

DESCRIPTION

LIGHT DIFFUSION PLATE AND DIRECT SURFACE LIGHT SOURCE UNIT

TECHNICAL FIELD

[0001]

The present invention relates to a light diffusion plate and to a direct surface light source unit.

BACKGROUND

[0002]

Light diffusion plates are used for direct liquid crystal display device and the like. The direct liquid crystal display device is a display device comprising a liquid crystal cell and a backlight device arranged directly below the liquid crystal cell. Here, in the backlight device, LED is used as the light source, and the light diffusion plate is arranged at the front side of the light source. Further, styrene-based resin composition can be used as the resin which constitutes the light diffusion plate (Patent Literature 1).

CITATION LIST

PATENT LITERATURE

[0003]

[Patent Literature 1] JP-A-2010-134461

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004]

However, in order to meet the demand for high brightness, the LED used as the light source has become higher in power. Accordingly, heat generation amount has increased, thereby resulting in insufficient long-term durability of the light diffusion plate prepared with conventional styrene-based resin composition. In addition, there are cases where strength does not meet the requirement.

[0005]

The present invention has been made by taking the afore-

mentioned problems into consideration. The present invention provides a light diffusion plate comprising a styrene-based resin composition, which can achieve superior long-term durability and strength.

SOLUTION TO PROBLEM

[0006]

According to the present invention, a light diffusion plate, comprising a styrene-based resin composition, wherein: the styrene-based resin composition comprises a styrene-based resin (A), an antioxidant (B), and a light diffuser (C); the antioxidant (B) includes at least one selected from phosphorus antioxidant (B-1), phenol antioxidant (B-2), and phosphorus/phenol antioxidant (B-3); the phosphorus antioxidant (B-1) and the phosphorus/phenol antioxidant (B-3) in total are contained by 0.001 to 0.5 parts by mass with respect to 100 parts by mass of the styrene-based resin; the phenol antioxidant (B-2) and the phosphorus/phenol antioxidant (B-3) in total are contained by 0.001 to 0.5 parts by mass with respect to 100 parts by mass of the styrene-based resin; the light diffuser (C) is contained by 0.1 to 10 parts by mass with respect to 100 parts by mass of the styrene-based resin; and t-butyl catechol is contained by 0.1 to 10 $\mu\text{g/g}$ in the styrene-based resin composition, is provided.

[0007]

The present inventors have conducted extensive studies, and have found that when content of t-butyl catechol, phosphorus antioxidant, phenol antioxidant, phosphorus/phenol antioxidant, and light diffuser in the styrene-based resin composition is within a predetermined range, long-term durability and strength is superior, thereby resulting in completion of the invention.

[0008]

Hereinafter, various embodiments of the present invention will be exemplified. The following embodiments can be combined with each other.

Preferably, the phosphorus antioxidant (B-1) is at least one selected from: 2,2'-methylenebis(4,6-di-tert-butyl-1-phenyloxy) (2-ethylhexyloxy)phosphorus, tris(2,4-di-tert-butylphenyl)phosphite, 3,9-bis(2,6-di-tert-butyl-4-methylphenoxy)-2,4,8,10-tetraoxa-3,9-diphosphaspiro[5,5]undecane, tetrakis(2,4-di-tert-butylphenyl)

[1,1-biphenyl]-4,4'-diylbisphosphonite, and bis(2,4-di-tert-butyl-6-methylphenyl)ethyl phosphite.

Preferably, the phenol antioxidant (B-2) is at least one selected from: 6-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propoxy]-2,4,8,10-tetra-tert-butylldibenzo[d,f][1,3,2]dioxaphosphine, octadecyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate, ethylenebis(oxyethylene)bis[3-(5-tert-butyl-4-hydroxy-m-tolyl)propionate], pentaerythritol tetrakis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate], and 3,9-bis[2-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propionyloxy]-1,1-dimethylethyl]-2,4,8,10-tetraoxaspiro[5,5]undecane.

Preferably, the phosphorus/phenol antioxidant (B-3) is 6-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propoxy]-2,4,8,10-tetra-tert-butylldibenzo[d,f][1,3,2]dioxaphosphine.

Preferably, the light diffuser (C) is at least one selected from cross-linked acryl-based polymer particles, cross-linked styrene-based polymer particles, and cross-linked siloxane-based polymer particles.

Preferably, the styrene-based resin (A) has a weight average molecular weight (M_w) of 200,000 to 400,000, and a ratio of the weight average molecular weight (M_w) and number average molecular weight (M_n) (M_w/M_n) is 1.0 to 3.0.

Preferably, the light diffusion plate is used for LED light source.

Preferably, the direct surface light source unit comprises the light diffusion plate.

