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(54) Title: POLY(ARYLENE ETHER) COMPOSITION, METHOD, AND ARTICLE BACKGROUND OF THE INVENTION

(57) Abstract: The ultraviolet light stability of a poly(arylene ether)/elastomer composition is improved when the ultraviolet light stabilizers are pre-compounded with at least a portion of the elastomer component of the composition. A method of preparing the poly(arylene ether) composition is described, as are the composition itself and articles prepared from the composition.



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POLY(ARYLENE ETHER) COMPOSITION, METHOD, AND ARTICLE
BACKGROUND OF THE INVENTION

[0001] Poly(arylene ether) is a type of plastic known for its excellent water resistance, dimensional stability, and inherent flame retardancy. Properties such as strength, stiffness, chemical resistance, and heat resistance can be tailored by blending it with various other plastics in order to meet the requirements of a wide variety of consumer products, for example, plumbing fixtures, electrical boxes, automotive parts, and insulation for wire and cable.

[0002] Poly(vinyl chloride) is currently the commercially dominant material for flame retardant wire and cable insulation. However, poly(vinyl chloride) is a halogenated material. There is mounting concern over the environmental impact of halogenated materials, and non-halogenated alternatives are being sought. There is therefore a strong desire – and in some places a legislative mandate – to replace poly(vinyl chloride) with non-halogenated polymer compositions. Given the popularity of white-colored small appliances and personal electronic devices, there is also a particular need for white or off-white colored cable insulation compositions that retain their color after photochemical aging.

[0003] Recent research has demonstrated that halogen-free poly(arylene ether) compositions can possess the physical and flame retardant properties needed for use as wire and cable insulation. See, for example, U.S. Patent Application Publication Nos. US 2006/131050 A1 and US 2006/131052 A1 and US 2006/135661 A1 of Mhetar et al., US 2006/131053 A1 and US 2006/134416 A1 of Kubo et al., US 2006/131059 A1 of Xu et al., and US 2006/135695 A1 of Guo et al. However, the compositions disclosed in these references are difficult to formulate in a white or off-white color, or they exhibit insufficient thermal or photochemical color stability, or both. And, while the problem of photochemical yellowing of poly(arylene ether)-containing compositions has long been known, existing solutions to this problem are either ineffective or impractical for white and off-white wire and cable insulation. For example, in one approach, photochemical yellowing of the poly(arylene ether) is compensated for by the incorporation of a photobleachable dye. See, for example, U.S. Patent Nos. 4,493,915 and 4,551,494 to Lohmeijer. This approach is not effective in white and off-white poly(arylene ether) compositions because the presence of the photobleachable dye is incompatible with the desired white or off-white color. In another approach, the surface of an article comprising a polyphenylene ether and a second resin is treated with solvent to selectively remove polyphenylene ether from the surface of the article.

See, for example, U.S. Patent No. 5,055,494 to van der Meer. This approach is impractical for wire and cable insulation because of the large surface area that would need to be solvent treated.

[0004] There therefore remains a need for poly(arylene ether) compositions that exhibit the physical and flame retardant properties required for wire and cable insulation and further exhibit color stability after prolonged light exposure.

BRIEF DESCRIPTION OF THE INVENTION

[0005] The above-described and other drawbacks are alleviated by a method of forming a thermoplastic composition, comprising: melt-kneading 20 to 40 weight percent of a poly(arylene ether), 10 to 60 weight percent of a thermoplastic elastomer, 5 to 25 weight percent of a flame retardant, and 0.4 to 10 weight percent of an ultraviolet radiation stabilizer composition comprising at least two ultraviolet stabilizing compounds selected from different subgroups of the group consisting of a first subgroup consisting of ultraviolet radiation absorbers, a second subgroup consisting of hindered amine light stabilizers, and a third subgroup consisting of cycloaliphatic epoxy compounds to form a thermoplastic composition; wherein all weight percents are based on the total weight of the composition; wherein the ultraviolet radiation stabilizer composition is provided in the form of an ultraviolet radiation stabilizer masterbatch comprising the ultraviolet radiation stabilizer composition and the thermoplastic elastomer; and wherein the thermoplastic composition comprises less than or equal to 20 weight percent of rubber-modified polystyrene.

[0006] Another embodiment is a thermoplastic composition prepared by the above method, wherein the poly(arylene ether) comprises a poly(2,6-dimethyl-1,4-phenylene ether) having an intrinsic viscosity of 0.35 to 0.6 deciliter per gram measured at 25°C in chloroform; wherein the thermoplastic composition comprises 20 to 30 weight percent of the poly(arylene ether); wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer, a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer, and a random copolymer of ethylene and propylene; wherein the thermoplastic composition comprises 25 to 35 weight percent of the thermoplastic elastomer; wherein the flame retardant comprises melamine polyphosphate and magnesium hydroxide; wherein the thermoplastic composition comprises 13 to 20 weight percent of the flame retardant; wherein the ultraviolet radiation stabilizer composition comprises 0.3 to 1.2 weight percent of a benzotriazole ultraviolet radiation absorber, 0.3 to 1.5 weight percent of a hindered amine light stabilizer, and to 0.6 weight percent of a cycloaliphatic epoxy

compound; wherein the method further comprises melt kneading 4 to 12 weight percent of a polybutene with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition; wherein the polybutene has a number average molecular weight of 600 to 1,000 atomic mass units; wherein the method further comprises melt kneading 2 to 5 weight percent of titanium dioxide with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, the ultraviolet radiation stabilizer composition, and the polybutene; wherein the composition comprises less than 5 weight percent of rubber-modified polystyrene; and wherein the thermoplastic composition exhibits a CIELAB color shift, ΔE , less than or equal to 2 measured according to ASTM D2244 after 300 hours exposure to xenon arc exposure according to ASTM D4459.

[0007] Another embodiment is an ultraviolet radiation stabilizer masterbatch, comprising: 80 to 99 weight percent of a thermoplastic elastomer selected from the group consisting of hydrogenated block copolymers of an alkenyl aromatic compound and a conjugated diene, polyolefin block copolymers having a polyethylene or polypropylene block and block that is a copolymer of ethylene and a C₃-C₁₂ olefin, random copolymers of ethylene and a C₃-C₁₂ alpha-olefin, and mixtures thereof, and 1 to 20 weight percent of an ultraviolet radiation stabilizer composition comprising at least two ultraviolet stabilizing compounds selected from different subgroups of the group consisting of a first subgroup consisting of ultraviolet radiation absorbers, a second subgroup consisting of hindered amine light stabilizers, and a third subgroup consisting of cycloaliphatic epoxy compounds; wherein all weight percents are based on the total weight of the ultraviolet radiation stabilizer masterbatch.

[0008] These and other embodiments are described in detail below.

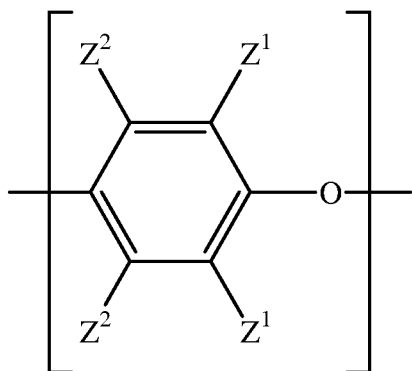
DETAILED DESCRIPTION OF THE INVENTION

[0009] In their course of their research on light-colored thermoplastic compositions, the present inventors were aware of the photochemical yellowing challenge inherent in poly(arylene ether)s. They therefore initially expected that blends of poly(arylene ether)s and thermoplastic elastomer resins would benefit from compounding methods in which ultraviolet radiation stabilizers are preferentially distributed into the poly(arylene ether)-containing phase. However, it was unexpectedly discovered that improved photostability of the blends was obtained when ultraviolet radiation stabilizers were pre-compounded with the thermoplastic elastomer component. Specifically, the resulting blends show improved photostability (reduced photochemical yellowing) compared to blends in which all

components are melt blended simultaneously, as well as blends in which the ultraviolet radiation stabilizers were pre-compounded with the poly(arylene ether) component.

[0010] Thus, one embodiment is a method of forming a thermoplastic composition, comprising: melt-kneading 20 to 40 weight percent of a poly(arylene ether), 10 to 60 weight percent of a thermoplastic elastomer, 5 to 25 weight percent of a flame retardant, and 0.4 to 10 weight percent of an ultraviolet radiation stabilizer composition comprising at least two ultraviolet stabilizing compounds selected from different subgroups of the group consisting of a first subgroup consisting of ultraviolet radiation absorbers, a second subgroup consisting of hindered amine light stabilizers, and a third subgroup consisting of cycloaliphatic epoxy compounds to form a thermoplastic composition; wherein all weight percents are based on the total weight of the composition; wherein the ultraviolet radiation stabilizer composition is provided in the form of an ultraviolet radiation stabilizer masterbatch comprising the ultraviolet radiation stabilizer composition and the thermoplastic elastomer; and wherein the thermoplastic composition comprises less than or equal to 20 weight percent of rubber-modified polystyrene.

[0011] The first component present in the melt-kneaded mixture is the poly(arylene ether). In some embodiments, the poly(arylene ether) comprises repeating structural units having the formula



wherein for each structural unit, each Z^1 is independently halogen, unsubstituted or substituted $\text{C}_1\text{-C}_{12}$ hydrocarbyl with the proviso that the hydrocarbyl group is not tertiary hydrocarbyl, $\text{C}_1\text{-C}_{12}$ hydrocarbylthio (that is, $(\text{C}_1\text{-C}_{12} \text{ hydrocarbyl})\text{S-}$), $\text{C}_1\text{-C}_{12}$ hydrocarbyloxy, or $\text{C}_2\text{-C}_{12}$ halohydrocarbyloxy wherein at least two carbon atoms separate the halogen and oxygen atoms; and each Z^2 is independently hydrogen, halogen, unsubstituted or substituted $\text{C}_1\text{-C}_{12}$ hydrocarbyl with the proviso that the hydrocarbyl group is not tertiary hydrocarbyl, $\text{C}_1\text{-C}_{12}$ hydrocarbylthio, $\text{C}_1\text{-C}_{12}$ hydrocarbyloxy, or $\text{C}_2\text{-C}_{12}$ halohydrocarbyloxy wherein at least two carbon atoms separate the halogen and oxygen atoms. As used herein, the term

“hydrocarbyl”, whether used by itself, or as a prefix, suffix, or fragment of another term, refers to a residue that contains only carbon and hydrogen. The residue can be aliphatic or aromatic, straight-chain, cyclic, bicyclic, branched, saturated, or unsaturated. It can also contain combinations of aliphatic, aromatic, straight chain, cyclic, bicyclic, branched, saturated, and unsaturated hydrocarbon moieties.

