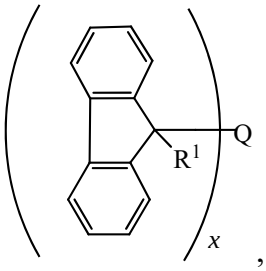
at least one cross-linking compound having a structure selected from the group consisting of:



, (I)



, and (II)



, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0; and

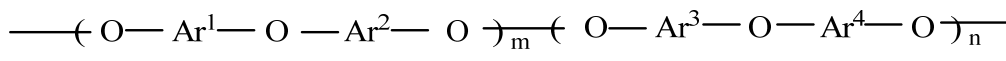
wherein the dehalogenated organic polymer is formed by a process comprising reacting an organic polymer having at least one halogen-containing reactive group with an alkali metal compound to break a bond between the organic polymer having the at least one halogen-containing reactive group and a halogen atom in the at least one halogen containing reactive group to form an intermediate.

~~36.~~ 34. The organic polymer composition according to claim ~~35~~ 33, wherein the dehalogenated organic polymer is a debrominated organic polymer.

~~37.~~ 35. The organic polymer composition according to claim ~~35~~ 33, further comprising a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the dehalogenated organic polymer.

~~38.~~ 36. The organic polymer composition according to claim ~~35~~ 33, wherein the dehalogenated organic polymer is a polymer selected from poly(arylene ether)s, polysulfones, polyethersulfones, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s and polyaramids.

~~39.~~ 37. The organic polymer composition according to claim ~~38~~ 36, wherein the dehalogenated organic polymer is a poly(arylene ether) including polymer repeating units in its backbone having the following structure:



(XIII)

wherein Ar^1, Ar^2, Ar^3 and Ar^4 are identical or different aryl radicals, m = 0 to 1.0, and n = 1-m.

~~40.~~ 38. The organic polymer composition according to claim ~~35~~ 33, wherein the dehalogenated organic polymer is formed by reacting the intermediate with acetic acid to form the dehalogenated organic polymer.

~~41.~~ 39. The organic polymer composition according to claim ~~40~~ 38, wherein the alkali metal compound is selected from the group consisting of R^5-M', wherein M' is an alkali metal and R^5 is H or a branched or straight chain organic group selected from alkyl, alkenyl, aryl and aralkyl groups of from 1 to about 30 carbon atoms having from 0 to about 10 ester or ether groups along or in a chain or structure of the group, and wherein R^5 may be substituted or unsubstituted.

~~42.~~ 40. The organic polymer composition according to claim ~~41~~ 39, wherein the alkali metal compound is *t*-butyllithium.

~~43.~~ 41. The organic polymer composition according to claim ~~40~~ 38, wherein the halogen-containing reactive group is a bromine-containing reactive group.

~~44.~~ 42. The organic polymer composition according to claim ~~40~~ 39, wherein the organic polymer having at least one halogen-containing end group is reacted with the alkali metal compound in a solvent and the organic polymer having the at least one halogen-containing end group is dried prior to reacting in the solvent.

~~45.~~ 43. A molded article formed using the organic polymer composition of claim ~~35~~ 33.

~~46.~~ 44. The molded article of claim ~~45~~ 43, wherein the molded article is formed using extrusion, injection molding, blow molding, blown film molding, compression molding, or injection/compression molding.

~~47.~~ 45. An article of manufacture formed from the composition according to claim ~~35~~ 33, wherein the article of manufacture is selected from acid-resistant coatings; chemical-casted films; extruded films; solvent-casted films; blown films; encapsulated products; insulation; packaging; composite cells; connectors; sealing assemblies, including O-rings, V-rings, U-cups, gaskets; bearings; valve seats; adapters; wiper rings; chevron back-up rings; and tubing.

~~48.~~ 46. A method of controlling the cross-linking reaction rate of an organic polymer having at least one halogen-containing reactive group during a cross-linking reaction, comprising:

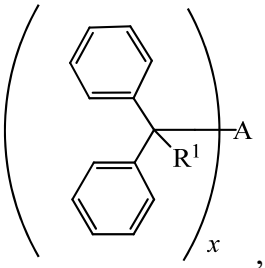
(a) reacting the organic polymer having at least one halogen-containing reactive group with an alkali metal compound to break a bond between the organic polymer having the at least one halogen-containing reactive group and a halogen atom in the at least one halogen-containing reactive group, and to form an intermediate having a carbocation;

(b) reacting the intermediate having the carbocation with acetic acid to form a dehalogenated organic polymer; and

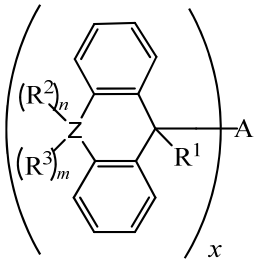
(c) cross-linking the dehalogenated organic polymer using a cross-linking reaction comprising a cross-linking compound selected from the group of:



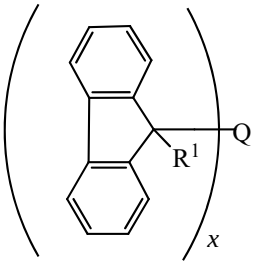
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wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0.