MODE FOR CARRYING OUT THE INVENTION

[0009]

Hereinafter, embodiments of the present invention will be described. The characteristic features shown in the following embodiments can be combined with each other. Here, an invention can be established independently for each one of the characteristic features.

[0010]

1. light diffusion plate

The light diffusion plate according to one embodiment of the present invention is a light diffusion plate comprising a styrene-based resin composition. The thickness of the light diffusion plate

is not particularly limited. Here, the thickness is 1 to 3 mm for example. In addition, the light diffusion plate can be laminated with a UV absorbing layer which is formulated with UV absorbent and light stabilizer.

[0011]

The light diffusion plate according to one embodiment can have an antistatic agent applied thereon. When the antistatic agent is applied, adhesion of dust and the like due to static electricity can be suppressed after installing the light diffusion plate onto the backlight device. Therefore, the light diffusion plate can be used for a long period of time without deterioration of brightness. In addition, the light diffusion plate of the present invention can have fine surface roughness such as embossing on both sides or on one side thereof. Otherwise, the light diffusion plate can have a semicircular or elliptical lens shape or a prism shape formed on both sides or on one side thereof.

[0012]

<styrene-based resin composition>

The styrene-based resin composition comprises a styrene-based resin (A), an antioxidant (B), and a light diffuser (C). The content of t-butyl catechol in the styrene-based resin composition is 0.1 to 10 $\mu\text{g/g}$. When the content is in such range, long-term durability and strength becomes superior. The content of the t-butyl catechol is, particularly for example, 0.1, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, or 10 $\mu\text{g/g}$, and can be in the range between the two values exemplified herein. When the content of t-butyl catechol is less than 0.1 $\mu\text{g/g}$, the effect of suppressing oxidation degradation during thermoforming process becomes small, thereby resulting in degradation of the strength of the light diffusion plate. When the content of t-butyl catechol exceeds 10 $\mu\text{g/g}$, t-butyl catechol itself serves as a colorant, and thus not only the long-term durability of the light diffusion plate deteriorate, but strength also deteriorates.

[0013]

<styrene-based resin (A)>

Styrene-based resin (A) is a resin obtained by polymerizing styrene-based monomer as the main component. In particular, styrene-based resin is a resin which contains more than 50% of styrene-based monomer. The styrene-based monomer is either one of or a mixture of

two or more of styrene, α -methyl styrene, o-methyl styrene, p-methyl styrene, m-methyl styrene, ethyl styrene, p-t-butyl styrene and the like which are aromatic styrene-based monomers. Preferably, styrene-based monomer is styrene. In addition, styrene-based resin (A) can be a copolymer obtained by copolymerizing a monomer which is copolymerizable with the styrene-based monomer, with the styrene-based monomer. As the monomer which is copolymerizable with the styrene-based monomer, for example, acrylic acid monomer such as acrylic acid and methacrylic acid; vinyl cyanide monomer such as acrylonitrile and methacrylonitrile; acryl-based monomer such as butyl acrylate, ethyl acrylate, methyl acrylate, and methyl methacrylate; α,β -ethylene unsaturated carboxylic acid such as maleic anhydride and fumaric acid; imide-based monomer such as phenyl maleimide and cyclohexyl maleimide; can be mentioned. These monomers can be used alone, or two or more of these can be used in combination. [0014]

The weight average molecular weight (M_w) of the styrene-based resin (A) is preferably 200,000 to 400,000, more preferably 200,000 to 290,000. In addition, the ratio of the weight average molecular weight (M_w) with respect to number average molecular weight (M_n) of the styrene-based resin (A), (M_w/M_n) is preferably 1.0 to 3.0, more preferably 1.5 to 2.5. Further, the ratio of the Z average molecular weight (M_z) with respect to the weight average molecular weight (M_w) of the styrene-based resin (A), (M_z/M_w) is preferably 1.0 to 2.0. When they are in such range, both of formability and strength of the light diffusion plate can be achieved. When the weight average molecular weight (M_w) is 200,000 or more, the strength is superior. When the weight average molecular weight (M_w) is 400,000 or less, the formability is superior. When the ratio of the weight average molecular weight (M_w) and the number average molecular weight (M_n) is 1.0 or more, the formability is superior. When the ratio of the weight average molecular weight (M_w) and the number average molecular weight (M_n) is 3.0 or less, strength is superior. When the ratio of the Z average molecular weight (M_z) and the weight average molecular weight (M_w), (M_z/M_w) is 1.0 or more, formability is superior. When the ratio of the Z average molecular weight (M_z) and the weight average molecular weight (M_w), (M_z/M_w) is 2.0 or less, strength is superior.

[0015]

<antioxidant (B)>

Antioxidant (B) comprises at least one of phosphorus antioxidant (B-1), phenol antioxidant (B-2), and phosphorus/phenol antioxidant (B-3).