[0012] In some embodiments, the poly(arylene ether) comprises 2,6-dimethyl-1,4-phenylene ether units, 2,3,6-trimethyl-1,4-phenylene ether units, or a combination thereof.

[0013] The poly(arylene ether) can comprise molecules having aminoalkyl-containing end group(s), typically located in a position ortho to the hydroxy group. Also frequently present are tetramethyldiphenoquinone (TMDQ) end groups, typically obtained from 2,6-dimethylphenol-containing reaction mixtures in which tetramethyldiphenoquinone by-product is present. The poly(arylene ether) can be in the form of a homopolymer, a copolymer, a graft copolymer, an ionomer, or a block copolymer, as well as combinations comprising at least one of the foregoing.

[0014] The poly(arylene ether) can have a number average molecular weight of 3,000 to 40,000 atomic mass units (AMU) and a weight average molecular weight of 5,000 to 80,000 AMU, as determined by gel permeation chromatography using monodisperse polystyrene standards, a styrene divinyl benzene gel at 40°C and samples having a concentration of 1 milligram per milliliter of chloroform. The poly(arylene ether) can have an intrinsic viscosity of 0.05 to 1.0 deciliter per gram (dL/g), as measured in chloroform at 25°C, specifically 0.1 to 0.8 dL/g, more specifically 0.2 to 0.6 dL/g, even more specifically 0.3 to 0.6 dL/g. Those skilled in the art understand that intrinsic viscosity of a poly(arylene ether) can increase by up to 30% on melt kneading. The above intrinsic viscosity range of 0.05 to 1.0 deciliter per gram is intended to encompass intrinsic viscosities both before and after melt kneading to form the composition. A blend of poly(arylene ether)s having different intrinsic viscosities can be used.

[0015] In some embodiments, the poly(arylene ether) molecular weight distribution is characterized by a weight average molecular weight and a peak molecular weight, and the ratio of the weight average molecular weight to the peak molecular weight is about 1.3 : 1 to about 4 : 1, specifically 1.5:1 to about 3:1, more specifically 1.8:1 to about 2.5:1. As used herein, the term “peak molecular weight” is defined as the most commonly occurring molecular weight in the molecular weight distribution. In statistical terms, the peak molecular weight is the mode of the molecular weight distribution. In practical terms, when the molecular weight is determined by a chromatographic method such as gel permeation

chromatography, the peak molecular weight is the poly(arylene ether) molecular weight of the highest point in a plot of molecular weight on the x-axis versus absorbance on the y-axis. In some embodiments, the poly(arylene ether) molecular weight distribution is at least bimodal. In the context of a molecular weight distribution, the term “bimodal” means that a plot of molecular weight on the x-axis versus frequency on the y-axis has two local maxima. The term “at least bimodal” means that the plot has two or more local maxima. In some embodiments, the molecular weight distribution comprises a first local maximum having a first molecular weight (corresponding to M_p) and a second local maximum having a second molecular weight that is greater than the first molecular weight, and the ratio of the second molecular weight to the first molecular weight is about 2 : 1 to about 4 : 1.

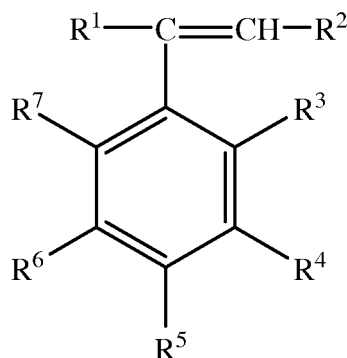
[0016] The thermoplastic composition comprises 20 to 40 weight percent of the poly(arylene ether), based on the total weight of the composition. Within this range, the poly(arylene ether) amount specifically can be 22 to 30 weight percent, more specifically 24 to 28 weight percent.

[0017] In addition to the poly(arylene ether), the melt-kneaded mixture comprises a thermoplastic elastomer. As used herein the term “thermoplastic elastomer” refers to an elastomeric copolymer comprising repeating units derived from ethylene and/or a C_3 - C_{12} alpha-olefin. Suitable thermoplastic elastomers include hydrogenated block copolymers of an alkenyl aromatic compound and a conjugated diene, polyolefin block copolymers having a (hard) polyethylene or polypropylene block and (soft) block that is a copolymer of ethylene and a C_3 - C_{12} olefin, random copolymers of ethylene and a C_3 - C_{12} alpha-olefin, and mixtures thereof.

[0018] The thermoplastic elastomer can comprise a hydrogenated block copolymer of an alkenyl aromatic compound and a conjugated diene. For brevity, this component is referred to herein as the “hydrogenated block copolymer”. The hydrogenated block copolymer may comprise 10 to 90 weight percent of poly(alkenyl aromatic) content and 90 to 10 weight percent of hydrogenated poly(conjugated diene) content. In some embodiments, the poly(alkenyl aromatic) content is 10 to 45 weight percent, specifically 20 to 40 weight percent. In other embodiments, the poly(alkenyl aromatic) content is greater than 45 weight percent to 90 weight percent, specifically 55 to 80 weight percent. The hydrogenated block copolymer can have a weight average molecular weight of 40,000 to 400,000 atomic mass units. The number average molecular weight and the weight average molecular weight may be determined by gel permeation chromatography and based on comparison to polystyrene standards. In some embodiments, the hydrogenated block copolymer has a weight average

molecular weight of 200,000 to 400,000 atomic mass units, specifically 220,000 to 350,000 atomic mass units. In other embodiments, the hydrogenated block copolymer can have a weight average molecular weight of 40,000 to less than 200,000 atomic mass units, specifically 40,000 to 180,000 atomic mass units, more specifically 40,000 to 150,000 atomic mass units.

[0019] The alkenyl aromatic monomer used to prepare the hydrogenated block copolymer can have the structure



wherein R^1 and R^2 each independently represent a hydrogen atom, a C_1 - C_8 alkyl group, or a C_2 - C_8 alkenyl group; R^3 and R^7 each independently represent a hydrogen atom, a C_1 - C_8 alkyl group, a chlorine atom, or a bromine atom; and R^4 , R^5 , and R^6 each independently represent a hydrogen atom, a C_1 - C_8 alkyl group, or a C_2 - C_8 alkenyl group, or R^4 and R^5 are taken together with the central aromatic ring to form a naphthyl group, or R^5 and R^6 are taken together with the central aromatic ring to form a naphthyl group. Specific alkenyl aromatic monomers include, for example, styrene, chlorostyrenes such as p-chlorostyrene, and methylstyrenes such as alpha-methylstyrene and p-methylstyrene. In some embodiments, the alkenyl aromatic monomer is styrene.

[0020] The conjugated diene used to prepare the hydrogenated block copolymer can be a C_4 - C_{20} conjugated diene. Suitable conjugated dienes include, for example, 1,3-butadiene, 2-methyl-1,3-butadiene, 2-chloro-1,3-butadiene, 2,3-dimethyl-1,3-butadiene, 1,3-pentadiene, 1,3-hexadiene, and the like, and combinations thereof. In some embodiments, the conjugated diene is 1,3-butadiene, 2-methyl-1,3-butadiene, or a combination thereof. In some embodiments, the conjugated diene consists of 1,3-butadiene.

[0021] The hydrogenated block copolymer is a copolymer comprising (A) at least one block derived from an alkenyl aromatic compound and (B) at least one block derived from a conjugated diene, in which the aliphatic unsaturated group content in the block (B) is at least partially reduced by hydrogenation. In some embodiments, the aliphatic unsaturation in the (B) block is reduced by at least 50 percent, specifically at least 70 percent. The arrangement

of blocks (A) and (B) includes a linear structure, a grafted structure, and a radial teleblock structure with or without a branched chain. Linear block copolymers include tapered linear structures and non-tapered linear structures. In some embodiments, the hydrogenated block copolymer has a tapered linear structure. In some embodiments, the hydrogenated block copolymer has a non-tapered linear structure. In some embodiments, the hydrogenated block copolymer comprises a B block that comprises random incorporation of alkenyl aromatic monomer. Linear block copolymer structures include diblock (A-B block), triblock (A-B-A block or B-A-B block), tetrablock (A-B-A-B block), and pentablock (A-B-A-B-A block or B-A-B-A-B block) structures as well as linear structures containing 6 or more blocks in total of A and B, wherein the molecular weight of each A block may be the same as or different from that of other A blocks, and the molecular weight of each B block may be the same as or different from that of other B blocks. In some embodiments, the hydrogenated block copolymer is a diblock copolymer, a triblock copolymer, or a combination thereof.

[0022] In some embodiments, the hydrogenated block copolymer is a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer. In some embodiments, the hydrogenated block copolymer is a polystyrene-poly(ethylene-propylene) diblock copolymer. These block copolymers do not include the residue of any functionalizing agents or any monomers other than those indicated by their names.

[0023] In some embodiments, the hydrogenated block copolymer excludes the residue of monomers other than the alkenyl aromatic compound and the conjugated diene. In some embodiments, the hydrogenated block copolymer consists of blocks derived from the alkenyl aromatic compound and the conjugated diene. It does not comprise grafts formed from these or any other monomers. It also consists of carbon and hydrogen atoms and therefore excludes heteroatoms.

[0024] In some embodiments, the hydrogenated block copolymer includes the residue of one or more acid functionalizing agents, such as maleic anhydride.

[0025] In some embodiments, the thermoplastic elastomer comprises a polystyrene-poly(ethylene-propylene) diblock copolymer.

[0026] In some embodiments, the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer.

[0027] In some embodiments, the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer.

[0028] Methods for preparing hydrogenated block copolymers are known in the art and many hydrogenated block copolymers are commercially available. Illustrative

commercially available hydrogenated block copolymers include the polystyrene-poly(ethylene-propylene) diblock copolymers available from Kraton Polymers as KRATON G1701 and G1702; the polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymers available from Kraton Polymers as KRATON G1641, G1650, G1651, G1654, G1657, G1726, G4609, G4610, GRP-6598, RP-6924, MD-6932M, MD-6933, and MD-6939; the polystyrene-poly(ethylene-butylene-styrene)-polystyrene (S-EB/S-S) triblock copolymers available from Kraton Polymers as KRATON RP-6935 and RP-6936, the polystyrene-poly(ethylene-propylene)-polystyrene triblock copolymers available from Kraton Polymers as KRATON G1730; the maleic anhydride-grafted polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymers available from Kraton Polymers as KRATON G1901, G1924, and MD-6684; the maleic anhydride-grafted polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer available from Kraton Polymers as KRATON MD-6670; the polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer comprising 67 weight percent polystyrene available from Asahi Kasei Elastomer as TUFTEC H1043; the polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer comprising 42 weight percent polystyrene available from Asahi Kasei Elastomer as TUFTEC H1051; the polystyrene-poly(butadiene-butylene)-polystyrene triblock copolymers available from Asahi Kasei Elastomer as TUFTEC P1000 and P2000; the polystyrene-polybutadiene-poly(styrene-butadiene)-polystyrene block copolymer available from Asahi Kasei Elastomer as S.O.E.-SS L601; the hydrogenated radial block copolymers available from Chevron Phillips Chemical Company as K-Resin KK38, KR01, KR03, and KR05; the polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer comprising 60 weight polystyrene available from Kuraray as SEPTON S8104; the polystyrene-poly(ethylene-ethylene/propylene)-polystyrene triblock copolymers available from Kuraray as SEPTON S4044, S4055, S4077, and S4099; and the polystyrene-poly(ethylene-propylene)-polystyrene triblock copolymer comprising 65 weight percent polystyrene available from Kuraray as SEPTON S2104. Mixtures of two of more hydrogenated block copolymers may be used.

