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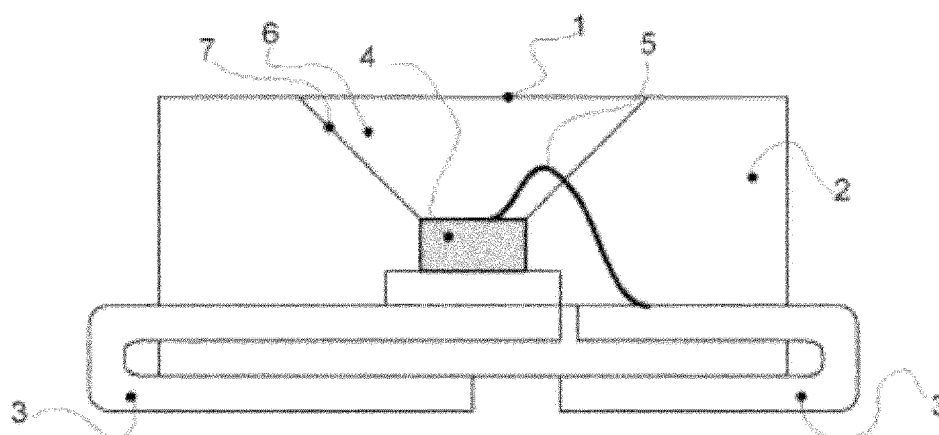


Fig. 1

(57) Abstract: Described herein are light emitting diode ("LED") housings having excellent whiteness. The LED housings are formed from polyphenylene sulfide ("PPS") blends including a PPS and (i) a polyamide 6 ("PA6") or (ii) a functionalized, non-aromatic elastomer. For clarity, in some embodiments, the PPS polymer includes both a PA6 and a functionalized, non-aromatic elastomer. It was surprisingly discovered that addition of PA6 or a functionalized, non-aromatic elastomer to PPS resulted in a polymer blend having significantly improved whiteness. The PPS polymer blends further include a reinforcing agent and, optionally, other additives.



POLYPHENYLENE SULFIDE POLYMER BLENDS AND CORRESPONDING ARTICLES

This application claims priority to U.S. provisional application No. 62/630,345 filed February 14, 2018, the whole content of this application being incorporated herein by reference for all purposes.

5 FIELD OF THE INVENTION

The invention relates to LED housings including polyphenylene sulfide (“PPS”) polymer blends with excellent initial whiteness and whiteness retention after heat and light aging.

10 BACKGROUND OF THE INVENTION

Light emitting diodes (“LEDs”) are seeing significantly increased usage to their significant advantages over conventional lighting. In general, LEDs require less power and are more efficient, environmentally friendly, and resistant to breakage relative to traditional light sources such as incandescent light bulbs or fluorescent lighting.

Due to increasing consumer and industrial demands for ever increasing LED housing performance, polymer compositions for LED housings are required to have desirable whiteness (*e.g.* reflectance) as well as mechanical performance (*e.g.* tensile strength and elongation). For example, the higher the whiteness, the greater the amount of light is reflected to the observer. Moreover, as LED assemblies are becoming smaller (*e.g.*, due to higher resolution or smaller area of video displays), increased mechanical performance is required to help avoid breakage of the LED housing and resultant loss of reflectance.

25 SUMMARY OF THE INVENTION

In a first aspect, the invention relates to a light emitting diode (“LED”) housing containing a polymer blend including a polyphenylene sulfide (“PPS”), at least 3 wt.% of a polyamide 6 (“PA6”) or at least 3wt.% to 8 wt.% of a functionalized, non-aromatic elastomer, and from 5 wt.% to 30 wt.% of a

reinforcing agent; wherein wt. % is relative to the total weight of the polymer blend. The LED housing of claim 1, wherein the polymer blend comprises from 35 wt.% to 60 wt.% of the PPS. In some embodiments, the polymer blend comprises at least 3 wt.% of the PA6 and is free of the functionalized, non-aromatic elastomer. In some embodiments, the polymer blend comprises at least 3 wt.% of the PA6 and at least 3 wt.% to 8 wt.% of the functionalized, non-aromatic elastomer. In some embodiments, the weight ratio of PA6/functionalized, non-aromatic elastomer is at least 1.4. Additionally or alternatively, the weight ratio of PPS/PA6 is at least 4.

10 In some embodiments, the polymer blend comprises 5 wt.% to 12 wt.% of the PA6. Additionally or alternatively, in some embodiments, the polymer blend comprises at least 3 wt.% to 8 wt.% of the functionalized, non-aromatic elastomer and is free of the PA6. In some embodiments, the polymer blend comprises from 10 wt.% to 20 wt.% of a white pigment selected from the group
15 consisting of titanium dioxide, magnesium oxide, zinc sulfide, barium sulfate and any combination of one or more thereof, preferably titanium dioxide. In some embodiments, the reinforcing agent is a glass fiber, preferably an E-CR glass fiber. Additionally or alternatively, in some embodiments, the elastomer is epoxy-functionalized preferably an epoxy-functionalized copolymer of ethylene
20 and glycidyl methacrylate. In some embodiments, the LED housing comprises at least a portion having a thickness of no more than 0.6 mm, preferably 0.4mm and wherein the at least a portion comprises the PPS polymer blend.

In another aspect, the invention is directed to an LED assembly comprising the LED housing as described above.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic representation showing a side view of a top-view LED assembly.

Fig. 2 is a schematic representation showing a side view of a power LED
30 assembly.

DETAILED DESCRIPTION OF THE INVENTION

Described herein are light emitting diode (“LED”) housings having excellent whiteness. The LED housings are formed from polyphenylene sulfide (“PPS”) polymer blends including a PPS and (i) a polyamide 6 (“PA6”) or (ii) a functionalized, non-aromatic elastomer. For clarity, in some embodiments, the PPS polymer includes both a PA6 and a functionalized, non-aromatic elastomer. It was surprisingly discovered that addition of PA6 or a functionalized, non-aromatic elastomer to PPS resulted in a polymer blend having significantly improved whiteness. The PPS polymer blends, further include a reinforcing agent and, optionally, other additives.