[0016]

The styrene-based resin composition contains, with respect to 100 parts by mass of the styrene-based resin, phosphorus antioxidant (B-1) and phosphorus/phenol antioxidant (B-3) by total of 0.001 to 0.5 parts by mass, preferably 0.05 to 0.3 parts by mass. When the total content is in such range, the light diffusion plate is superior in long-term durability and strength. The total content of the phosphorus antioxidant (B-1) and phosphorus/phenol antioxidant (B-3) with respect to 100 parts by mass of the styrene-based resin is, particularly for example, 0.001, 0.005, 0.01, 0.02, 0.03, 0.04, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, or 0.5 parts by mass, and can be in the range between the two values exemplified herein.

[0017]

The phenol antioxidant (B-2) and the phosphorus/phenol antioxidant (B-3) are contained by total of 0.001 to 0.5 parts by mass, preferably 0.02 to 0.3 parts by mass, and further preferably 0.05 to 0.15 parts by mass. When the total content is in such range, the light diffusion plate is superior in long-term durability and strength. The total content of the phenol antioxidant (B-2) and phosphorus/phenol antioxidant (B-3) with respect to 100 parts by mass of the styrene-based resin is, particularly for example, 0.001, 0.005, 0.01, 0.02, 0.03, 0.04, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, or 0.5 parts by mass, and can be in the range between the two values exemplified herein.

[0018]

The phosphorus antioxidant (B-1) is phosphate or phosphite which does not have phenolic hydroxyl group in its basic structure, and is preferably a phosphite which is a trivalent phosphorus compound. The phosphorus antioxidant (B-1) is, for example, at least one selected from 2,2'-methylenebis(4,6-di-tert-butyl-1-phenyloxy) (2-ethylhexyloxy)phosphorus, tris(2,4-di-tert-butylphenyl)phosphite, 3,9-bis(2,6-di-tert-butyl-4-methylphenoxy)-2,4,8,10-tetraoxa-3,9-diphosphaspiro[5,5]undecane, tetrakis(2,4-di-tert-butylphenyl) [1,1-biphenyl]-4,4'-diylbisphosphonite, bis(2,4-di-tert-butyl-6-methylphenyl)ethyl phosphite, and the like.

[0019]

The phenol antioxidant (B-2) is an antioxidant which has a phenolic hydroxyl group in its basic structure and is not phosphate nor phosphite. The phenol antioxidant (B-2) is, for example, at least one selected from octadecyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate, ethylenebis(oxyethylene)bis[3-(5-tert-butyl-4-hydroxy-m-tolyl)propionate], pentaerythritol tetrakis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate], 3,9-bis[2-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propionyloxy]-1,1-dimethylethyl]-2,4,8,10-tetraoxaspiro[5,5]undecane, and the like.

[0020]

The phosphorus/phenol antioxidant (B-3) is phosphate or phosphite which has a phenolic hydroxyl group in its basic structure, and is preferably a phosphite which is a trivalent phosphorus compound having a phenolic hydroxyl group in its basic structure. The phosphorus/phenol antioxidant (B-3) is, for example, 6-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propoxy]-2,4,8,10-tetra-tert-butylldibenzo[d,f][1,3,2]dioxaphosphine and the like.

[0021]

<light diffuser (C)>

In the styrene-based resin composition, the content of the light diffuser (C) with respect to 100 parts by mass of the styrene-based resin is 0.1 to 10 parts by mass, preferably 0.5 to 3 parts by mass, and further preferably 0.8 to 1.5 parts by mass. When the content is in such range, the light diffusion plate is superior in long-term durability and strength. The content of the light diffuser (C) with respect to 100 parts by mass of the styrene-based resin is, particularly for example, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, or 10 parts mass, and can be in the range between the two values exemplified herein.

[0022]

The light diffuser (C) are particles having a refractive index which differs from that of the styrene-based resin composition. There is no limitation to usage so long as it has an effect to diffuse the incident light. For example, organic particles such as cross-linked styrene-based polymer particles, cross-linked acryl-based polymer particles, and cross-linked siloxane-based polymer particles; and inorganic particles such as glass beads, silica particles, aluminum hydroxide particles, calcium carbonate particles,

barium sulfate particles, titanium oxide particles, and talc can be used. Among these, at least one selected from cross-linked acryl-based polymer particles, cross-linked styrene-based polymer particles, and cross-linked siloxane-based polymer particles is preferable. The mean particle size of the light diffuser (C) is preferably 1 to 20 μm . When the mean particle size of the light diffuser (C) is less than 1 μm , the hue can deteriorate, and when the mean particle size of the light diffuser (C) exceeds 20 μm , there are cases where light diffusing property is not sufficient.