[0029] The thermoplastic elastomer can comprise a polyolefin block copolymer comprising a (hard) polyethylene or polypropylene block and (soft) block that is a copolymer of ethylene and a C₃-C₁₂ olefin. Such block copolymers and methods for their preparation are known in the art. Commercially available examples of polyolefin block copolymers include those sold by Dow under the INFUSE trade name, those sold by Advanced Elastomer Systems under the VISTAFLEX trade name, those sold by Ferro Corporation under the FERROFLEX trade name, those sold by Republic Plastics under the ETA and RTA trade

names, those sold by LyondellBasell Advanced Polyolefins under the DEXFLEX trade name, those sold by A. Schulman under the POLYTROPE trade name, those sold by Teknor Apex under the TELCAR trade name, those sold by DSM under the KELBUROU trade name, those sold by British Vita under the VITACOM TPO trade name, and those sold by SABIC under the VESTOLEN trade name.

[0030] The thermoplastic elastomer can comprise a random copolymer of ethylene and a C₃-C₁₂ alpha-olefin. The C₃-C₁₂ alpha-olefin can be, for example, propylene, 1-butene, or 1-octene. In some embodiments, the thermoplastic elastomer comprises a random copolymer of ethylene and propylene.

[0031] The thermoplastic elastomer can comprise a mixture of the above-described elastomers. For example, the thermoplastic elastomer can comprise a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer and a random copolymer of ethylene and propylene. The thermoplastic elastomer can also comprise a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer, a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer, and a random copolymer of ethylene and propylene.

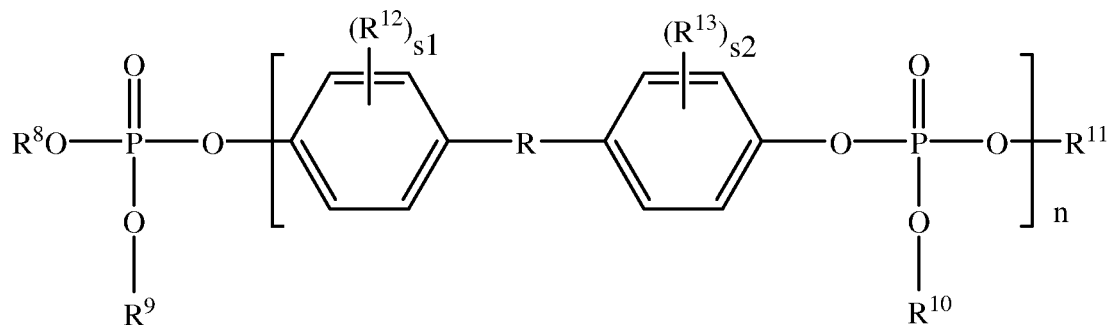
[0032] The thermoplastic composition comprises the thermoplastic elastomer in an amount of 10 to 60 weight percent, based on the total weight of the composition. Within this range, the thermoplastic elastomer amount can be specifically 20 to 45 weight percent, more specifically 25 to 35 weight percent.

[0033] In addition to the poly(arylene ether) and the thermoplastic elastomer, the melt-kneaded composition comprises a flame retardant. The flame retardant is a chemical compound or mixture of chemical compounds capable of improving the flame retardancy of the thermoplastic composition. Suitable flame retardants include organophosphate esters, metal dialkyl phosphinates, nitrogen-containing flame retardants, metal hydroxides, and mixtures thereof.

[0034] In some embodiments, the flame retardant comprises an organophosphate ester. Exemplary organophosphate ester flame retardants include, but are not limited to, phosphate esters comprising phenyl groups, substituted phenyl groups, or a combination of phenyl groups and substituted phenyl groups, bis-aryl phosphate esters based upon resorcinol such as, for example, resorcinol bis(diphenyl phosphate), as well as those based upon bisphenols such as, for example, bisphenol A bis(diphenyl phosphate). In some embodiments, the organophosphate ester is selected from tris(alkylphenyl) phosphates (for example, CAS Reg. No. 89492-23-9 or CAS Reg. No. 78-33-1), resorcinol bis(diphenyl phosphate) (CAS Reg. No. 57583-54-7), bisphenol A bis(diphenyl phosphate) (CAS Reg. No.

181028-79-5), triphenyl phosphate (CAS Reg. No. 115-86-6), tris(isopropylphenyl) phosphates (for example, CAS Reg. No. 68937-41-7), and mixtures of two or more of the foregoing organophosphate esters.

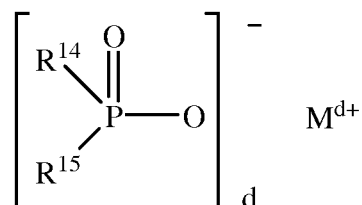
[0035] In some embodiments the organophosphate ester comprises a bis-aryl phosphate having the formula



wherein R is independently at each occurrence a C₁-C₁₂ alkylene group; R¹² and R¹³ are independently at each occurrence a C₁-C₅ alkyl group; R⁸, R⁹, and R¹¹ are independently a C₁-C₁₂ hydrocarbyl group; R¹⁰ is independently at each occurrence a C₁-C₁₂ hydrocarbyl group; n is 1 to 25; and s₁ and s₂ are independently an integer equal to 0, 1, or 2. In some embodiments OR⁸, OR⁹, OR¹⁰ and OR¹¹ are independently derived from phenol, a monoalkylphenol, a dialkylphenol or a trialkylphenol.

[0036] As readily appreciated by one of ordinary skill in the art, the bis-aryl phosphate is derived from a bisphenol. Exemplary bisphenols include 2,2-bis(4-hydroxyphenyl)propane (so-called bisphenol A), 2,2-bis(4-hydroxy-3-methylphenyl)propane, bis(4-hydroxyphenyl)methane, bis(4-hydroxy-3,5-dimethylphenyl)methane and 1,1-bis(4-hydroxyphenyl)ethane. In some embodiments, the bisphenol comprises bisphenol A.

[0037] In some embodiments, the flame retardant comprises a metal dialkyl phosphinate. As used herein, the term “metal dialkyl phosphinate” refers to a salt comprising at least one metal cation and at least one dialkyl phosphinate anion. In some embodiments, the metal dialkyl phosphinate has the formula

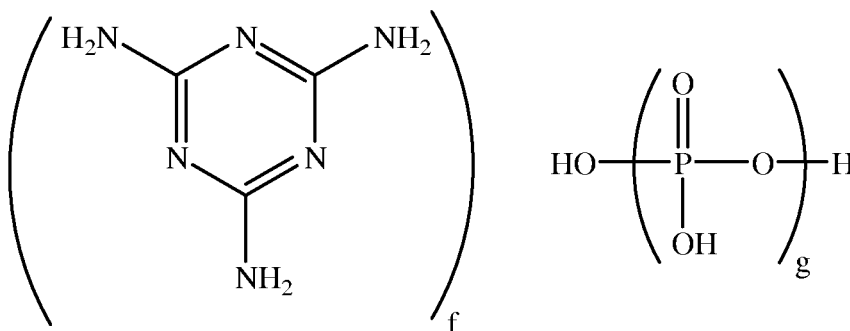


wherein R¹⁴ and R¹⁵ are each independently C₁-C₆ alkyl; M is calcium, magnesium, aluminum, or zinc; and d is 2 or 3. Examples of R¹⁴ and R¹⁵ include methyl, ethyl, n-propyl, isopropyl, n-butyl, tert-butyl, n-pentyl, and phenyl. In some embodiments, R¹⁴ and R¹⁵ are

ethyl, M is aluminum, and d is 3 (that is, the metal dialkyl phosphinate is aluminum tris(diethyl phosphinate)).

[0038] In some embodiments, the metal dialkyl phosphinate is in particulate form. The metal dialkyl phosphinate particles may have a median particle diameter (D50) less than or equal to 40 micrometers, or, more specifically, a D50 less than or equal to 30 micrometers, or, even more specifically, a D50 less than or equal to 25 micrometers. Additionally, the metal dialkyl phosphinate may be combined with a polymer, such as a poly(arylene ether), a polyolefin, a polyamide, a block copolymer, or combination thereof, to form a masterbatch. The metal dialkyl phosphinate masterbatch comprises the metal dialkyl phosphinate in an amount greater than is present in the thermoplastic composition. Employing a masterbatch for the addition of the metal dialkyl phosphinate to the other components of the thermoplastic composition can facilitate addition and improve distribution of the metal dialkyl phosphinate.

[0039] In some embodiments, the flame retardant comprises a nitrogen-containing flame retardant comprising a nitrogen-containing heterocyclic base and a phosphate or pyrophosphate or polyphosphate acid. In some embodiments, the nitrogen-containing flame retardant has the formula



wherein g is 1 to 10,000, and the ratio of f to g is 0.5:1 to 1.7:1, specifically 0.7:1 to 1.3:1, more specifically 0.9:1 to 1.1:1. It will be understood that this formula includes species in which one or more protons are transferred from the phosphate group(s) to the melamine group(s). When g is 1, the nitrogen-containing flame retardant is melamine phosphate (CAS Reg. No. 20208-95-1). When g is 2, the nitrogen-containing flame retardant is melamine pyrophosphate (CAS Reg. No. 15541 60-3). When g is, on average, greater than 2, the nitrogen-containing flame retardant is a melamine polyphosphate (CAS Reg. No. 56386-64-2). In some embodiments, the nitrogen-containing flame retardant is melamine pyrophosphate, melamine polyphosphate, or a mixture thereof. In some embodiments in which the nitrogen-containing flame retardant is melamine polyphosphate, g has an average value of greater than 2 to 10,000, specifically 5 to 1,000, more specifically 10 to 500. In

some embodiments in which the nitrogen-containing flame retardant is melamine polyphosphate, g has an average value of greater than 2 to 500. Methods for preparing melamine phosphate, melamine pyrophosphate, and melamine polyphosphate are known in the art, and all are commercially available. For example, melamine polyphosphates may be prepared by reacting polyphosphoric acid and melamine, as described, for example, in U.S. Pat. No. 6,025,419 to Kasowski et al., or by heating melamine pyrophosphate under nitrogen at 290°C to constant weight, as described in International Patent Application No. WO 98/08898 A1 to Jacobson et al.