~~49.~~ 47. The method according to claim ~~48~~ 46, wherein the at least one halogen-containing reactive group is represented by $-R^6\text{-}(X)_p$, wherein R^6 is carbon or a branched or straight chain organic group selected from alkyl, alkenyl, aryl and aralkyl groups of from 1 to about 30 carbon atoms having from 0 to about 10 ester or ether groups along or in a chain or structure of the group, and wherein R^6 may be substituted or unsubstituted; and X is a halogen atom and *p* is an integer that is 1 or 2.

~~50.~~ 48. The method according to claim ~~48~~ 46, wherein the alkali metal compound is selected from the group consisting of R^5-M', wherein M' is an alkali metal and R^5 is H or a branched or straight chain organic group selected from alkyl, alkenyl, aryl and aralkyl groups of from 1 to about 30 carbon atoms having from 0 to about 10 ester or ether groups along or in a chain or structure of the group, and wherein R^5 may be substituted or unsubstituted.

~~51.~~ 49. The method according to claim ~~48~~ 46, wherein the organic polymer having the at least one halogen-containing end group is reacted with the alkali metal compound in a solvent, wherein the solvent is selected from a heptanes, tetrahydrofuran, and a diphenyl ether.

~~52.~~ 50. The method according to claim ~~51~~ 48, wherein the organic polymer having the at least one halogen-containing end group is dried prior to reacting with the alkali metal compound in the solvent.

~~53.~~ 51. The method according to claim ~~48~~ 46, wherein step (a) occurs at a temperature of less than about -20°C.

~~54.~~ 52. The method according to claim ~~53~~ 51, wherein step (a) occurs at a temperature of less than about -70°C for a period of about 2 hours.

~~55.~~ 53. The method according to claim ~~48~~ 46, wherein step (c) further comprises providing a cross-linking reaction additive selected from an organic acid and/or an acetate compound,

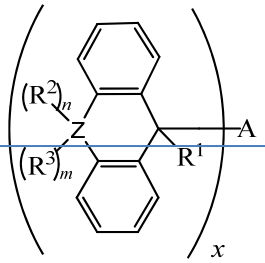
wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the dehalogenated organic polymer.

~~56.~~ 54. The method according to claim ~~55~~ 53, further comprising before step (c) heating the cross-linking compound and the cross-linking reaction additive in a separate composition such that oligomerization of the cross-linking compound occurs to form the reactive intermediate oligomer.

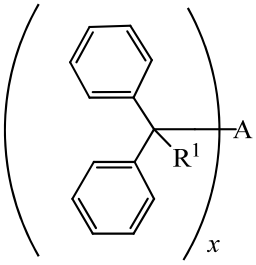
~~57.~~ 55. A method of preparing an elastomeric material, comprising

(a) providing an aromatic polymer which is nonelastomeric at room temperature;

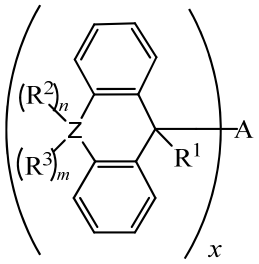
(b) cross-linking the aromatic polymer using a cross-linking compound to form a cross-linked aromatic polymer that is substantially cured, wherein the cross-linking compound has a structure selected from the group consisting of:



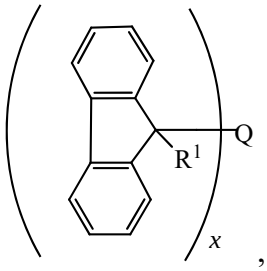
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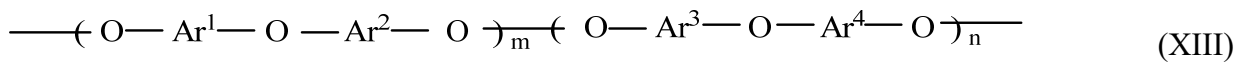
wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0; and

(c) heating the cross-linked aromatic polymer to a temperature at or above a glass transition temperature of the cross-linked aromatic polymer.

~~58.~~ 56. The method of preparing an elastomeric material according to claim ~~57~~ 55, wherein, in step (b), the aromatic polymer is at least 80% cured.

~~59.~~ 57. The method of preparing an elastomeric material according to claim ~~58~~ 56, wherein the aromatic polymer is at least about 90% cured.