[0023]

<other additives>

The styrene-based resin composition can be formulated with various additives as necessary to an extent that it does not impair the properties of the present invention. The kind of the additive is not particularly limited so long as it is generally used in plastics. For example, flame retardant, lubricant, processing aid, anti-blocking agent, antistatic agent, antifogging agent, light resistance improver, softening agent, plasticizer, inorganic reinforcing agent, crosslinking agent, pigment, dye, and mixtures thereof can be mentioned.

[0024]

2. manufacturing method of styrene-based resin composition and light diffusion plate

The styrene-based resin composition of the present invention can be manufactured by formulating antioxidant (B) and light diffuser (C) to the styrene-based resin (A). The antioxidant (B) and light diffuser (C) can be added when the styrene-based resin is polymerized, or the antioxidant (B) and light diffuser (C) can be dry blended after polymerizing the styrene-based resin (A), and can be melt and kneaded with an extruder. Further, manufacture can be also carried out by melting and kneading the antioxidant (B) and light diffuser (C) with a small amount of styrene-based resin before-hand to obtain a pellet master batch, and then dry blending the master batch with the styrene-based resin (A) followed by melting and kneading.

[0025]

As the polymerization method of the styrene-based resin, known styrene polymerization method such as bulk polymerization, solution polymerization, suspension polymerization, and emulsion polymerization can be mentioned. In terms of quality and

productivity, bulk polymerization and solution polymerization are preferable, and it is preferable that these methods are continuous polymerization. As the solvent, alkylbenzene such as benzene, toluene, ethylbenzene, and xylene; ketone such as acetone and methyl ethyl ketone; and aliphatic hydrocarbon such as hexane and cyclohexane can be used.

[0026]

When the styrene-based resin (A) is polymerized, polymerization auxiliary agent such as polymerization initiator, chain transfer agent, crosslinking agent, and other polymerization auxiliary agent can be used as necessary. As the polymerization initiator, radical polymerization initiator is preferable. Known radical polymerization initiator, for example, peroxyketal such as 1,1-di(t-butylperoxy)cyclohexane, 2,2-di(t-butylperoxy)butane, 2,2-di(4,4-di-t-butylperoxycyclohexyl)propane, and 1,1-di(t-amylperoxy)cyclohexane; hydroperoxide such as cumene hydroperoxide and t-butyl hydroperoxide; alkyl peroxide such as t-butyl peroxyacetate and t-amyl peroxyisononanoate; dialkyl peroxide such as t-butyl cumyl peroxide, di-t-butyl peroxide, dicumyl peroxide, and di-t-hexyl peroxide; peroxy ester such as t-butyl peroxyacetate, t-butyl peroxy benzoyate, and t-butyl peroxy isopropyl monocarbonate; peroxycarbonate such as t-butyl peroxy isopropyl carbonate and polyether tetrakis(t-butyl peroxycarbonate); N,N'-azobis(cyclohexane-1-carbonitrile), N,N'-azobis(2-methylbutyronitrile), N,N'-azobis(2,4-dimethylvaleronitrile), N,N'-azobis[2-(hydroxymethyl)propionitrile] and the like can be mentioned. These polymerization initiators can be used alone, or two or more of these can be used in combination. As the chain transfer agent, aliphatic mercaptan, aromatic mercaptan, pentaphenyl ethane, alpha-methylstyrene dimer, and terpinolene can be mentioned for example.

[0027]

When continuous polymerization is performed, the styrene-based resin can be manufactured by a method comprising polymerization step, devolatilization step, and pelletizing step.

[0028]

First, in the polymerization step, conventional complete stirred tank-type agitation tank or column reactor are used. The polymerization reaction is controlled by adjusting the polymerization temperature and the like to achieve target molecular

weight, molecular weight distribution, and reaction conversion rate.
[0029]

The polymerization solution containing the polymer after the polymerization step is transferred to the devolatilization step, and the unreacted monomer and the polymerization solvent are removed. The devolatilization step comprises a vacuum devolatilization tank equipped with a heater, a devolatilizing extruder equipped with a vent, and the like. The molten polymer after the devolatilization step is transferred to the pelletizing step. In the pelletizing step, the molten resin is extruded into strands from a porous die, and processed into pellets by cold cut method, air-cooled hot cutting method or underwater hot cutting method.

[0030]

The content of t-butyl catechol in the styrene-based resin composition can be adjusted by adjusting the content at starting of the polymerization of the styrene-based resin (A), and by adjusting the content during the devolatilization step and the like thereafter. The content of t-butyl catechol can be adjusted by adding t-butyl catechol before or after adding antioxidant (B) or light diffuser (C) to the styrene-based resin (A).