[0040] The nitrogen-containing flame retardant can have a low volatility. For example, in some embodiments, the nitrogen-containing flame retardant exhibits less than 1 percent weight loss by thermogravimetric analysis when heated at a rate of 20°C per minute from 25 to 280°C, specifically 25 to 300°C, more specifically 25 to 320°C.

[0041] In some embodiments, the flame retardant comprises a metal hydroxide. Suitable metal hydroxides include all those capable of providing fire retardancy, as well as combinations of such metal hydroxides. The metal hydroxide can be chosen to have substantially no decomposition during processing of the fire additive composition and/or flame retardant thermoplastic composition. Substantially no decomposition is defined herein as amounts of decomposition that do not prevent the flame retardant additive composition from providing the desired level of fire retardancy. Exemplary metal hydroxides include, but are not limited to, magnesium hydroxide (for example, CAS Reg. No. 1309-42-8), aluminum hydroxide (for example, CAS Reg. No. 21645-51-2), cobalt hydroxide (for example, CAS Reg. No. 21041-93-0) and combinations of two or more of the foregoing. In some embodiments, the metal hydroxide comprises magnesium hydroxide. In some embodiments the metal hydroxide has an average particle size less than or equal to 10 micrometers and/or a purity greater than or equal to 90 weight percent. In some embodiments it is desirable for the metal hydroxide to contain substantially no water, for example as evidenced by a weight loss of less than 1 weight percent upon drying at 120°C for 1 hour. In some embodiments the metal hydroxide can be coated, for example, with stearic acid or other fatty acid.

[0042] In some embodiments, the flame retardant comprises melamine polyphosphate and magnesium hydroxide.

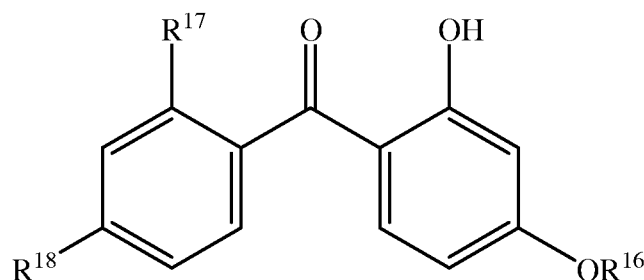
[0043] The flame retardant is present in the thermoplastic composition in an amount of 5 to 25 weight percent of a flame retardant, based on the total weight of the thermoplastic composition. Within this range, the flame retardant amount can be 10 to 20 weight percent, specifically 14 to 18 weight percent. When the flame retardant comprises two or more

components, these components can be used in any amount, provided that the total amount of flame retardant is in the range of 5 to 25 weight percent.

[0044] In addition to the poly(arylene ether), the thermoplastic elastomer, and the flame retardant, the thermoplastic composition comprises an ultraviolet radiation stabilizer composition. The ultraviolet radiation stabilizer composition comprises at least two ultraviolet stabilizing compounds selected from different subgroups of the group consisting of a first subgroup consisting of ultraviolet radiation absorbers, a second subgroup consisting of hindered amine light stabilizers, and a third subgroup consisting of cycloaliphatic epoxy compounds.

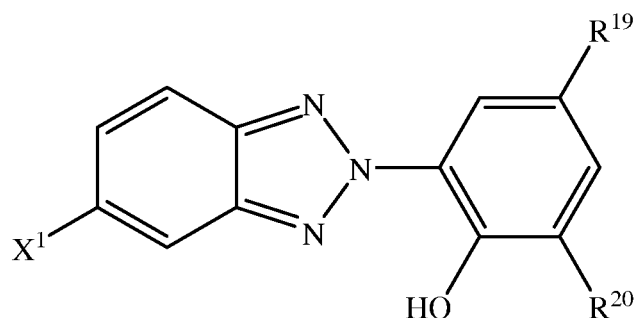
[0045] Classes of ultraviolet radiation absorbers include benzophenones, benzotriazoles, triazines, oxanilides, and cyanoacrylates.

[0046] Benzophenone ultraviolet radiation absorbers include those having the structure



wherein R^{16} , R^{17} , and R^{18} are each independently hydrogen or C_1 - C_{12} alkyl. Illustrative benzophenone ultraviolet radiation absorbers include benzoersorcinol (CAS Reg. No. 131-56-6; UVINUL 400 from BASF), oxybenzone (CAS Reg. No. 131-57-7; CYASORB UV-9 from Cytec), and octabenzone (CAS Reg. No. 1843-05-6; CYASORB UV-531 from Cytec).

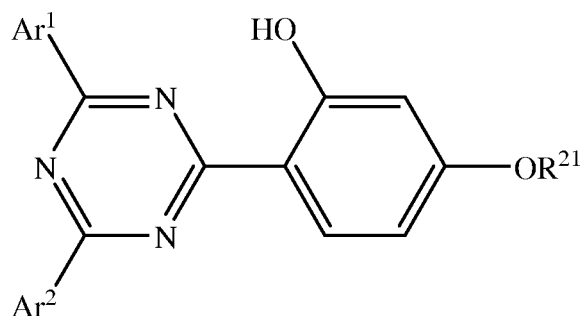
[0047] Benzotriazole ultraviolet radiation absorbers include those having the structure



wherein X^1 is hydrogen or chloro; R^{19} is C_1 - C_{12} alkyl; and R^{20} is hydrogen or C_1 - C_{12} alkyl. Illustrative benzotriazole ultraviolet radiation absorbers include 2-(2'-hydroxy-5'-tert-octylphenyl)benzotriazole (CAS Reg. No. 3147-75-9; CYASORB 5411 from Cytec), 2-(2'-hydroxy-3',5'-di-tert-butylphenyl)benzotriazole (CAS Reg. No. 3846-71-7; TINUVIN 320

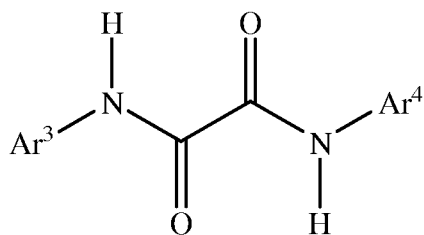
from Ciba Specialty Chemicals), and 2-(2'-hydroxy-3',5'-di-tert-pentylphenyl)benzotriazole (CAS Reg. No. 25973-55-1; TINUVIN 328 from Ciba Specialty Chemicals).

[0048] Triazine ultraviolet radiation absorbers include those having the structure



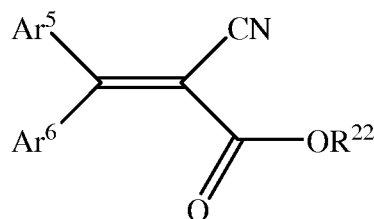
wherein Ar¹ and Ar² are each independently an optionally substituted C₆-C₁₈ aryl group, and R₂₁ is hydrogen or a C₁-C₁₂ hydrocarbyl group. Illustrative triazine ultraviolet radiation absorbers include 2-[4,6-bis(2,4-dimethylphenyl)-1,3,5-triazin-2-yl]-5-(octyloxy)phenol (CAS Reg. No. 2725-22-6; CYASORB UV-1164 from Cytec), and 2-[4,6-diphenyl-1,3,5-triazin-2-yl]-5-(hexyloxy)phenol (CAS Reg. No. 147315-50-2); TINUVIN 1577 from Ciba Specialty Chemicals).

[0049] Oxanilide ultraviolet radiation absorbers include those having the structure



wherein Ar³ and Ar⁴ are each independently an optionally substituted C₆-C₁₈ aryl group. Illustrative oxanilide ultraviolet radiation absorbers include N-(2-ethoxyphenyl)-N'-(4-ethylphenyl)ethylene diamide (CAS Reg. No. 23949-66-8; CANDUVOR VSU from Clariant), and N-(2-ethoxy-5-tert-butyl-phenyl)-N'-(2-ethylphenyl)ethylene diamide (CAS Reg. No. 35001-52-6; SANDUVOR EPU from Clariant).

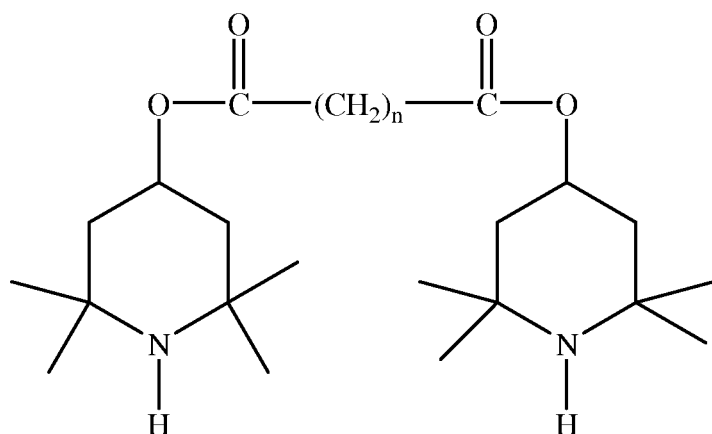
[0050] Cyanoacrylate ultraviolet radiation absorbers include those having the structure



wherein Ar⁵ and Ar⁶ are each independently an optionally substituted C₆-C₁₈ aryl group, and R²² is a C₁-C₁₂ alkyl group. Illustrative cyanoacrylate ultraviolet radiation absorbers include

ethyl-2-cyano-3,3-diphenyl acrylate (CAS Reg. No. 5232-99-5; UVINUL 3035 from BASF), and 2-ethylhexyl-2-cyano-3,3-diphenylacrylate (CAS Reg. No. 6197-30-4; UVINUL 3039 from BASF).

[0051] Hindered amine light stabilizers generally comprise a 5- or 6-membered ring comprising a nitrogen atom bonded to two quaternary carbons. For example, suitable hindered amine light stabilizers include those having the structure



wherein n is 2 to 12, and specifically wherein n is 8. In some embodiments, the hindered amine light stabilizer is bis(2,2,6,6-tetramethyl-4-piperidiny)sebacate, CAS Reg. No. 52829-07-9.