Traditionally, polyamides and polyesters are used for LED housings, though they suffer from drawbacks that limit their usage in LED housing application settings. For example, as LED housings are required to become smaller and smaller, greater demands are placed on the mechanical integrity of the housing compositions. Concomitantly, the whiteness of the LED housing must be maintained, if not increased, due to increased industrial and consumer demand for increasing reflectivity. While polyamides have sufficient mechanical strength, they often do not have desirable whiteness. On the other hand, while polyesters have reasonable whiteness, they generally have insufficient mechanical strength at dimensions according to industry goals (*e.g.* thickness of no more than 0.6 mm, or no more than 0.4 mm). Accordingly, PPS is an attractive polymer, due to its mechanical strength and improved flow properties, but generally lacks sufficient whiteness. By blending PPS with PA6 or a functionalized non-aromatic elastomer, it was surprisingly found that the resulting polymer blends had both sufficient mechanical and whiteness.

The initial whiteness can be measured as the initial reflectance of the PPS polymer blend. Initial reflectance can be measured as described in the Examples below. In some embodiments, the PPS polymer blend has an initial reflectance at 460 nm of at least 70 %, at least 75%, or at least 82%. Additionally or alternatively, in some embodiments, the PPS polymer blend has an initial reflectance at 540 nm of at least 80%, at least 85%, or at least 88%. Additionally or alternatively, in some embodiments, the PPS polymer blend has an initial

reflectance at 620 nm of at least 80%, at least 85%, or at least 90%. Moreover, in some embodiments, the PPS polymer blend can have a tensile elongation of at least 1.2%, or at least 1.5%, or at least 2%. Tensile elongation can be measured as described in the Examples below.

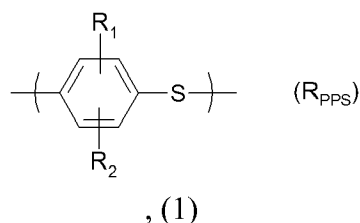
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The Polyphenylene Sulfide Polymer

The PPS polymer blend includes PPS. As used herein, PPS denotes any polymer having, relative to the total number of recurring units in the polymer, at least 50 mole percent ("mol%") of a recurring unit (R_{PPS}) represented by the

10

following formula:



where R_1 and R_2 , equal to or different from each other, are selected from the group consisting of hydrogen atoms, halogen atoms, C_1 - C_{12} alkyl groups, C_7 - C_{24} alkylaryl groups, C_7 - C_{24} aralkyl groups, C_6 - C_{24} arylene groups, C_1 - C_{12} alkoxy groups, and C_6 - C_{18} aryloxy groups, and substituted or unsubstituted arylene sulfide groups, the arylene groups of which are also linked by each of their two ends to two sulfur atoms forming sulfide groups via a direct C-S linkage thereby creating branched or cross-linked polymer chains.

Preferably, both R_1 and R_2 are hydrogen. In some embodiments, the PPS has at least 60 mol%, at least 70 mol%, at least 80 mol%, at least 90 mol%, at least 95 mol%, at least 99 mol%, or at least 99.9 mol% of recurring unit (R_{PPS}), relative to the total number of recurring units in the PPS.

In some embodiments, the weight average molecular weight of the PPS is from 30,000 grams per mole ("g/mol") to 70,000 g/mol, preferably from 35,000 g/mol to 60,000 g/mol. Weight average molecular weight can be determined by gel permeation chromatography (GPC) using ASTM D5296 with polystyrene standards.

25

In some embodiments, the PPS polymer blend includes is at least 30 weight percent ("wt.%"), at least 35 wt.%, at least 38 wt.%, at least 40 wt.%, or at least 42 wt.% of the PPS. As used herein wt.% is relative to the total weight of the PPS polymer blend, unless explicitly noted otherwise.

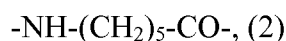
5 Additionally or alternatively, in some embodiments, the PPS polymer blend includes no more than 60 wt.%, no more than 58 wt.%, no more than 55 wt.%, no more than 52 wt.%, or no more than 50 wt.% of the PPS. In some embodiments, the PPS polymer blend includes from 30 wt.% to 60 wt.%, from 35 wt.% to 55 wt.%, from 38 wt.% to 52 wt.%, from 40 wt.% to 50 wt.%, or

10 from 42 wt.% to 48 wt.% of the PPS.

The Polyamide 6 Polymer

In some embodiments, the PPS polymer blend includes PA6. As used herein, a PA6 denotes any polymer having, relative to the total number of

15 recurring units in the polymer, at least 50 mol.% of a recurring unit (R_{PA6}) represented by the following formula:



In some embodiments, the PA6 has at least 60 mol.%, at least 70 mol.%, at least 80 mol.%, at least 90 mol.%, at least 95 mol.%, at least 99 mol.%, or at least

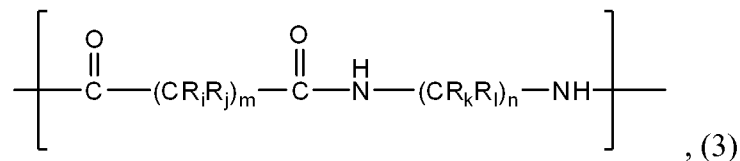
20 99.9 mol% of the recurring unit (R_{PA6}), relative to the total number of recurring units in the PA6. In some embodiments, recurring unit (R_{PA6}) can be synthesized from a lactam or aminoacids having the structure $\text{NH}_2-(\text{CH}_2)_5-\text{COOH}$.

In some embodiments, the PA6 includes recurring units different from recurring unit (R_{PA6}). In one such embodiment, the PA6 includes a recurring

25 unit (R_{PA*}), which results from the condensation product of at least one diacid (or derivatives thereof), and at least one diamine (or derivatives thereof). The diacid can be selected among a large variety of aliphatic or aromatic components having at least two acidic moieties $-\text{COOH}$ and can also include heteroatoms (*e.g.*, O, N or S). Similarly, the diamine can be selected among a large variety of

30 aliphatic or aromatic components having at least two amine moieties $-\text{NH}_2$ and can also include heteroatoms (*e.g.*, O, N or S).