[0031]

The light diffusion plate can be manufactured by molding the styrene-based resin composition by various methods such as extrusion molding and injection molding. Here, the light diffusion plate is manufactured preferably by extrusion molding. As an example of the extrusion molding, a method in which the styrene-based resin composition is melt and kneaded using a single-screw extruder or a twin-screw extruder, followed by continuous extrusion using a T-dice, and then cooling and solidifying using a cooling roll unit can be mentioned. When surface roughness is provided on the surface of the light diffusion plate, a transfer mold is provided on the surface of the cooling roll, and the shape of the transfer mold is adjusted to form a desired surface roughness. Further, when a surface layer is laminated on both sides or one side of the light diffusion plate, methods such as co-extrusion method, lamination method, thermal bonding method, solvent bonding method, casting method, surface coating method and the like can be adopted.

[0032]

3. others

The light diffusion plate according to one embodiment of the present invention can be used as a light diffusion plate for LED light source.

In addition, the direct surface light source unit according to one embodiment of the present invention is a direct surface light source unit having the afore-mentioned light diffusion plate.

EXAMPLE

[0033]

Hereinafter, the present invention will be explained in further detail with reference to the Examples. However, these Examples are merely for exemplification, and shall not limit the scope of the present invention.

[0034]

1. measurement method

<molecular weight>

Number average molecular weight (M_n), weight average molecular weight (M_w), and Z average molecular weight (M_z) were measured using gel permeation chromatography (GPC) with the following conditions.

GPC Instrument: Shodex GPC-101, available from Showa Denko K.K.

Column: PLgel 10 μ m MIXED-B, available from Polymer Laboratories Inc.

Mobile phase: tetrahydrofuran

Sample concentration: 0.2 mass%

Temperature: oven 40 °C, inlet 35 °C, detector 35 °C

Detector: refractive index detector

Molecular weight is calculated as polystyrene equivalent molecular weight obtained for each of the elution time of the elution curve of monodisperse polystyrene.

[0035]

<melt mass flow rate (MFR)>

Measurement was carried out in accordance with JIS K 7210 under the conditions of 200 °C temperature and 49 N load.

[0036]

<Vicat softening temperature>

Measurement was carried out in accordance with JIS K 7206 under conditions of 50 °C/hr programming rate and 50 N evaluation load.

[0037]

<content of t-butyl catechol (TBC)>

After dissolving 0.2 g of styrene-based resin in a small amount of THF, 200 μ L of BSTFA (N,O-bis(trimethylsilyl)trifluoroacetamide) was added to perform trimethylsilyl-derivatization treatment. Subsequently, volume was fixed to 10 mL with THF, and the supernatant solution separated by centrifugation was analyzed with gas chromatography mass spectrometry (GC/MS) under the following conditions. Here, concentration was determined with a calibration curve prepared in advance.

GC Instrument: 7890A, available from Agilent Technologies

Column: DB-5ms (0.25 mm i.d. x 30 m), liquid phase film thickness 0.25 μ m, available from Agilent Technologies

Column temperature: 50 °C (1 min) – (20 °C/min temperature increase) – 320 °C (6.5 min) total 20 min

Inlet: 300 °C, 1.5 mL/min, (split ratio 1:5)

Injection amount: 1 μ L

MS Instrument: 5975C, available from Agilent Technologies

Interface temperature: 320 °C

MS detection conditions: SIM measurement TBC (m/z for quantitative analysis 295, m/z for verification 310)

[0038]

<total light transmittance, YI>

Total light transmittance in the thickness direction of the light diffusion plate was measured in accordance with JIS-K7105 using turbidimeter NDH5000 available from NIPPON DENSHOKU INDUSTRIES CO., LTD.

[0039]

<YI>

YI of light diffusion plate was measured in accordance with reflection method of JIS-K7105 using colorimeter/color-difference meter NDJ4000 available from NIPPON DENSHOKU INDUSTRIES CO., LTD.

[0040]

<average brightness difference>

Liquid crystal panel, various optical films, and light diffusion plate were removed from commercially available 20-inch direct LED liquid crystal television. The central portion of the light diffusion plate was cut out by a 115 mm x 115 mm square. Evaluation test pieces of 115 mm x 115 mm prepared by cutting the light diffusion plate obtained by Examples and Comparative Examples, or evaluation test pieces of 115 mm x 115 mm after durability test

were installed in the cut out portion, and then replaced into the flame of the liquid crystal television. Subsequently, two commercially available light diffusion films were laminated on the front surface of the light diffusion plate, and one brightness enhancement film ("DBFF", available from 3M) was further laminated on the front surface side thereof. With the LED turned on, the brightness of each spot (51 x 51 = 2601 locations) was measured over the entire front surface of the liquid crystal television using a multi-point brightness meter. Average value of these brightness was taken as the average brightness (cd/m²). In addition, average brightness difference (%) was obtained from the following equation.

average brightness difference (%) = [(average brightness of Examples)-(average brightness of Comparative Example 1)]/(average brightness of Comparative Example 1) x 100

[0041]

<diffusion rate>

Goniophotometer available from Optec was used to allow white light from the light source to enter the surface of the light diffusion plate with an angle perpendicular to the surface. The brightness of the transmitted light at the angle of 5 degrees, 20 degrees, and 70 degrees when the angle perpendicular to the surface of the light diffusion plate was taken as 0 degrees were measured. Diffusion rate was obtained from the following equation.