[0052] Cycloaliphatic epoxy compounds include, for example, cyclopentene oxide, cyclohexene oxide, 4-vinylcyclohexene oxide, 4-vinylcyclohexene dioxide, 3,4-epoxycyclohexylmethyl 3',4'-epoxycyclohexylcarboxylate (CAS Reg. No. 2386-87-0), 4-alkoxymethylcyclohexene oxides, acyloxymethylcyclohexene oxides, 1,3-bis(2-(3,4-epoxycyclohexyl)ethyl)-1,1,3,3-tetramethydisiloxane, 2-epoxy-1,2,3,4-tetrahydronaphthalene, and the like, and mixtures thereof.

[0053] The total amount of ultraviolet radiation stabilizer composition is 0.4 to 10 weight percent, based on the total weight of the thermoplastic composition. Within this range, the ultraviolet radiation stabilizer composition can be 0.8 to 6 weight percent, specifically 1.2 to 3 weight percent. When present, the ultraviolet radiation absorber is typically used in an amount of 0.3 to 1.2 weight percent, specifically 0.6 to 0.8 weight percent, based on the total weight of the composition. When present, the hindered amine light stabilizer is typically used in an amount of 0.3 to 1.5 weight percent, specifically 0.6 to 1.2 weight percent, based on the total weight of the composition. When present, the cycloaliphatic epoxy compound is typically used in an amount of 0.1 to 0.6 weight percent, specifically 0.2 to 0.5 weight percent, more specifically 0.3 to 0.4 weight percent, based on the total weight of the composition.

[0054] In some embodiments, the ultraviolet radiation stabilizer composition comprises 0.3 to 1.2 weight percent of a benzotriazole ultraviolet radiation absorber, 0.3 to 1.5 weight percent of a hindered amine light stabilizer, and 0.1 to 0.6 weight percent of a cycloaliphatic epoxy compound.

[0055] The ultraviolet radiation stabilizer composition is provided in the form of an ultraviolet radiation stabilizer masterbatch comprising the ultraviolet radiation stabilizer composition and the thermoplastic elastomer. As demonstrated in the working examples below, pre-compounding the ultraviolet radiation stabilizer composition with the thermoplastic elastomer unexpectedly improves the ultraviolet light resistance of the composition compared to compositions in which the ultraviolet radiation stabilizer composition is added separately or pre-compounded with the poly(arylene ether) component. Given the known ultraviolet instability of poly(arylene ether)s, it is very surprising that the ultraviolet light resistance of a poly(arylene ether)-containing composition could be improved by pre-compounding the ultraviolet radiation stabilizer with a component other than the poly(arylene ether).

[0056] As the ultraviolet radiation stabilizer masterbatch is described as comprising the ultraviolet radiation stabilizer composition and the thermoplastic elastomer, it will be understood that the radiation stabilizer masterbatch can contain some or all of the total thermoplastic elastomer content of the thermoplastic composition. Similarly, the ultraviolet radiation stabilizer masterbatch can contain some or all of the total ultraviolet radiation stabilizer composition. In some embodiments, at least 50 weight percent, specifically at least 90 weight percent, more specifically 100 weight percent, of the ultraviolet radiation stabilizer composition is incorporated into the ultraviolet radiation stabilizer masterbatch. In some embodiments, at least 50 weight percent, specifically at least 90 weight percent, more specifically 100 weight percent, of the thermoplastic elastomer is incorporated into the ultraviolet radiation stabilizer masterbatch. Also, to the extent that the thermoplastic elastomer comprises two or more chemically distinct thermoplastic elastomer components, the radiation stabilizer masterbatch can contain some or all of the distinct elastomer components.

[0057] The ultraviolet radiation stabilizer masterbatch is prepared by melt-kneading the ultraviolet radiation stabilizer composition and the thermoplastic elastomer to produce an intimate blend. Illustrative examples of specific compounding conditions are provided in the working examples below.

[0058] The thermoplastic composition comprises less than or equal to 20 weight percent of rubber-modified polystyrene. It has been observed that incorporation of rubber-modified polystyrene in amounts greater than 20 weight percent is associated with reduced stability to ultraviolet radiation. In some embodiments, the composition comprises rubber-modified polystyrene in an amount less than or equal to 15 weight percent, specifically less than or equal to 10 weight percent, more specifically less than or equal to 5 weight percent, even more specifically less than or equal to 1 weight percent, yet more specifically less than or equal to 0.1 weight percent. In some embodiments, the composition excludes rubber-modified polystyrene. In this context, “excludes” means that no rubber-modified polystyrene is intentionally added to the composition.

[0059] In addition to the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition, the thermoplastic composition can, optionally, comprise additional components. For example, in some embodiments, the thermoplastic composition further comprises polyethylene, polypropylene, or a mixture thereof. This component is distinguished from the thermoplastic elastomer in that the terms “polyethylene” and “polypropylene” refer to homopolymers of ethylene and propylene, respectively, whereas the thermoplastic elastomer is by definition a copolymer. When present, the amount of the polyethylene, polypropylene, or a mixture thereof is 5 to 60 weight percent, based on the total weight of the thermoplastic composition. Within this range, the amount of the polyethylene, polypropylene, or a mixture thereof can be 10 to 40 weight percent, more specifically 15 to 30 weight percent. The polyethylene and/or polypropylene is incorporated via melt kneading with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition.

[0060] In some embodiments, the thermoplastic composition excludes polyethylene and polypropylene.

[0061] Another optional component is polybutene. Thus, in some embodiments, the thermoplastic composition comprises 4 to 12 weight percent of a polybutene, based on the total weight of the composition. Within this range, the polybutene amount can be 6 to 10 weight percent. In some embodiments, the polybutene has a number average molecular weight of 600 to 1,000 atomic mass units. These polybutene number average molecular weight values are uncorrected values measured by gel permeation chromatography using polystyrene standards. The polybutene is incorporated via melt kneading with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition.

[0062] In some embodiments the thermoplastic composition excludes polybutene.

[0063] Another optional component is a colorant or a mixture of colorants. As used herein, the term “colorant” includes dyes and pigments. The present method is particularly useful for improving the ultraviolet stability of light-colored thermoplastic compositions. Accordingly, in some embodiments, the thermoplastic composition comprises a white pigment. Suitable white pigments include, for example, calcium carbonate, kaolin, talc, calcium sulfate, barium sulfate, titanium dioxide, zinc oxide, zinc sulfide, zinc carbonate, satin white, aluminum silicate, diatomaceous earth, calcium silicate, magnesium silicate, synthetic amorphous silica, colloidal silica, colloidal alumina, pseudo-boehmite, aluminum hydroxide, alumina, modified alumina, lithopone, zeolite, hydrated halloysite, magnesium carbonate, magnesium hydroxide, and mixtures thereof. In some embodiments, the white pigment is zinc sulfide, titanium dioxide (including rutile titanium dioxide), or a mixture thereof. In some embodiments, the white pigment is titanium dioxide. The colorant is incorporated via melt kneading with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition.

[0064] In some embodiments, the thermoplastic composition excludes any polymer not taught herein as required or optional. For example, in some embodiments the thermoplastic composition excludes homopolystyrenes. As another example, in some embodiments the thermoplastic composition excludes polyamides.

[0065] The thermoplastic composition is formed by melt kneading the ultraviolet radiation stabilizer masterbatch with the poly(arylene ether), the flame retardant, and any optional components. Melt-kneading equipment is known in the art and includes single-screw and twin-screw type extruders and similar mixing devices that can apply shear to the components. In some embodiments, all components, including the ultraviolet radiation stabilizer masterbatch, are added at the feedthroat of the extruder. In other embodiments, the poly(arylene ether) and the flame retardant are melt kneaded to form a first blend, which is then melt kneaded with the ultraviolet radiation stabilizer masterbatch.

[0066] In a specific embodiment, the poly(arylene ether) comprises a poly(2,6-dimethyl-1,4-phenylene ether) having an intrinsic viscosity of 0.35 to 0.6 deciliter per gram measured at 25°C in chloroform; the thermoplastic composition comprises 20 to 30 weight percent of the poly(arylene ether); the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer, a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer, and a random copolymer of ethylene and propylene; the thermoplastic composition comprises 25 to 35 weight percent of

the thermoplastic elastomer; the flame retardant comprises melamine polyphosphate and magnesium hydroxide; the thermoplastic composition comprises 13 to 20 weight percent of the flame retardant; the ultraviolet radiation stabilizer composition comprises 0.3 to 1.2 weight percent of a benzotriazole ultraviolet radiation absorber, 0.3 to 1.5 weight percent of a hindered amine light stabilizer, and to 0.6 weight percent of a cycloaliphatic epoxy compound; the method further comprises melt kneading 4 to 12 weight percent of a polybutene with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition; wherein the polybutene has a number average molecular weight of 600 to 1,000 atomic mass units; the method further comprises melt kneading 2 to 5 weight percent of titanium dioxide with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, the ultraviolet radiation stabilizer composition, and the polybutene; and the composition comprises less than 5 weight percent of rubber-modified polystyrene.

[0067] One embodiment is a thermoplastic composition prepared according to the method, which is distinguished from prior art compositions by its improved stability to ultraviolet radiation. Thus, one embodiment is a thermoplastic composition prepared according to the above method and exhibiting a CIELAB color shift, ΔE , less than or equal to 2 measured according to ASTM D2244 after 300 hours exposure to xenon arc exposure according to ASTM D4459. In some embodiments, the thermoplastic composition exhibits a CIE lightness value, L^* , value of at least 70 measured according to ASTM D2244-05. In some embodiments, the lightness value, L^* , is at least 80. In some embodiments, the lightness value, L^* , is 70 to 95, specifically 75 to 90, more specifically 80 to 90, still more specifically 85 to 88.

[0068] The composition can be flexible. One objective correlate of the subject term "flexibility" is flexural modulus. Thus, in some embodiments the thermoplastic composition exhibits a flexural modulus less than or equal to 1,000 megapascals, measured at 23°C according to ASTM D790-03. In some embodiments, the flexural modulus is 20 to 1,000 megapascals, specifically 20 to 500 megapascals, more specifically 50 to 200 megapascals, even more specifically 35 to 150 megapascals, still more specifically 50 to 100 megapascals. Values of flexural modulus are measured according to ASTM D 790-03, Method A, on samples having dimensions 1.27 centimeters (0.5 inch) by 12.7 centimeters (5 inches) by 3.175 millimeters (0.125 inch), using a support span length of 5.08 centimeters (2 inches) and a rate of crosshead motion of 1.27 millimeters/minute (0.05 inch/minute).

[0069] Another embodiment is an article comprising the thermoplastic composition. The composition is particularly useful for fabricating insulation for wire and cable, where the wire cable further comprises a conductor (e.g., an electrical conductor or a light conductor).