In one embodiment in which the PA6 includes recurring unit (R_{PA*}), recurring unit (R_{PA*}) is represented by the following formula:



where each R_i , R_j , R_k , and R_l on each carbon atom is independently selected from the group consisting of a hydrogen, a halogen, an alkyl, an alkenyl, an ether, a thioether, an ester, an amide, an imide, an alkali or alkaline earth metal sulfonate, an alkyl sulfonate, an alkali or alkaline earth metal phosphonate, an alkyl phosphonate, an amine, an quaternary ammonium, and any combination thereof; -m is an integer from 0 to 10; and n is an integer from 6 to 12.

In other embodiments in which the PA6 includes recurring unit (R_{PA*}), recurring unit (R_{PA*}) is formed from the condensation of at least one aliphatic diacid or derivative thereof (acid halogenides, especially chlorides, acid anhydrides, acid salts, acid amides) and at least one aromatic diamine or derivative thereof. In other embodiments, recurring unit (R_{PA*}) is formed from the condensation of- at least an aromatic diacid, or derivative thereof and at least an aliphatic diamine, or derivative thereof.

Examples of desirable aromatic diamines include, but are not limited to, m-phenylene diamine ("MPD"), p-phenylene diamine ("PPD"), 3,4'-diaminodiphenyl ether ("3,4' ODA"), 4,4'-diaminodiphenyl ether ("4,4'-ODA"), p-xylylene diamine ("PXDA") and m-xylylenediamine ("MXDA").

Examples of desirable aliphatic diacids include, but are not limited to, oxalic acid (HOOC-COOH), malonic acid ($\text{HOOC-CH}_2\text{-COOH}$), succinic acid [$\text{HOOC-(CH}_2)_2\text{-COOH}$], glutaric acid [$\text{HOOC-(CH}_2)_3\text{-COOH}$], 2,2-dimethyl-glutaric acid [$\text{HOOC-C(CH}_3)_2\text{-(CH}_2)_2\text{-COOH}$], adipic acid [$\text{HOOC-(CH}_2)_4\text{-COOH}$], 2,4,4-trimethyl-adipic acid [$\text{HOOC-CH(CH}_3\text{)-CH}_2\text{-C(CH}_3)_2\text{-CH}_2\text{-COOH}$], pimelic acid [$\text{HOOC-(CH}_2)_5\text{-COOH}$], suberic acid [$\text{HOOC-(CH}_2)_6\text{-COOH}$], azelaic acid [$\text{HOOC-(CH}_2)_7\text{-COOH}$], sebacic acid [$\text{HOOC-(CH}_2)_8\text{-COOH}$], undecanedioic

acid [HOOC-(CH₂)₉-COOH], dodecanedioic acid [HOOC-(CH₂)₁₀-COOH] and tridecanedioic acid [HOOC-(CH₂)₁₁-COOH].

Examples of desirable aliphatic diamines include, but are not limited to, 1,2 diaminoethane, 1,2-diaminopropane, propylene-1,3-diamine, 1,3 diaminobutane, 1,4-diaminobutane (putrescine), 1,5-diaminopentane (cadaverine), 2-methyl-1,5-diaminopentane, hexamethylenediamine, 3-methylhexamethylenediamine, 2,5 dimethylhexamethylenediamine, 2,2,4-trimethyl-hexamethylenediamine, 2,4,4-trimethyl-hexamethylenediamine, 1,7-diaminoheptane, 1,8-diaminooctane, 2,2,7,7-tetramethyloctamethylenediamine, 1,9-diaminononane, 5-methyl-1,9-diaminononane, 1,10-diaminodecane, 1,11-diaminoundecane, 1,12 diaminododecane and N,N-Bis(3-aminopropyl)methylamine.

Examples of desirable aromatic diacids include, but are not limited to, isophthalic acid (IPA), terephthalic acid (TPA), naphthalendicarboxylic acids (e.g. naphthalene-2,6-dicarboxylic acid), 2,5-pyridinedicarboxylic acid, 2,4 pyridinedicarboxylic acid, 3,5-pyridinedicarboxylic acid, 2,2 bis(4 carboxyphenyl)propane, bis(4-carboxyphenyl)methane, 2,2 bis(4 carboxyphenyl)hexafluoropropane, 2,2-bis(4-carboxyphenyl)ketone, 4,4' bis(4-carboxyphenyl)sulfone, 2,2-bis(3-carboxyphenyl)propane, bis(3 carboxyphenyl)methane, 2,2-bis(3-carboxyphenyl)hexafluoropropane, 2,2 bis(3-carboxyphenyl)ketone, and bis(3-carboxyphenoxy)benzene.

In some embodiments, the weight average molecular weight of the PA6 may be from 5,000 to 50,000 g/mol, preferably from 10,000 to 40,000 g/mol. The weight average molecular weight can be determined by gel permeation chromatography (GPC) using ASTM D5296 with polystyrene standards.

In embodiments in which the PPS polymer blends includes PA6, the concentration of the PA6 is at least 3 wt.%. In some embodiments, the PPS polymer blend includes at least 5 wt.%, at least 5.5 wt.%, at least 6 wt.% or at least 6.5 wt.% of the PA6. Additionally or alternative, in some embodiments, the PPS polymer blend includes no more than 20 wt.% of the PA6. In some embodiments, the PPS polymer blend includes no more than 15 wt.%, no more than 12 wt.%, no more than 11 wt.%, or no more than 10 wt.% of the PA6. In

some embodiments, the PPS polymer blend includes from 3 wt.% to 15 wt.% of the PA6. In some such embodiments, the PPS polymer blend includes from 5 wt.% to 12 wt.%, from 5.5 wt.% to 11 wt.%, from 6 wt.% to 10 wt.%, or from 6.5 wt.% to 9 wt.% of the PA6.