Light diffusion rate (%) = (brightness at 20 degrees + brightness at 70 degrees)/(brightness at 5 degrees x 2) x 100

[0042]

<strength>

The light diffusion plate was cut out into 200 mm x 200 mm square, and used as evaluation test piece. A ball of 16.6 g weight was used to measure 50 % impact-failure height in accordance with JIS K-7211. Evaluation was made in accordance with the following criteria.

A: 50 % impact-failure height was more than 40 cm

B: 50 % impact-failure height was 20 to 40 cm

C: 50 % impact-failure height was less than 20 cm

[0043]

2. durability test

The light diffusion plate was cut out into 115 mm x 115 mm square, and was used as evaluation test piece. The evaluation test

piece was exposed for 1,000 hours in a 80 °C gear oven HISPEC HT310 available from Kusumoto Chemicals, Ltd.

[0044]

The results of long-term durability evaluation are shown as each of the measurement results after the durability test.

[0045]

3. synthesis of styrene-based resin

Styrene-based resins PS-1 to PS-5 were synthesized in accordance with the conditions shown in Table 1.

[0046]

(synthesis of PS-1)

First reactor and second reactor which are complete stirred agitation tanks and third reactor which is a plug flow reactor with static mixer were connected in series to constitute a polymerization step. Manufacture of styrene-based resin was performed in accordance with the conditions shown in Table 1. Volume of each of the reactors were set as 39 liters for the first reactor, 39 liters for the second reactor, and 16 liters for the third reactor. Raw material solution was prepared with the raw material composition shown in Table 1, and the raw material solution was continuously supplied to the first reactor with the flow rate shown in Table 1. The polymerization initiator was added to the raw material solution and mixed uniformly so that the addition concentration (concentration based on the mass of the raw material styrene) at the inlet of the first reactor would satisfy the value shown in Table 1. The polymerization initiator shown in Table 1 are as follows.

polymerization initiator-1: 2,2-di(4,4-t-butyl peroxy cyclohexyl)propane (PERTETRA A, available from NOF CORPORATION was used)

polymerization initiator-2: 1,1-di(t-butylperoxy)cyclohexane (PERHEXA C, available from NOF CORPORATION was used)

In the third reactor, temperature gradient was provided in the direction of the flow. Temperature was adjusted so as to satisfy the temperatures at the middle portion and exit portion as shown in Table 1.

Subsequently, the solution including the polymer taken out continuously from the third reactor was introduced into a two-stage sequential vacuum devolatilization tanks equipped with a preheater. The temperature of the preheater was adjusted so that the resin

temperature shown in Table 1 was satisfied. Pressure was adjusted to the pressure shown in Table 1 to separate unreacted styrene and ethylbenzene. Thereafter, the polymer was extruded into strands from a porous die, and the strand was cooled and cut into pellets by cold cut method.

[0047]

PS-2 to PS-5 were synthesized in a similar manner as PS-1 except for altering the conditions as shown in Table 1.

[0048]

[Table 1]

Table 1		condition 1	condition 2	condition 3	condition 4	condition 5
name of resin		PS-1	PS-2	PS-3	PS-4	PS-5
amount of raw material supplied	kg/hr	12.0	11.2	12.6	11.2	11.2
	mass%	83.5	84.0	81.5	84.0	84.0
raw material	styrene	16.5	16.0	18.5	16.0	16.0
	ethyl benzene					
amount of TBC in feeded raw material	$\mu\text{g/g}$	8.0	8.5	8.0	1.0	25
polymerization initiator-1	ppm *1	—	400	150	400	400
polymerization initiator-2	ppm *1	—	—	100	—	—
reaction temp.	first reactor	132	116	120	116	116
	second reactor	132	120	135	120	120
	third reactor (middle portion)	135	140	145	140	140
	third reactor (exit portion)	140	150	155	150	150
first devolatilization tank	resin temperature	160	160	160	160	160
	pressure	65	65	65	65	65
second devolatilization tank	resin temperature	230	235	230	235	235
	pressure	0.8	0.8	0.8	0.8	0.8
polymer property	Mn	15.0	12.0	7.5	12.2	11.0
	Mw	27.0	37.0	28.0	37.2	34.0
	Mz	43.5	72.0	59.2	73.2	69.0
	Mw/Mn	1.80	3.08	3.73	3.05	3.09
	Mz/Mw	1.61	1.95	2.11	1.97	2.03
	melt mass flow rate	2.3	1.1	2.7	1.1	1.3
	Vicat softening temperature	102.0	103.0	101.0	103.0	102.0
	TBC	1.5	1.5	2.5	<0.1	15.0
	$\mu\text{g/g}$					

*1 concentration based on mass with respect to total monomer

[0049]

4. Examples and Comparative Examples

Examples and Comparative Examples were performed in accordance with the following procedures.