[0070] The invention includes the ultraviolet radiation stabilizer masterbatch itself. Thus, one embodiment is an ultraviolet radiation stabilizer masterbatch, comprising: 80 to 99 weight percent of a thermoplastic elastomer selected from the group consisting of hydrogenated block copolymers of an alkenyl aromatic compound and a conjugated diene, polyolefin block copolymers having a (hard) polyethylene or polypropylene block and (soft) block that is a copolymer of ethylene and a C₃-C₁₂ olefin, random copolymers of ethylene and a C₃-C₁₂ alpha-olefin, and mixtures thereof; and 1 to 20 weight percent of an ultraviolet radiation stabilizer composition comprising at least two ultraviolet stabilizing compounds selected from different subgroups of the group consisting of a first subgroup consisting of ultraviolet radiation absorbers, a second subgroup consisting of hindered amine light stabilizers, and a third subgroup consisting of cycloaliphatic epoxy compounds; wherein all weight percents are based on the total weight of the ultraviolet radiation stabilizer masterbatch. Within the range of 80 to 99 weight percent, the thermoplastic elastomer amount can be 85 to 98 weight percent, specifically 90 to 96 weight percent, more specifically 92 to 94 weight percent. Within the range of 1 to 20 weight percent, the ultraviolet radiation stabilizer composition amount can be 2 to 15 weight percent, specifically 4 to 10 weight percent, more specifically 6 to 8 weight percent.

[0071] The invention includes at least the following embodiments:

[0072] Embodiment 1: A method of forming a thermoplastic composition, comprising: melt-kneading 20 to 40 weight percent of a poly(arylene ether), 10 to 60 weight percent of a thermoplastic elastomer, 5 to 25 weight percent of a flame retardant, and 0.4 to 10 weight percent of an ultraviolet radiation stabilizer composition comprising at least two ultraviolet stabilizing compounds selected from different subgroups of the group consisting of a first subgroup consisting of ultraviolet radiation absorbers, a second subgroup consisting of hindered amine light stabilizers, and a third subgroup consisting of cycloaliphatic epoxy compounds to form a thermoplastic composition; wherein all weight percents are based on the total weight of the composition; wherein the ultraviolet radiation stabilizer composition is provided in the form of an ultraviolet radiation stabilizer masterbatch comprising the ultraviolet radiation stabilizer composition and the thermoplastic elastomer; and wherein the thermoplastic composition comprises less than or equal to 20 weight percent of rubber-modified polystyrene.

[0073] Embodiment 2: The method of embodiment 1, wherein the thermoplastic elastomer is selected from the group consisting of hydrogenated block copolymers of an alkenyl aromatic compound and a conjugated diene, polyolefin block copolymers having a polyethylene or polypropylene block and block that is a copolymer of ethylene and a C₃-C₁₂ olefin, random copolymers of ethylene and a C₃-C₁₂ alpha-olefin, and mixtures thereof.

[0074] Embodiment 3: The method of embodiment 1 or 2, wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-propylene) diblock copolymer.

[0075] Embodiment 4: The method of embodiment 1 or 2, wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer.

[0076] Embodiment 5: The method of embodiment 1 or 2, wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer.

[0077] Embodiment 6: The method of embodiment 1 or 2, wherein the thermoplastic elastomer comprises a random copolymer of ethylene and propylene.

[0078] Embodiment 7: The method of any of embodiments 1, 2, 4, and 6, wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer and a random copolymer of ethylene and propylene.

[0079] Embodiment 8: The method of any of embodiments 1, 2, 4, 5, 6, and 7, wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer, a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer, and a random copolymer of ethylene and propylene.

[0080] Embodiment 9: The method of any of embodiments 1-8, wherein the ultraviolet radiation stabilizer composition comprises 0.3 to 1.2 weight percent of a benzotriazole ultraviolet radiation absorber, 0.3 to 1.5 weight percent of a hindered amine light stabilizer, and 0.1 to 0.6 weight percent of a cycloaliphatic epoxy compound.

[0081] Embodiment 10: The method of any of embodiments 1-9, wherein the flame retardant is selected from the group consisting of organophosphate esters, metal dialkyl phosphinates, nitrogen-containing flame retardants, metal hydroxides, and mixtures thereof.

[0082] Embodiment 11: The method of any of embodiments 1-10, wherein the flame retardant comprises melamine polyphosphate and magnesium hydroxide.

[0083] Embodiment 12: The method of any of embodiments 1-11, further comprising melt kneading 5 to 60 weight percent of polyethylene, polypropylene, or a mixture thereof with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition.

[0084] Embodiment 13: The method of any of embodiments 1-12, further comprising melt kneading 4 to 12 weight percent of a polybutene with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition.

[0085] Embodiment 14: The method of embodiment 13, wherein the polybutene has a number average molecular weight of 600 to 1,000 atomic mass units.

[0086] Embodiment 15: The method of any of embodiments 1-14, wherein the thermoplastic composition excludes rubber-modified polystyrene.

[0087] Embodiment 16: The method of any of embodiments 1-15, wherein the melt-kneading the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer comprises melt kneading the poly(arylene ether) and the flame retardant to form a first blend, and melt kneading with the first blend with the ultraviolet radiation stabilizer masterbatch.

[0088] Embodiment 17: The method of embodiment 1, wherein the poly(arylene ether) comprises a poly(2,6-dimethyl-1,4-phenylene ether) having an intrinsic viscosity of 0.35 to 0.6 deciliter per gram measured at 25°C in chloroform; wherein the thermoplastic composition comprises 20 to 30 weight percent of the poly(arylene ether); wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer, a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer, and a random copolymer of ethylene and propylene; wherein the thermoplastic composition comprises 25 to 35 weight percent of the thermoplastic elastomer; wherein the flame retardant comprises melamine polyphosphate and magnesium hydroxide; wherein the thermoplastic composition comprises 13 to 20 weight percent of the flame retardant; wherein the ultraviolet radiation stabilizer composition comprises 0.3 to 1.2 weight percent of a benzotriazole ultraviolet radiation absorber, 0.3 to 1.5 weight percent of a hindered amine light stabilizer, and to 0.6 weight percent of a cycloaliphatic epoxy compound; wherein the method further comprises melt kneading 4 to 12 weight percent of a polybutene with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition; wherein the polybutene has a number average molecular weight of 600 to 1,000 atomic mass units; wherein the method further comprises melt kneading 2 to 5 weight percent of titanium dioxide with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, the ultraviolet radiation stabilizer composition, and the polybutene; and wherein the composition comprises less than 5 weight percent of rubber-modified polystyrene.

[0089] Embodiment 18: A thermoplastic composition prepared according to the method of embodiment 17 and exhibiting a CIELAB color shift, ΔE , less than or equal to 2 measured according to ASTM D2244 after 300 hours exposure to xenon arc exposure according to ASTM D4459.

[0090] Embodiment 19: The thermoplastic composition of embodiment 18, further exhibiting a CIE lightness value, L^* , value of at least 70 measured according to ASTM D2244.

[0091] Embodiment 20: The composition of embodiment 18 or 19, further exhibiting a flexural modulus less than or equal to 1,000 megapascals, measured at 23°C according to ASTM D790.

[0092] Embodiment 21: An article comprising the thermoplastic composition of any of embodiments 18-20.

[0093] Embodiment 22: The article of embodiment 21, wherein the article comprises cable insulation comprising the thermoplastic composition.

[0094] Embodiment 23: An ultraviolet radiation stabilizer masterbatch, comprising: 80 to 99 weight percent of a thermoplastic elastomer selected from the group consisting of hydrogenated block copolymers of an alkenyl aromatic compound and a conjugated diene, polyolefin block copolymers having a polyethylene or polypropylene block and block that is a copolymer of ethylene and a C_3 - C_{12} olefin, random copolymers of ethylene and a C_3 - C_{12} alpha-olefin, and mixtures thereof, and 1 to 20 weight percent of an ultraviolet radiation stabilizer composition comprising at least two ultraviolet stabilizing compounds selected from different subgroups of the group consisting of a first subgroup consisting of ultraviolet radiation absorbers, a second subgroup consisting of hindered amine light stabilizers, and a third subgroup consisting of cycloaliphatic epoxy compounds; wherein all weight percents are based on the total weight of the ultraviolet radiation stabilizer masterbatch.

[0095] The invention is further illustrated by the following non-limiting examples.

EXAMPLE 1, COMPARATIVE EXAMPLES 1 AND 2

[0096] The following examples illustrate the unexpected ultraviolet stability improvement associated with pre-compounding the ultraviolet radiation stabilizer composition with the thermoplastic elastomer.

[0097] Table 1 lists the components used in the working examples.

Table 1

Component Designation	Description
PPE	Poly(2,6-dimethyl-1,4-phenylene ether) having an intrinsic viscosity of 0.46 deciliter per gram as measured in chloroform at 25°C; obtained as PPO 646 from SABIC Innovative Plastics.
SBS	Polystyrene-polybutadiene-polystyrene triblock copolymer (CAS Reg. No. 9003-55-8) having a polystyrene content of 31%; obtained as KRATON D1101 from Kraton Polymers.
SEP	Polystyrene-poly(ethylene/propylene) diblock copolymer (CAS Reg. No. 68648-89-5) having a polystyrene content of 37 weight percent; obtained as KRATON G1701 from Kraton Polymers.
S-(EB/S)-S	Polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer having a polystyrene content of 39%; obtained as KRATON RP6936 from Kraton Polymers.
SEBS	Polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer (CAS. Reg. No. 66070-58-4) having a polystyrene content of 13%; obtained as KRATON G-1657 from Kraton Polymers.
TPE	A melt-kneaded blend comprising about 40 weight percent polystyrene-poly(ethylene-butylene)-polystyrene, about 10 weight percent ethylene-propylene rubber, and about 50 weight percent mineral oil; obtained as TPE-SB2400 from Sumitomo Chemicals.
Polybutene	Liquid polybutene (CAS Reg. No. 9003-29-6) having a number average molecular weight of about 800 atomic mass units; obtained as Indopol H-50 from Innovene.
HIPS	High-impact polystyrene (rubber-modified polystyrene) having a polystyrene content of 89.7 weight percent and a polybutadiene content of 10.3 weight percent; obtained as FX510 from NOVA Chemicals.
Benzophenone UVA	2-Hydroxy-4- <i>n</i> -octoxybenzophenone (CAS Reg. No. 1843-05-6); obtained as CYASORB UV-531 from Cytec.
Benzotriazole UVA	2-(2'-Hydroxy-5'-octylphenyl)benzotriazole (CAS Reg. No. 3147-75-9); obtained as CYASORB UV-5411 from Cytec.
HALS	Bis(2,2,6,6-tetramethyl-4-piperidiny) sebacate (CAS Reg. No. 52829-07-9); obtained as TINUVIN 770 from Ciba Specialty Chemicals.
TiO ₂	Titanium dioxide having an average particle size of 0.2 micrometer; obtained as Ti-Pure R103-15 from DuPont.
Carbon black	Carbon black having an iodine absorption of 231 grams per kilogram as determined by ASTM D1510-02a; obtained as Monarch 800 from Cabot.
Ultramarine blue	Ultramarine blue pigment (CAS Reg. No. 57455-37-5); obtained as Ultramarine 5085 from Holliday Pigments.
Pigment brown	Pigment brown 24, chromium/antimony/titanium oxide (CAS Reg. No. 68186-90-3); obtained as SICOTAN Yellow K2001 FG from BASF.