5 As noted above, in some embodiments, the PPS polymer blend is free of the PA6. As used herein, a PPS polymer blend free of PA6 has a PA6 concentration of less than 1 wt.%, less than 0.5 wt.%, or less than 0.1 wt.%.

In some embodiments in which the PPS polymer blends includes PA6, the weight ratio PPS/PA6 is at least 4, at least 4.5, at least 5, at least 5.5.
10 Additionally or alternatively, in some embodiments, the weight ratio PPS/PA6 is no more than 20, no more than 18, no more than 16 or no more than 14.

The Functionalized, Non-Aromatic Elastomer

In some embodiments, the PPS polymer blend includes a functionalized,
15 non-aromatic elastomer. In such embodiments, the PPS polymer blend includes 3 to 8 wt.% of the functionalized, non-aromatic elastomer. As used herein an “elastomer” denotes a polymer having: (i) a low glass transition temperature (T_g) (a T_g below 25°C, preferably below 0°C or more preferably below -25°C), and (ii) a low modulus (Young’s Modulus) (a modulus below 200 MPa, preferably
20 below 100 MPa).

The polymer backbone of the elastomer is non-aromatic. For the sake of clarity, the backbone does not include an aryl and arylene group (or moiety), e.g. a styrene group (or moiety). In some embodiments, the backbone of the elastomer may be, for example, an olefin (co)polymer and can notably be
25 selected from elastomeric backbones comprising polyethylenes copolymers, e.g. ethylene-butene; ethylene-octene; polypropylenes and copolymers thereof; polybutenes; polyisoprenes; ethylene-propylene-rubbers (“EPR”); ethylene-propylene-diene monomer rubbers (“EPDM”); ethylene-acrylate rubbers; butadiene-acrylonitrile rubbers, ethylene-acrylic acid (“EAA”), ethylene-
30 vinylacetate (“EVA”) or mixture of one or more of the above.

Furthermore, the polymer backbone of the elastomer is a grafted polymer backbone, referred to herein as a functionalized elastomer backbone. The

functionalization of the backbone can result from the copolymerization of monomers which include the functionalization or from the grafting of the polymer backbone with a further component.

5 Examples of desirable functionalized, non-aromatic elastomers include, but are not limited to, are terpolymers of ethylene, acrylic ester and glycidyl methacrylate; copolymers of ethylene and butyl ester acrylate; copolymers of ethylene, butyl ester acrylate and glycidyl methacrylate; ethylene-maleic anhydride copolymers; EPR grafted with maleic anhydride; EPDM grafted with maleic anhydride ("EPDM-g-MAH") or mixture of one or more of the above.
10 Examples of commercially available functionalized aliphatic elastomers according to the present invention are Exxelor[®] polymer resins (e.g. Exxelor[®] VA 1801) from Exxon Mobil and Lotader[®] polymer resins (e.g., Lotader[®] AX8840) from Arkema.

15 In some embodiments, the polymer backbone is functionalized with maleic anhydride. In one such embodiment, the functionalized, non-aromatic elastomer is EPDM grafted with maleic anhydride (EPDM-g-MAH). In another embodiment, the polymer backbone is functionalized with an epoxy group. In one such embodiment, the functionalized, non-aromatic elastomer is an epoxy functionalized copolymer of ethylene and glycidyl methacrylate.

20 In embodiments in which the PPS polymer blends includes a functionalized, non-aromatic elastomer, the PPS polymer blend includes at least 3 wt.%, at least 3.5 wt.%, or at least 4 wt.% of the functionalized, non-aromatic elastomer. Additionally or alternatively, in some embodiments, the PPS polymer blend includes no more than 8 wt.%, no more than 7.5 wt.%, no more than
25 7 wt.%, or no more than 6.5 wt.% of the functionalized, non-aromatic elastomer.

30 As noted above, in some embodiments, the PPS polymer blend is free of the functionalized, non-aromatic elastomer. As used herein, a PPS polymer blend free of the functionalized, non-aromatic elastomer has a functionalized, non-aromatic elastomer concentration of less than 1 wt.%, less than 0.5 wt.% or less than 0.1 wt.%.

 In some embodiments, the PPS polymer blend is free of an aromatic elastomer. For clarity, a PPS polymer blend is free of an aromatic elastomer

when the concentration of the aromatic elastomer is no more than 1 wt.%, preferable no more 0.5, more preferably no more than 0.1 wt.%. Examples of aromatic elastomers include, but are not limited to, acrylonitrile-butadiene-styrene rubbers ("ABS"); block copolymers styrene ethylene butadiene styrene ("SEBS"); block copolymers styrene butadiene styrene ("SBS"); core-shell elastomers of methacrylate-butadiene-styrene ("MBS") type, or mixture of one or more of the above.

In some embodiments in the PPS polymer blends includes both the PA6 and functionalized, non-aromatic elastomer, According to an embodiment, the weight ratio PA6/functionalized, non-aromatic elastomer is at least 1. In some such embodiments, the weight ratio PA6/functionalized, non-aromatic elastomer is at least 1.2, at least 1.3, at least 1.4, at least 1.5, or at least 1.6. Additionally or alternatively, in some embodiments, the weight ratio PA6/functionalized, non-aromatic elastomer is no more than 2, no more than 1.9, no more than 1.8, no more than 1.75 or no more than 1.7.

The Reinforcing Agent

The PPS polymer blend includes at least 5 wt.% of a reinforcing agent. Reinforcing agents, also called reinforcing fibers or reinforcing fillers, are selected from fibrous and particulate reinforcing agents. A fibrous reinforcing filler is considered herein to be a material having length, width and thickness, wherein the average length is significantly larger than both the width and thickness. Generally, such a material has an aspect ratio, defined as the average ratio between the length and the largest of the width and thickness of at least 5, at least 10, at least 20 or at least 50.

The reinforcing filler may be selected from mineral fillers (such as talc, mica, kaolin, calcium carbonate, calcium silicate, magnesium carbonate), glass fibers, carbon fibers, synthetic polymeric fibers, aramid fibers, aluminum fibers, titanium fibers, magnesium fibers, boron carbide fibers, rock wool fibers, steel fibers and wollastonite.