[0050]

<Example 1>

With respect to 100 parts by mass of styrene-based resin (PS-1) containing t-butyl catechol (TBC) by the amount shown in Table 1, 0.2 parts by mass of phosphorus antioxidant (HP-10), 0.1 parts by mass of phosphorus/phenol antioxidant (GP), and 1.0 parts by mass of light diffuser (MBX-8) were mixed using a blender. The mixture was further mixed using a single-screw extruder having a screw diameter of 40 mm under 230 °C of screw temperature and 100 rpm of screw rotation number, thereby obtaining the styrene-based resin composition.

[0051]

Subsequently, the styrene-based resin composition was supplied to a single-screw extruder equipped with a vent having a screw diameter of 90 mm and L/D of 32. The styrene-based resin composition was melt and kneaded at 200 to 235 °C, followed by ejection from a T-die having a lip width of 1000 mm and lip-opening degree of 3.0 mm, at a T-die temperature on 245 to 250 °C. The ejected resin composition was cooled and solidified using a vertical arranged three roll mill, and then the end face was trimmed to obtain a light diffusion plate with a width of 800 mm and a thickness of 2.0 mm. The initial optical properties of the light diffusion plate were measured in accordance with the measurement methods, and initial strength was measured. Thereafter, durability test was performed, and the optical properties after the durability test were measured in accordance with the measurement methods. Results are shown in Table 2.

[0052]

<Examples 2 to 15, Comparative Examples 1 to 7>

Examples 2 to 15 and Comparative Examples 1 to 7 were performed in a similar manner as Example 1 by altering the conditions shown in Table 2 and Table 3, thereby obtaining the resin compositions and the light diffusion plates. Measurements were performed and the results are shown in Table 2 and Table 3.

[0053]

[Table 2]

Table 2			Example															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
formulation	styrene-based resin	type	PS-1	PS-1	PS-1	PS-1	PS-1	PS-1	PS-1	PS-1	PS-1	PS-1	PS-1	PS-1	PS-2	PS-3	PS-2	
	(A)	addition amount	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	phosphorus antioxidant	type	HP-10	168	PEP-36	P-EPQ	38	168	168	168	168	168	—	HP-10	HP-10	HP-10	HP-10	168
	(B-1)	parts by mass	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0	0.2	0.2	0.2	0.05	0.1	
	phenol antioxidant	type	—	—	—	—	—	—	1076	245	1010	AO80	—	—	—	—	1076	1076
	(B-2)	addition amount	0	0	0	0	0	0.1	0.05	0.02	0.05	0	0	0	0	0.05	0.1	
	phosphorus/phenol antioxidant (B-3)	type	GP	GP	GP	GP	GP	—	—	—	—	—	GP	GP	GP	GP	—	—
	light diffuser (C)	type	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	SBX-8	KMP-590	MBX-8	MBX-8	MBX-8
	total of B-1 and B-3	parts by mass	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	0.5	1.0	1.0	1.0
	total of B-2 and B-3	parts by mass	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.05	0.3	0.3	0.3	0.05	0.1
composition	total of B-2 and B-3	parts by mass	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.02	0.05	0.05	0.1	0.1	0.1	0.05	0.1	
	content of TBC	$\mu\text{g/g}$	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.5	1.5	
evaluation	total light transmittance	%	61	62	60	61	60	58	58	58	59	57	57	60	58	57	58	
	optical property	YI	2.5	2.7	2.5	2.8	2.5	3.0	3.0	2.8	2.9	3.0	2.6	2.8	3.1	3.0	3.1	
	average brightness difference	—	5.4	5.8	5.2	4.8	5.3	4.5	4.1	4.2	4.5	4.0	5.0	4.5	4.0	4.1	4.0	
	diffusion rate	—	72	72	72	72	72	73	72	73	74	72	60	75	70	72	73	
	total light transmittance	%	60	61	60	60	59	57	57	57	57	55	56	59	58	55	55	
	long-term durability (80°C × 1,000h)	YI	2.6	2.8	2.7	2.9	2.7	3.4	3.6	3.4	3.5	4.0	2.7	2.8	3.4	4.0	3.7	
strength	average brightness difference	—	5.2	5.4	5.0	4.7	5.0	4.0	3.8	3.7	4.5	2.8	4.8	4.3	3.0	4.4	3.2	
	—	—	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A	