BPADP	Bisphenol A bis(diphenyl phosphate) (CAS Reg. No. 5945-33-5); obtained as BPADP from Supresta.
MPP	Melamine polyphosphate (CAS Reg. No. 218768-84-4); obtained as MELAPUR 200/70 from Ciba Specialty Chemicals.
Mg(OH) ₂	Magnesium hydroxide (CAS Reg. No. 1309-32-8); obtained as Kisuma 5A from Kyowa Chemical Industry, or as Magshield UF from Martin Marietta Magnesia Specialties.
Erucamide	Erucamide (CAS Reg. No. 112-84-5); obtained as Kemamide E Ultra from PMC Biogenix Inc.
Antioxidant 1	1,2-Bis(3,5-di-tert-butyl-4-hydroxyhydrocinnamoyl)hydrazine (CAS Reg. No. 32687-78-8); obtained as IRGANOX MD 1024 from Ciba Specialty Chemicals.
Antioxidant 2	N-Octadecyl-3-(3,5 di-t.Bu-4-hydroxyphenyl)propionate (CAS Reg. No. 2082-79-3); obtained as IRGANOX 1076 from Ciba Specialty Chemicals.
ZnS	Zinc sulfide (CAS Reg. No. 1314-98-3); obtained as Sachtolith HD from Sachtleben.
MgO	Magnesium oxide (CAS Reg. No. 1309-48-4); obtained as Mag-Chem HSA-10 from Western Reserve.
Cycloaliphatic epoxy	3,4-Epoxy cyclohexylmethyl 3',4'-epoxycyclohexylcarboxylate (CAS Reg. No. 2386-87-0); obtained as ERL-4221 from Dow.

[0098] An ultraviolet radiation stabilizer masterbatch in the thermoplastic elastomer polystyrene-poly(ethylene-butylene) diblock copolymer (SEP) was prepared by melt-kneading 96.67 weight percent of SEP with 1.11 weight percent of 2-hydroxy-4-*n*-octoxybenzophenone, and 2.22 weight percent of the hindered amine light stabilizer bis(2,2,6,6-teramethyl-4-piperidiny) sebacate. A corresponding ultraviolet radiation stabilizer masterbatch in high-impact polystyrene (HIPS) instead of SEP was also prepared. A representative procedure for preparing masterbatches is as follows. Compounding was conducted using a Prism co-rotating twin-screw extruder having a 24-millimeter screw diameter. The extrusion barrel setpoints were Zone 1 (Feed throat, unheated), Zone 2 (80°F, 27°C), Zone 3 (250°F, 121°C), Zone 4 (300°F, 149°C), Zone 5 (325°F, 163°C), Zone 6 (350°F, 177°C), Zone 7 (350°F, 177°C), Zone 8 (350°F, 177°C), Die (350°F, 177°C). The Feed Rate was 55 pounds/hour (25 kilograms/hour), the screw speed was set at 350 revolutions per minute (rpm), and the machine torque was 75%. The extruded strands were cooled in a 5 foot (1.5 meter) long water bath, and pelletized using a pelletizer. An attempt to prepare a corresponding ultraviolet radiation stabilizer masterbatch in polystyrene-polybutadiene-polystyrene triblock copolymer (SBS) was unsuccessful because the material would not strand, and was instead spitting out of the die. The material recovered was darker and yellower than the other blends, suggesting degradation.

[0099] Three thermoplastic compositions were prepared using the components specified in Table 2, where the ultraviolet radiation stabilizer masterbatch in SEP is abbreviated “SEP/UVA”, and the ultraviolet radiation stabilizer masterbatch in HIPS is abbreviated “HIPS/UVA”. All component amounts in Table 2 are in parts by weight. The thermoplastic compositions were prepared using a Prism co-rotating twin-screw extruder having a 24-millimeter screw diameter. The extrusion barrel setpoints were Zone 1 (Feed throat, unheated), Zone 2 (250°F, 121°C), Zone 3 (400°F, 204°C), Zone 4 (450°F, 232°C), Zone 5 (475°F, 246°C), Zone 6 (510°F, 266°C), Zone 7 (520°F), Zone 8 (520°F, 271°C), Die (520°F, 271°C). The Feed Rate was 40 pounds/hr (18 kilograms/hour), and the screw speed was set at 600 rpm. The liquid BPADP flame retardant was added in using a downstream injection port on the extruder. The extruded strands were cooled in a 5 foot (1.5 meter) long water bath, and pelletized using a pelletizer. Plaques of dimensions 5.08 centimeters × 7.62 centimeters × 0.254 centimeter (2 inches × 3 inches × 0.100 inch) were molded using a Nissei molding machine with barrel set points of Rear (470°F, 243°C), Mid (490°F, 254°C), Front (500°F, 260°C), Nozzle (500°F, 260°C). The tool temperature (mold face) was set at 170°F (77°C). The injection time was set for 14 seconds, the cooling time for 20 seconds, and the hold time for 30 seconds.

[0100] The UV stability of the compositions was tested according to ASTM D4459-99, “Standard Practice for Xenon-Arc Exposure of Plastics Intended for Indoor Applications”. Specifically, the procedure used an exposure device obtained from Atlas as Ci4000, having a 3500 watt lamp, a radiant exposure of 0.3 watts per square-meter (W/m²), and the ability to control the temperature at 55°C and the humidity at 55 percent relative humidity. CIELAB ΔE values were measured at 300 and 500 hours of exposure.

[0101] Color differences were measured according to ASTM D2244-05, “Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates”. Color difference (ΔE) values were calculated according to the CIELAB color difference formula as follows:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

wherein $\Delta L^* = L_1^* - L_2^*$

$$\Delta a^* = a_1^* - a_2^*$$

$$\Delta b^* = b_1^* - b_2^*$$

and wherein L_1^* , a_1^* , and b_1^* are the lightness, red-green coordinate, and yellow-blue coordinate, respectively, prior to the exposure to the test, and L_2^* , a_2^* , and b_2^* are lightness, red-green coordinate, and yellow-blue coordinate, respectively, after exposure to the test.

[0102] Results are presented in Table 2. Comparative Example 1 is a control composition in which the ultraviolet radiation stabilizer composition was present in the thermoplastic composition but not pre-compounded with any other component. Comparative Example 1 exhibits ΔE values of 10.22 and 14.21 at 300 and 500 hours exposure, respectively. Example 1, which was very similar to Comparative Example 1 except that the ultraviolet radiation stabilizer composition was pre-compounded with the SEP component, exhibited smaller ΔE values (improved ultraviolet stability) of 8.85 and 11.70 at 300 and 500 hours exposure, respectively. Comparative Example 2, in which high-impact polystyrene was substituted for half of the SEP and in which the ultraviolet radiation stabilizer composition was provided half as a masterbatch in SEP and the other half as a masterbatch in HIPS, exhibited higher ΔE values (worse ultraviolet stability) than Comparative Example 1.

Table 2

	Ex. 1	C. Ex. 1	C. Ex. 2
COMPOSITIONS			
PPE	36.67	36.13	36.67
TiO ₂	3.30	3.25	3.30
Carbon black	0.0018	0.0018	0.0018
Ultramarine blue	0.0234	0.0231	0.0234
Pigment brown	0.0002	0.0002	0.0002
BPADP	15.00	14.78	15.00
SEP	0	44.33	0
SBS/UVA	0	0	0
SEP/UVA	45.00	0	22.50
HIPS/UVA	0	0	22.50
Benzophenone UVA	0	0.49	0
HALS	0	0.99	0
PROPERTIES			
ΔE at 300 hours	8.85	10.22	14.76
ΔE at 500 hours	11.70	14.21	17.66

EXAMPLES 2-3, COMPARATIVE EXAMPLES 3-5

[0103] These examples further illustrate the ultraviolet stability advantage of pre-compounding the ultraviolet radiation stabilizer composition with the thermoplastic elastomer, the thermoplastic polyolefin, or both.

[0104] The masterbatches and thermoplastic compositions in Table 3 were compounded on a Werner-Pfleiderer 30-millimeter co-rotating twin-screw extruder (ratio of length to screw diameter (L/D) = 32, 10 barrels) with self-wiping screws. The barrel set temperatures were 200-220-250-250°C from zone 1 (extruder feedthroat) to the die. The total feed rate was set to 30 pounds/hour (14 kilograms/hour) and the screw rotated at 300 rpm. Flame retardant was added directly to the extruder at barrel 2 with a dedicated liquid pump. Extruded strands were cooled through a 5 foot (1.5 meter) long circulating water bath before being chopped into granules by a Labtech pelletizer. Plaques of dimensions 5.08 centimeters × 7.62 centimeters × 0.254 centimeter (2 inches × 3 inches × 0.100 inch) were injection-molded on a Van Dorn 120T molding machine with barrel set temperatures of 450°F/232°C (rear) to 500°F/260°C (nozzle). The tool temperature was set to 120°F/49°C and the cycle time was about 45 seconds.

[0105] The first ultraviolet radiation stabilizer masterbatch, designated “SEBS/UVA” in Table 3, consisted of 51.24 parts by weight SEBS-RP6936, 21.57 parts by weight TPE, 21.57 parts by weight SEBS-KG1657, 0.89 parts by weight cycloaliphatic epoxy, 2.02 parts by weight benzotriazole UVA, and 2.70 parts by weight HALS. The second ultraviolet radiation stabilizer masterbatch, designated “PPE/FR/UVA” in Table 3, consisted of 82.96 parts by weight PPE, 1.26 parts by weight cycloaliphatic epoxy, 2.86 parts by weight benzotriazole UVA, 3.82 parts by weight HALS, and 9.1 parts by weight BPADP. The third ultraviolet radiation stabilizer masterbatch, designated “PPE/UVA” in Table 3, consisted of 92.06 parts by weight PPE, 1.26 parts by weight cycloaliphatic epoxy, 2.86 parts by weight benzotriazole UVA, and 3.82 parts by weight HALS.