Among fibrous fillers, glass fibers are preferred; they include chopped strand A-, E-, C-, D-, S- and R-glass fibers, as described in chapter 5.2.3,

p. 43 48 of Additives for Plastics Handbook, 2nd edition, John Murphy. Preferably, the filler is chosen from fibrous fillers. It is more preferably a reinforcing fiber that is able to withstand the high temperature applications. In some embodiments, the glass fiber can be an E-CR glass fiber (according to
5 ASTM D578 and ISO 2078), which is a boron-free glass fibers. Such glass fibers can be obtained commercially from 3B-The Fiberglass Company.

In some embodiments, the PPS polymer blend includes at least 10 wt.% of the reinforcing agent. Additionally or alternatively, in some embodiments, the PPS polymer blends includes no more than 30 wt.%, no more than 25 wt.%, or
10 no more than 20 wt.% of the reinforcing agent. In some embodiments, the PPS polymer blend includes 5 wt.% to 30 wt.%, 10 wt.% to 25 wt.%, or 10 wt.% to 20 wt.% of the reinforcing agent.

Optional Additives

15 In some embodiments, the polymer blend includes one or more optional additives. The optional additive can be selected from the group consisting of plasticizers, colorants, pigments (e.g. black pigments such as carbon black and nigrosine), antistatic agents, dyes, lubricants (e.g. linear low density polyethylene, calcium or magnesium stearate or sodium montanate), thermal
20 stabilizers, light stabilizers, flame retardants, nucleating agents and antioxidants.

In LED application settings, the PPS polymer blends includes a pigment, preferably a white pigment. Appropriate white pigments include, but are not limited to, titanium dioxide, magnesium oxide, zinc sulfide, barium sulfate and any combination of one or more thereof. When present in the PPS polymer
25 blend, the concentration of the white pigment is at least 10 wt.%, at least 15 wt.%, at least 20 wt.% or at least 25 wt.%. Additionally or alternatively, the concentration of the white pigment is no more than 50 wt.%, no more than 45 wt.%, no more than 40 wt.%, or no more than 35 wt.%. In some
30 embodiments, the white pigment concentration is from 10 wt.% to 50 wt.%, from 15 wt.% to 45 wt.%, from 20 wt.% to 40 wt.%, or from 25 wt.% to 35 wt.%.

In some embodiments, when present, the total concentration of additives, other than the white pigment, is from 0.1 wt.% to 10 wt.%, from 0.1 wt.% to 5 wt.%, from 0.5 wt.% to 5 wt. % or from 1 wt.% to 5 wt.%.

The PPS polymer blend may, in some embodiments, also include one or
5 more other polymers. Examples of such other polymers include, but are not limited to, polyaryletherketones or other polyamides (e.g. polyphthalamides). Significantly, the PPS polymer blend is free of any aromatic epoxy polymer. For clarity, the PPS polymer blend is free of any aromatic epoxy polymer when the concentration of the aromatic epoxy polymer is no more than 1 wt.%, no more
10 than 0.5 wt.%, or no more than 0.1 wt.%. Examples of such aromatic epoxy polymers include, but are not limited to, epoxy resins based on bisphenol-A, bisphenol-F, tetrabromobisphenol-A, phenol novolac, cresol novolac, amino phenol, methylene dianiline, isocyanuric acid, or mixture of one or more of the above.

15

Formation of the PPS Polymer Blends

The PPS polymer blends can be made using methods well known in the art. For example, in one embodiment, the PPS polymer blends can be made by melt-blending the polymers, the reinforcing agents, and the elastomer, optionally
20 any other components or additives.

Any melt-blending method may be used for mixing polymeric ingredients and non-polymeric ingredients in the context of the present invention. For example, polymeric ingredients and non-polymeric ingredients may be fed into a melt mixer, such as single screw extruder or twin screw extruder, agitator, single
25 screw or twin screw kneader, or Banbury mixer, and the addition step may be addition of all ingredients at once or gradual addition in batches. When the polymeric ingredient and non-polymeric ingredient are gradually added in batches, a part of the polymeric ingredients and/or non-polymeric ingredients is first added, and then is melt-mixed with the remaining polymeric ingredients and
30 non-polymeric ingredients that are subsequently added, until an adequately mixed composition is obtained. If a reinforcing agent presents a long physical

shape (for example, a long glass fiber), drawing extrusion molding may be used to prepare a reinforced composition.

Articles

5 The PPS polymer blends described above can be desirably incorporated into LED housings. LED assemblies include at least an LED and an LED housing. The LED is a doped semi-conductor including a p-n junction. Under the appropriate voltage, the LED emits visible light under recombination of the electrons with the holes. LED housings generally have a cavity that surrounds
10 the LED and reflects the light emitted from the LED in an outward direction (*e.g.* towards the lens if one is present). The cavity can be cylindrical, conical, parabolic or other geometry which desirably reflects the light in an outward direction. In other embodiments, the cavity can be generally parallel to the LED. The surface of the cavity is preferably smooth. In some embodiments, the LED
15 assembly includes an epoxy or silicon material. In such embodiments, the LED housing cavity, including the LED, is filled with an epoxy or silicone material. In some embodiments, the cavity has a portion comprising the PPS polymer blend and having a thickness of no more than 0.6 mm or no more than 0.4 mm. In some embodiments, the LED housing includes at least 50 wt.%, at least
20 60 wt.%, at least 70 wt.%, at least 80 wt.%, at least 90 wt.%, at least 95 wt.%, at least 99 wt.%, or at least 99.9 wt.% of the PPS polymer blend, wherein wt.% is relative to the total weight of the LED housing.

 The LED housing described herein can be advantageously incorporated into application settings including, but not limited to, LED displays (*e.g.* mobile
25 phone displays, television displays, video game displays, smart watch displays, computer displays (desktop and laptop), automotive interior displays and infotainment systems), desk lamps, headlights, household electrical appliance indicators and outdoor display apparatuses (*e.g.* such as traffic signals).