~~60.~~ 58. The method of preparing an elastomeric material according to claim ~~57~~ 55, wherein the aromatic polymer is a poly(arylene ether) including polymer repeating units having the following structure:

 (XIII)

wherein Ar^1, Ar^2, Ar^3 and Ar^4 are identical or different aryl radicals, *m* = 0 to 1.0, and *n* = 1-*m*.

~~61.~~ 59. The method of preparing an elastomeric material according to claim ~~57~~ 55, wherein step (b) further comprises cross-linking the organic polymer with the cross-linking compound and a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the organic polymer.

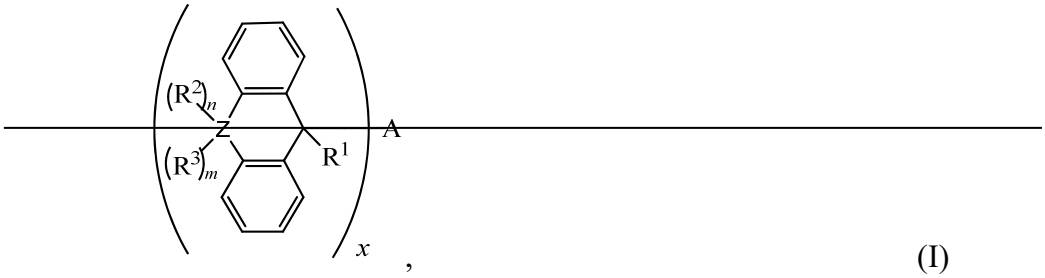
~~62.~~ 60. The method of preparing an elastomeric material according to claim ~~57~~ 55, wherein the method further comprises forming a composition comprising the cross-linked organic polymer and heating the composition to form a molded article and step (c) further comprises placing the molded article in use at a temperature at or above the glass transition temperature of the cross-linked organic polymer.

~~63.~~ 61. An elastomeric article formed by the method of claim ~~57~~ 55.

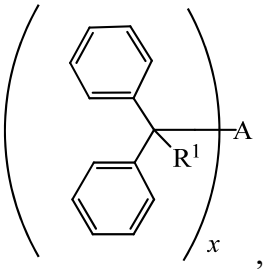
~~64.~~ 62. The elastomeric article according to claim ~~63~~ 61, selected from the group consisting of an O-ring, a V-ring, a U-cup, a gasket, at least one component of a seal stack, a packer element, a diaphragm, a thee seal, a bearing, a valve seat, an adapter, a wiper ring, a chevron seal back-up ring, and tubing.

~~65.~~ 63. A method of using an organic polymer that is not elastomeric at room temperature in an elastomeric application, comprising

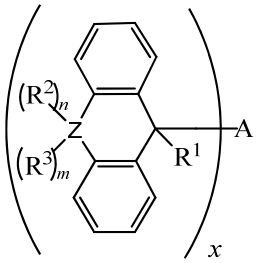
cross-linking the organic polymer using a cross-linking compound to form a cross-linked organic polymer to substantially cure the aromatic polymer, wherein the cross-linking compound has a structure selected from the group consisting of:



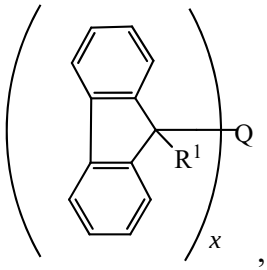
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, (III)

wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0; and

heating the cross-linked polymer in use at or above a glass transition temperature of the cross-linked polymer such that it becomes elastomeric.

~~66.~~ 64. The method of using an organic polymer in an elastomeric composition according to claim ~~65~~ 63, further comprising forming a composition comprising the cross-linked organic polymer, molding the composition into a molded article, placing the molded article in use and heating the molded article in use so as to heat the cross-linked polymer at or above the glass transition temperature of the cross-linked polymer.

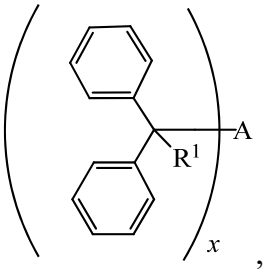
~~67.~~ 65. A method of preparing an elastomeric material, comprising:

(a) providing an aromatic polymer which is non-elastomeric at room temperature;

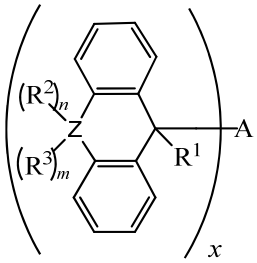
(b) cross-linking the aromatic polymer using a cross-linking compound to form a cross-linked aromatic polymer, wherein the cross-linking compound has a structure selected from the group consisting of:



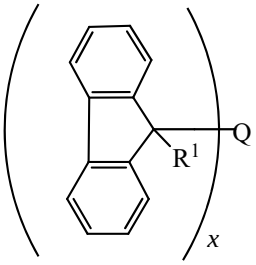
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wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, and wherein *x* is about 1.0 to about 6.0;

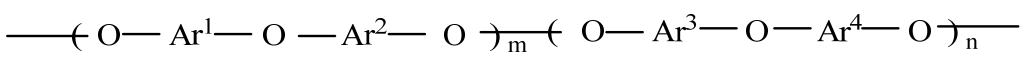
(c) heating the cross-linked aromatic polymer to a temperature at or above a glass transition temperature of the cross-linked aromatic polymer.