[0106] Results are presented in Table 3. Comparative Example 3 is a control composition in which the ultraviolet radiation stabilizer composition was present in the thermoplastic composition but not pre-compounded with any other component. Comparative Example 3 exhibited ΔE values of 2.73 and 2.59 at 300 and 500 hours exposure, respectively. Example 2, which was similar to Comparative Example 3 except that the ultraviolet radiation stabilizer composition was pre-compounded with the SEBS-RP6936, TPE, and SEBS-KG1657 components, exhibited smaller ΔE values (improved ultraviolet stability) of

0.97 and 1.24 at 300 and 500 hours exposure, respectively. Example 3 was identical to Example 2, except that the SEBS/UVA masterbatch was added to a downstream section of the extruder rather than the feed throat of the extruder when compounding the thermoplastic composition. Example 3 exhibited ΔE values of 1.02 and 1.18 at 300 and 500 hours exposure, respectively, which are much lower (better) than the corresponding values for Comparative Example 4, which has similar component amounts but was not prepared using an ultraviolet radiation stabilizer masterbatch. Comparative Examples 4 and 5 incorporated PPE/FR/UVA and PPE/UVA masterbatches, respectively. Their ΔE values at 300 and 500 hours were significantly higher (worse) than those for Comparative Example 3, in which the ultraviolet radiation stabilizer composition was not incorporated as a masterbatch. Given the known ultraviolet sensitivity of the poly(arylene ether) component, it is very surprising that pre-compounding the ultraviolet radiation stabilizer composition with the poly(arylene ether) has a detrimental effect on the composition. It is also very surprising that the best ultraviolet stability is exhibited by compositions in which the ultraviolet radiation stabilizer composition is pre-compounded with the thermoplastic elastomer, because such pre-compounding would have been expected to segregate the ultraviolet radiation stabilizer composition from the ultraviolet-sensitive poly(arylene ether) component and thereby decrease ultraviolet stability of the composition as a whole.

Table 3

	Ex. 2	C. Ex. 4	Ex. 3	C. Ex. 5	C. Ex. 6
COMPOSITIONS					
PPE	26.73	26.19	26.73	4.46	2.04
S-(EB/S)-S	0	18.43	0	18.42	18.42
TPE	0	7.76	0	7.75	7.76
Polybutene	7.92	7.76	7.92	7.75	7.76
SEBS	0	7.76	0	7.75	7.76
MPP	10.89	10.67	10.89	10.66	10.67
Mg(OH) ₂	5.94	5.82	5.94	5.82	5.82
Erucamide	0.40	0.39	0.40	0.39	0.39
Antioxidant 1	0.10	0.10	0.10	0.10	0.10
ZnS	0.15	0.15	0.15	0.15	0.15
MgO	0.15	0.15	0.15	0.15	0.15
Antioxidant 2	0.49	0.48	0.49	0.48	0.48
Cycloaliphatic epoxy	0	0.32	0	0	0
Benzotriazole UVA	0	0.73	0	0	0
HALS	0	0.97	0	0	0
SEBS/UVA	34.64	0	0	0	0
SEBS/UVA downstream	0	0	34.64	0	0
PPE/FR/UVA	0	0	0	26.17	0
PPE/UVA	0	0	0	0	26.18
TiO ₂	3.56	3.49	3.56	3.49	3.49
Ultramarine Blue	0.0253	0.0248	0.0253	0.0248	0.0248
Carbon Black	0.0020	0.0019	0.0020	0.0019	0.0019
Pigment Brown 24	0.0002	0.0002	0.0002	0.0002	0.0002
BPADP	9.01	8.83	9.01	6.44	8.82
PROPERTIES					
ΔE at 300 hours	0.97	2.73	1.02	3.11	3.68
ΔE at 500 hours	1.24	2.59	1.18	3.11	3.85

[0107] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

[0108] All cited patents, patent applications, and other references are incorporated herein by reference in their entirety. However, if a term in the present application contradicts or conflicts with a term in the incorporated reference, the term from the present application takes precedence over the conflicting term from the incorporated reference.

[0109] All ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.

[0110] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Further, it should further be noted that the terms “first,” “second,” and the like herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the particular quantity).

CLAIMS:

1. A method of forming a thermoplastic composition, comprising:
melt-kneading
20 to 40 weight percent of a poly(arylene ether),
10 to 60 weight percent of a thermoplastic elastomer,
5 to 25 weight percent of a flame retardant, and
0.4 to 10 weight percent of an ultraviolet radiation stabilizer composition
comprising at least two ultraviolet stabilizing compounds selected from
different subgroups of the group consisting of
a first subgroup consisting of ultraviolet radiation absorbers,
a second subgroup consisting of hindered amine light stabilizers, and
a third subgroup consisting of cycloaliphatic epoxy compounds
to form a thermoplastic composition;
wherein all weight percents are based on the total weight of the composition;
wherein the ultraviolet radiation stabilizer composition is provided in the form of an
ultraviolet radiation stabilizer masterbatch comprising the ultraviolet radiation stabilizer
composition and the thermoplastic elastomer; and
wherein the thermoplastic composition comprises less than or equal to 20 weight
percent of rubber-modified polystyrene.
2. The method of claim 1, wherein the thermoplastic elastomer is selected from
the group consisting of
hydrogenated block copolymers of an alkenyl aromatic compound and a conjugated
diene,
polyolefin block copolymers having a polyethylene or polypropylene block and block
that is a copolymer of ethylene and a C₃-C₁₂ olefin,
random copolymers of ethylene and a C₃-C₁₂ alpha-olefin, and
mixtures thereof.
3. The method of claim 1 or 2, wherein the thermoplastic elastomer comprises a
polystyrene-poly(ethylene-propylene) diblock copolymer.
4. The method of claim 1 or 2, wherein the thermoplastic elastomer comprises a
polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer.
5. The method of claim 1 or 2, wherein the thermoplastic elastomer comprises a
polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer.

6. The method of claim 1 or 2, wherein the thermoplastic elastomer comprises a random copolymer of ethylene and propylene.
7. The method of any of claims 1, 2, 4, and 6, wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer and a random copolymer of ethylene and propylene.
8. The method of any of claims 1, 2, 4, 5, 6, and 7, wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer, a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer, and a random copolymer of ethylene and propylene.
9. The method of any of claims 1-8, wherein the ultraviolet radiation stabilizer composition comprises
 - 0.3 to 1.2 weight percent of a benzotriazole ultraviolet radiation absorber,
 - 0.3 to 1.5 weight percent of a hindered amine light stabilizer, and
 - 0.1 to 0.6 weight percent of a cycloaliphatic epoxy compound.
10. The method of any of claims 1-9, wherein the flame retardant is selected from the group consisting of organophosphate esters, metal dialkyl phosphinates, nitrogen-containing flame retardants, metal hydroxides, and mixtures thereof.
11. The method of any of claims 1-10, wherein the flame retardant comprises melamine polyphosphate and magnesium hydroxide.
12. The method of any of claims 1-11, further comprising melt kneading 5 to 60 weight percent of polyethylene, polypropylene, or a mixture thereof with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition.
13. The method of any of claims 1-12, further comprising melt kneading 4 to 12 weight percent of a polybutene with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition.
14. The method of claim 13, wherein the polybutene has a number average molecular weight of 600 to 1,000 atomic mass units.
15. The method of any of claims 1-14, wherein the thermoplastic composition excludes rubber-modified polystyrene.
16. The method of any of claims 1-15, wherein the melt-kneading the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer comprises melt kneading the poly(arylene ether) and the flame retardant to form a first blend, and melt kneading with first blend with the ultraviolet radiation stabilizer masterbatch.

17. The method of claim 1,
wherein the poly(arylene ether) comprises a poly(2,6-dimethyl-1,4-phenylene ether) having an intrinsic viscosity of 0.35 to 0.6 deciliter per gram measured at 25°C in chloroform;
wherein the thermoplastic composition comprises 20 to 30 weight percent of the poly(arylene ether);
wherein the thermoplastic elastomer comprises a polystyrene-poly(ethylene-butylene)-polystyrene triblock copolymer, a polystyrene-poly(ethylene-butylene-styrene)-polystyrene triblock copolymer, and a random copolymer of ethylene and propylene;
wherein the thermoplastic composition comprises 25 to 35 weight percent of the thermoplastic elastomer;
wherein the flame retardant comprises melamine polyphosphate and magnesium hydroxide;
wherein the thermoplastic composition comprises 13 to 20 weight percent of the flame retardant;
wherein the ultraviolet radiation stabilizer composition comprises
0.3 to 1.2 weight percent of a benzotriazole ultraviolet radiation absorber,
0.3 to 1.5 weight percent of a hindered amine light stabilizer, and
0.1 to 0.6 weight percent of a cycloaliphatic epoxy compound;
wherein the method further comprises melt kneading 4 to 12 weight percent of a polybutene with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, and the ultraviolet radiation stabilizer composition; wherein the polybutene has a number average molecular weight of 600 to 1,000 atomic mass units;
wherein the method further comprises melt kneading 2 to 5 weight percent of titanium dioxide with the poly(arylene ether), the thermoplastic elastomer, the flame retardant, the ultraviolet radiation stabilizer composition, and the polybutene; and
wherein the composition comprises less than 5 weight percent of rubber-modified polystyrene.
18. A thermoplastic composition prepared according to the method of claim 17 and exhibiting a CIELAB color shift, ΔE , less than or equal to 2 measured according to ASTM D2244 after 300 hours exposure to xenon arc exposure according to ASTM D4459.
19. The thermoplastic composition of claim 18, further exhibiting a CIE lightness value, L^* , value of at least 70 measured according to ASTM D2244.
20. The composition of claim 18 or 19, further exhibiting a flexural modulus less than or equal to 1,000 megapascals, measured at 23°C according to ASTM D790.

21. An article comprising the thermoplastic composition of any of claims 18-20.
 22. The article of claim 21, wherein the article comprises a conductor and an insulation comprising the thermoplastic composition.
 23. An ultraviolet radiation stabilizer masterbatch, comprising:
 - 80 to 99 weight percent of a thermoplastic elastomer selected from the group consisting of
 - hydrogenated block copolymers of an alkenyl aromatic compound and a conjugated diene,
 - polyolefin block copolymers having a polyethylene or polypropylene block and block that is a copolymer of ethylene and a C₃-C₁₂ olefin,
 - random copolymers of ethylene and a C₃-C₁₂ alpha-olefin, and
 - mixtures thereof, and
 - 1 to 20 weight percent of an ultraviolet radiation stabilizer composition comprising at least two ultraviolet stabilizing compounds selected from different subgroups of the group consisting of
 - a first subgroup consisting of ultraviolet radiation absorbers,
 - a second subgroup consisting of hindered amine light stabilizers, and
 - a third subgroup consisting of cycloaliphatic epoxy compounds;
- wherein all weight percents are based on the total weight of the ultraviolet radiation stabilizer masterbatch.