 In some embodiments, the LED assembly can be selected from the group
30 consisting of top view LED assemblies, side view LED assemblies and power LED assemblies. Top view and side view LED assemblies comprise usually a basic housing, which, in general, acts as reflector; besides, top view and side

view LED assemblies usually do not comprise any heatsink slug. On the other hand, power LED assemblies comprise usually a heatsink slug, which, in general, acts as reflector; power LED assemblies usually further comprise a basic housing, which is a part distinct from the heatsink slug.

5 The top view LED assemblies are notably used in automotive lighting applications such as instrumental panel displays, stop lights and turn signals. The side view LED assemblies are notably used for mobile appliance applications such as, for example, cell phones and PDAs. The power LED assemblies are notably used in flashlights, automotive day light running lights,
10 signs and as backlight for LCD displays and TVs.

 The LED assembly can include at least one part comprising the PPS polymer blend as described above. The part is preferably selected from the group consisting of housings and heatsink slugs. The part made from the PPS polymer blend, as above detailed, is generally intended to act as reflector.

15 Preferably at least 50 wt. % and more preferably more than 80 wt. % of the part comprises the PPS polymer blend, being understood that the part may possibly further contain other materials, e.g. a metal; for example, for certain end uses, the surface of certain parts made from the PPS polymer blend, as above detailed, and acting as reflector, may be metal plated. More preferably, more
20 than 90 wt. % of the part comprises the PPS polymer blend. Still more preferably, the part consists essentially of the PPS polymer blend. The most preferably, the part consists of the PPS polymer blend.

 An exemplary embodiment of a top view LED assembly is provided in Fig. 1, which illustrates a sectional view of said embodiment. The top view LED
25 assembly 1 comprises a basic housing 2 comprising, and preferably consisting of, the PPS polymer blend as above detailed. As will be detailed hereafter, the basic housing 2 acts also as reflector cup. No heatsink slug is present. Usually, the LED assembly 1 further comprises a prefabricated electrical lead frame 3. Lead frame 3 can be advantageously encapsulated by injection molding with the
30 PPS polymer blend included in the basic housing 2. More generally, notwithstanding the particular embodiment, the LED housing can be desirably

formed by injection molding, though other molding approaches may also be used.

The basic housing 2 has a cavity 6. A semiconductor chip 4 that emits electromagnetic radiations, such as a LED chip, is mounted inside such cavity.

5 The semiconductor chip 4 is generally bonded and electrically contact-connected on one of the lead frame terminals by means of a bonding wire 5.

A transparent or translucent potting compound (e.g. an epoxy, a polycarbonate or a silicone resin, not shown in Fig. 1) is generally built into the cavity in order to protect the LED chip. It is customary, for the purpose of
10 increasing the external efficiency of the LED chip, to shape the cavity of the basic housing with non perpendicular inner areas in such a way that the cavity acquires a form opening towards the front side (the sectional view of the inner wall of the cavity may have, for instance, the form of an oblique straight line, as in the exemplary embodiment in accordance with Fig. 1, or that of a parabola).

15 Thus, the inner walls 7 of the cavity serve as reflector cup for the radiation which is emitted laterally by the semiconductor chip, notably reflecting this radiation towards the front side of the basic housing.

It is understood that the number of chips which can be mounted in the cavity of the basic housing, as well as the number of cavities which can be
20 formed inside a basic housing, is not restricted to one.

An exemplary embodiment of a power LED is provided in Fig. 2, which illustrates a sectional view of said embodiment. The power LED 8 comprises advantageously an aspherical lens 1 and a basic housing 2 comprising, and preferably consisting of, the PPS polymer blend, as above detailed. As in the
25 previous embodiment, the LED 8 further comprises a prefabricated electrical lead frame 3.

The power LED 8 also comprises a carrier body or heatsink slug 9 which may comprise, or consist of, the PPS polymer blend as above detailed. A cavity 6 is realized in the upper portion of the heatsink slug 9. A semiconductor LED
30 chip 4 that emits electromagnetic radiations is mounted on the bottom area of cavity 6 and it is generally fixed by means of a chip carrier substrate or solder connection 10 to the heatsink slug 9. The solder connection 10 is generally an

epoxy resin or another equivalent adhesive material. The LED chip is generally conductively connected to the electric terminals of the lead frame 3 via the bonding wires 5.

5 The inner walls 7 of the cavity 6 run generally from the bottom area of the cavity to the front side so as to form a reflector cup increasing the external efficiency of the LED chip. The inner walls 7 of the reflector cup may be, for example, straight and oblique or concavely curved (like in the exemplary embodiment in accordance with Fig. 2).

10 The lead frame 3 and the heatsink slug 9 are generally encapsulated within the basic housing 2. In order to protect the LED chip 4, the cavity is generally completely filled, likewise in the first exemplary embodiment of Fig. 1, with a radiation- transmissive, for example transparent, encapsulation compound (the encapsulant is not shown in Fig. 2). The PPS polymer blend as above detailed is particularly suitable for making basic housings and/or heatsink slugs
15 as above described, because, besides having excellent thermal conductivity thus allowing the heat produced by the optoelectronic device to be easily dissipated, it has also good mechanical properties, high heat deflection temperature, good plateability, good adhesion to lead frame, excellent optical properties, notably excellent initial whiteness and high retention of reflectance, even after prolonged
20 exposure to heat and radiation.

Should the disclosure of any patents, patent applications, and publications which are incorporated herein by reference conflict with the description of the present application to the extent that it may render a term unclear, the present description shall take precedence.

25

EXAMPLES

The examples demonstrate the formation and color and mechanical performance of the PPS polymer blends described herein.

To demonstrate initial whiteness, 6 samples were formed using one or
30 more of the following components:

- PPS: Ryton[®] PPS QA281 N, from Solvay Specialty Polymers USA, L.L.C.
- PA6: AK270, from Shaw Industries
- Glass Fibers: DS 8800-11P, from 3B (Braj Binani Group)
- 5 - Functionalized, Non-Aromatic Elastomer: Lotader[®] AX8840, from Arkema (epoxy functionalized copolymer of ethylene and glycidyl methacrylate)
- Titanium Dioxide: Ti-Pure[®] R-105 from The Chemours Company
- High Density Polyethylene (“HDPE”)
- 10 - Powdered Blend: Blend of lubricants and antioxidants obtained from Clariant Corporation as Conc. – Powder Blend 6118.