~~68.~~ 66. The method of preparing an elastomeric material according to claim ~~67~~ 65, wherein, in step (b), the aromatic polymer is at least about 80% cured.

~~69.~~ 67. The method of preparing an elastomeric material according to claim ~~68~~ 66, wherein the aromatic polymer is at least about 90% cured.

~~70.~~ 68. The method of preparing an elastomeric material according to claim ~~67~~ 65, wherein the aromatic polymer is selected from the group consisting of a poly(arylene ether)s, polysulfones, polyethersulfones, polyarylene sulfides, polyimides, polyamides, polyureas, polyurethanes, polyphthalamides, polyamide-imides, poly(benzimidazole)s, polyarylates, liquid crystalline polymers (LCPs) and polyaramids.

~~71.~~ 69. The method of preparing an elastomeric material according to claim ~~70~~ 68, wherein the aromatic polymer is a poly(arylene ether) polymer including polymer repeating having units of structure according to formula (XIII) below:



(XIII)

wherein Ar^1, Ar^2, Ar^3 and Ar^4 are identical or different aryl radicals, m is 0 to 1, and n is 1 - m.

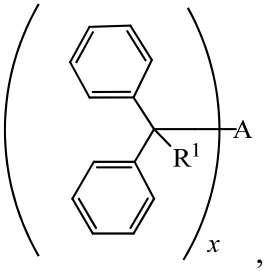
~~72.~~ 70. The method of preparing an elastomeric material according to claim ~~71~~ 69, wherein step (b) further comprises cross-linking the organic polymer with the cross-linking compound and a cross-linking reaction additive selected from an organic acid and/or an acetate compound, wherein the cross-linking reaction additive is capable of reacting with the cross-linking compound to form a reactive intermediate in the form of an oligomer, which reactive intermediate oligomer is capable of cross-linking the organic polymer.

~~73.~~ 71. A method of improving extrusion- and creep-resistance of a component for use in a high temperature sealing element or seal connector, comprising,

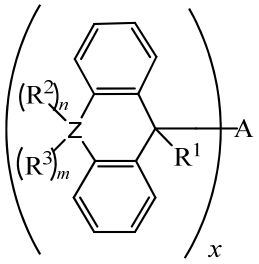
providing a composition comprising an aromatic polymer and a cross-linking compound, wherein the cross-linking compound has a structure selected from the group consisting of:



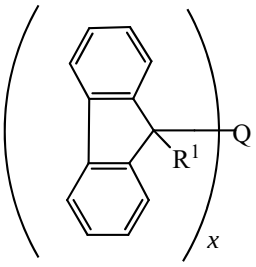
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wherein Q is a bond, wherein A is Q, an alkyl, an aryl, or an arene moiety having a molecular weight less than about 10,000 g/mol, wherein each of R^1, R^2, and R^3 has a molecular weight less than about 10,000 g/mol, wherein R^1, R^2, and R^3 are the same or different and selected from the group consisting of hydrogen, hydroxyl (-OH), amine ($-NH_2$), halide, ether, ester, amide, aryl, arene, or a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein m is from 0 to 2, n is from 0 to 2, and m + n is greater than or equal to zero and less than or equal to two, wherein Z is selected from the group of oxygen, sulfur, nitrogen, and a branched or straight chain, saturated or unsaturated alkyl group of one to about six carbon atoms, wherein *x* is about 1.0 to about 6.0;

subjecting the composition to a heat molding process to form the component and cross-link the aromatic polymer.

~~74.~~ 72. The method according to claim ~~73~~ 71, wherein the composition is unfilled.

~~75.~~ 73. The method according to claim ~~73~~ 71, wherein the aromatic polymer is selected from the group consisting of a polyarylene polymer, a polysulfone, a polyphenylene sulfide, a polyimide, a polyamide, a polyurea, a polyurethane, a polyphthalamide, a polyamide-imide, an aramid, a polybenzimidazole, and blends, copolymers and derivatives thereof.

~~76.~~ 74. A sealing component formed by the method of claim ~~73~~ 71.

~~77.~~ 75. The sealing component according to claim ~~76~~ 74, wherein the composition is unfilled.