The polymer compositions were form by compounding. Compounding was performed on a Coperion ZSK-26 R&D twin-screw extruder (26 mm extruder). The neat PPS resin was fed into barrel 1. Glass fibers were fed at
15 barrel 7. Optional ingredients when present were also included into barrel 1, possibly pre-mixed before being fed into barrel 1, with the exception of TiO₂ and the powdered blend, which were fed into barrel 5. Barrel conditions were specified in order to achieve a melt temperature between 310°C and 340°C. Screw speeds were set at 200 RPM. Feed rates were set according to the desired
20 composition of each formulation. In the case of the Coperion ZSK-26 extruder, the molten strands were cooled and crystallized in a water bath before being pelletized for further processing. In the case of the Leistritz extruder, the molten strands were cooled and crystallized along a conveyer sprayed with air. Sample parameters are displayed in Table 1 (all values are in wt.%).

TABLE 1

COMPONENT	CE1	E1	E2	E3	E4	E5
PPS	52.75	42.75	46.75	36.75	72.75	66.75
HDPE	0.25	0.25	0.25	0.25	0.25	0.25
TiO ₂	30	30	30	30		
Powdered Blend	2	2	2	2	2	2
PA6		10		10	10	10
Functionalized, Non-Aromatic Elastomer			6	6		6
Glass Fiber	15	15	15	15	15	15

To demonstrate color performance, the samples were tested for their initial reflectance (as molded). Initial reflectance refers to the measurement on a sample subsequent to molding but before it goes through any kind of heat or light treatment (*e.g.* heat or light aging). The compositions of E1-E5 and CE1 were each molded into discs of about 50 mm diameter with a thickness of about 1.6 mm. Initial reflectance was measured on a BKY-Gardner photo-spectrometer according to ASTM E-1331-09 using a D65 illuminant with a 10° observer. The results of color performance testing are displayed in Table 2.

TABLE 2

Property	CE1	E1	E2	E3	E4	E5
	Initial Reflectance (%)					
Reflectance (@460 nm)	81.96	85.82	82.66	85.95	74.08	75.90
Reflectance (@540 nm)	87.43	90.30	88.22	91.14	81.31	84.46
Reflectance (@620 nm)	89.48	91.89	90.79	93.19	83.90	87.55
	Mechanical Performance					
Tensile Elongation (%)	1.2	1.2	2	2.1	1.4	2.9
Tensile Strength (MPa)	97.3	97.6	91.4	89.7	96.5	118
Tensile Modulus	9680	9670	6800	6330	7190	6140

Samples including PA6 or a functionalized, non-aromatic elastomer had improved initial whiteness, relative to the corresponding sample free of PA6 and the functionalized, non-aromatic elastomer. Referring to Table 2, samples E1 to E3 all had improved initial whiteness over each wavelength, relative to sample CE1 (free of PA6 and functionalized, non-aromatic elastomer). Moreover,

sample E3 (PA6 and functionalized, non-aromatic elastomer) had the greatest improvement in initial whiteness relative to samples E2 and E3.

To demonstrate mechanical performance, ISO Type IA testing bars were formed and tensile properties were tested according to ISO 527-2. The results of mechanical testing are displayed in Table 2, above.

The embodiments above are intended to be illustrative and not limiting. Additional embodiments are within the inventive concepts. In addition, although the present invention is described with reference to particular embodiments, those skilled in the art will recognized that changes can be made in form and detail without departing from the spirit and scope of the invention. Any incorporation by reference of documents above is limited such that no subject matter is incorporated that is contrary to the explicit disclosure herein.

CLAIMS

1. A light emitting diode ("LED") housing comprising a polymer blend comprising:

- a polyphenylene sulfide ("PPS"),
- 5 – at least 3 wt.% of a polyamide 6 ("PA6") or at least 3wt.% to 8 wt.% of a functionalized, non-aromatic elastomer, and
- from 5 wt.% to 30 wt.% of a reinforcing agent;

wherein wt. % is relative to the total weight of the polymer blend.

10 2. The LED housing of claim 1, wherein the polymer blend comprises from 35 wt.% to 60 wt.% of the PPS.

3. The LED housing of either claim 1 or 2, wherein the polymer blend comprises at least 3 wt.% of the PA6 and is free of the functionalized, non-
15 aromatic elastomer.

4. The LED housing of either claim 1 or 2, wherein the polymer blend comprises at least 3 wt.% of the PA6 and at least 3 wt.% to 8 wt.% of the functionalized, non-aromatic elastomer.

20

5. The LED housing of any one of claims 1, 2 or 4, wherein the weight ratio of PA6/functionalized, non-aromatic elastomer is at least 1.4.

6. The LED housing of any one of claims 1, 2, 4 or 5, wherein the weight
25 ratio of PPS/PA6 is at least 4.

7. The LED housing of any one of claims 2 to 6, wherein the polymer blend comprises 5 wt.% to 12 wt.% of the PA6.

8. The LED housing of either claim 1 or 2, wherein the polymer blend comprises at least 3 wt.% to 8 wt.% of the functionalized, non-aromatic elastomer and is free of the PA6.
- 5 9. The LED housing of any one of claims 1 to 8, wherein the polymer blend comprises from 10 wt.% to 20 wt.% of a white pigment selected from the group consisting of titanium dioxide, magnesium oxide, zinc sulfide, barium sulfate and any combination of one or more thereof.
- 10 10. The LED housing of claim 9, wherein the white pigment is titanium dioxide.
11. The LED housing of any one of claims 1 to 10, wherein the reinforcing agent is a glass fiber, preferably an E-CR glass fiber.
- 15 12. The LED housing of any one of claims 1 to 11, wherein the elastomer is epoxy-functionalized.
13. The LED housing of any one of claims 1 to 12, wherein the elastomer is
20 an epoxy-functionalized copolymer of ethylene and glycidyl methacrylate.
14. The LED housing of any one of claims 1 to 13, wherein at the LED housing comprises at least a portion having a thickness of no more than 0.6 mm, preferably 0.4mm and wherein the at least a portion portion comprises the PPS
25 polymer blend.
15. An LED assembly comprising the LED housing of any one of claims 1 to 14.

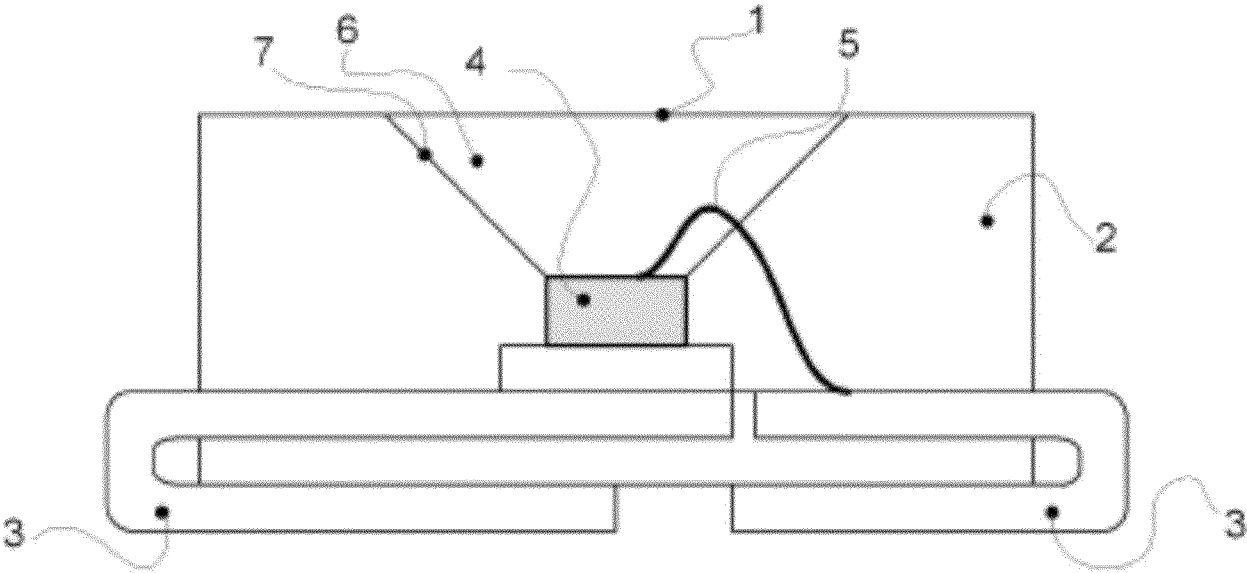


Fig. 1

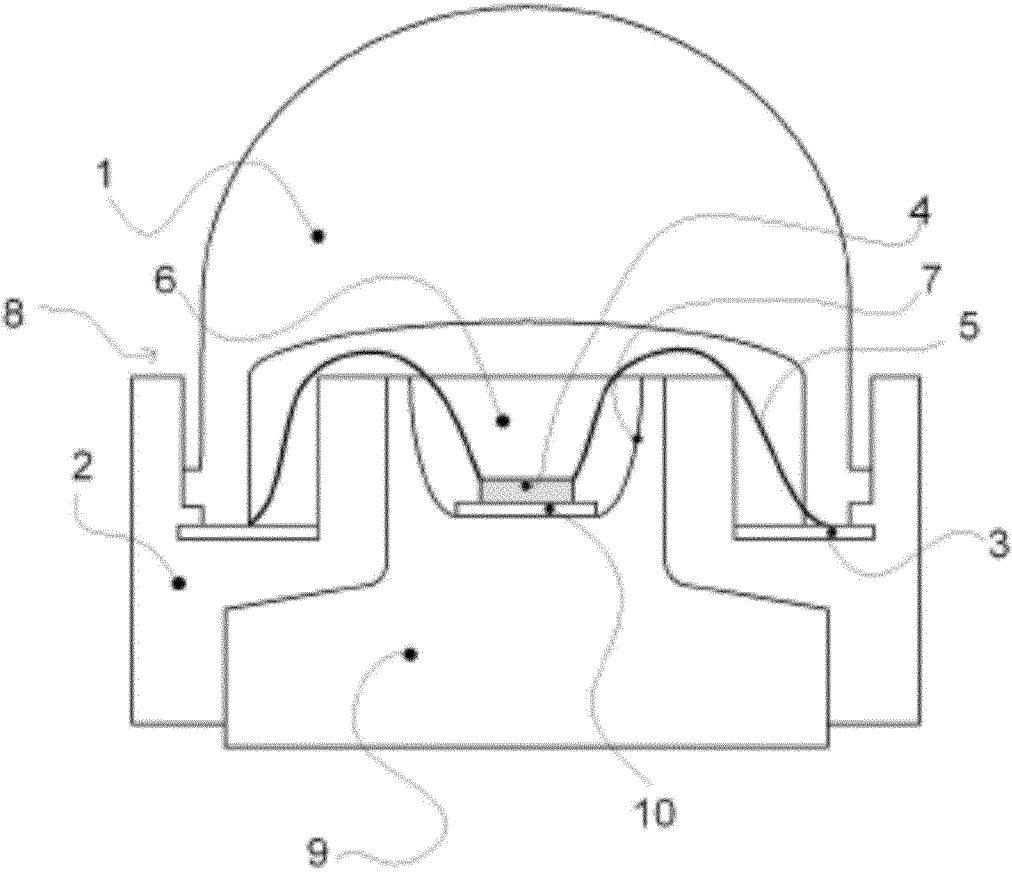


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/052829

A. CLASSIFICATION OF SUBJECT MATTER
INV. C08K3/00 C08K5/00 C08L77/00 C08L81/02 H01L23/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C08K C09J C08L H01L

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

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

EPO-Internal, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No

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