[0054]

[Table 3]

Table 3			Comparative Example						
			1	2	3	4	5	6	7
formulation	styrene-based resin (A)	type	PS-1	PS-2	PS-4	PS-5	PS-1	PS-1	PS-1
		addition amount	100	100	100	100	100	100	100
	phosphorus antioxidant (B-1)	type	—	—	168	168	168	—	—
		addition amount	0	0	0.1	0.1	0.5	0	0
	phenol antioxidant (B-2)	type	—	—	1076	1076	—	1076	1076
		addition amount	0	0	0.1	0.1	0	0.7	0.1
composition	phosphorus/phenol antioxidant (B-3)	type	—	—	—	—	GP	—	—
		addition amount	0	0	0	0	0.5	0	0
	light diffuser (C)	type	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8	MBX-8
		addition amount	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	total of B-1 and B-3		0	0	0.1	0.1	1.0	0	0
	total of B-2 and B-3		0	0	0.1	0.1	0.5	0.7	0.1
evaluation	content of TBC		1.5	1.5	<0.1	15	1.5	1.5	1.5
	optical property	total light transmittance Y1	55	54	58	55	55	56	58
		average brightness difference	3.3	3.5	3.0	4.7	4.8	3.1	3.0
		diffusion rate	0.0	-0.3	4.0	1.0	2.0	4.2	4.5
	long-term durability (80°C × 1,000h)	total light transmittance Y1	72	72	73	73	72	72	72
		average brightness difference	52	51	55	52	54	54	51
			7.8	8.7	3.7	6.3	5.2	6.2	7.0
	strength		-3.2	-3.5	3.2	0.1	2.0	0.3	0.1

[0055]

Each of the abbreviations shown in the Table represents the

followings.

HP-10: 2,2'-methylenebis(4,6-di-tert-butyl-1-phenyloxy) (2-ethylhexyloxy)phosphorus (HP-10, available from ADEKA Corporation)

168: tris(2,4-di-tert-butylphenyl)phosphite (Irgafos 168, available from BASF Japan, Ltd.)

PEP-36: 3,9-bis(2,6-di-tert-butyl-4-methylphenoxy)-2,4,8,10-tetraoxa-3,9-diphosphaspiro[5,5]undecane (PEP-36, available from ADEKA Corporation)

P-EPQ: tetrakis(2,4-di-tert-butylphenyl) [1,1-biphenyl]-4,4'-diylbisphosphonite (IrgafosP-EPQ, available from BASF Japan, Ltd.)

38: bis(2,4-di-tert-butyl-6-methylphenyl)ethyl phosphite (Irgafos 38, available from BASF Japan, Ltd.)

GP: 6-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propoxy]-2,4,8,10-tetra-tert-butyl-dibenzo[d,f][1,3,2]dioxaphosphine (Sumilizer GP, available from SUMITOMO CHEMICAL COMPANY, LIMITED)

1076: octadecyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate (Irganox 1076, available from BASF Japan, Ltd.)

245: ethylenebis(oxyethylene)bis[3-(5-tert-butyl-4-hydroxy-m-tolyl)propionate] (Irganox 245, available from BASF Japan, Ltd.)

1010: pentaerythritol tetrakis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate] (Irganox 1010, available from BASF Japan, Ltd.)

A080: 3,9-bis[2-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propionyloxy]-1,1-dimethylethyl]-2,4,8,10-tetraoxaspiro[5,5]undecane (A0-80, available from ADEKA Corporation)

MBX-8: acryl-based cross-linked particles (mean particle size of 8 μm , MBX-8, available from Sekisui Kasei Co., Ltd.)

SBX-8: polystyrene-based cross-linked particles (mean particle size of 8 μm , SBX-8, available from Sekisui Kasei Co., Ltd.)

KMP-590: silicone-based cross-linked particles (mean particle size of 2 μm , KMP-590, available from Shin-Etsu Chemical Co., Ltd.)

CLAIMS

1. A light diffusion plate, comprising a styrene-based resin composition, wherein:

the styrene-based resin composition comprises a styrene-based resin (A), an antioxidant (B), and a light diffuser (C);

the antioxidant (B) includes at least one selected from phosphorus antioxidant (B-1), phenol antioxidant (B-2), and phosphorus/phenol antioxidant (B-3);

the phosphorus antioxidant (B-1) and the phosphorus/phenol antioxidant (B-3) in total are contained by 0.001 to 0.5 parts by mass with respect to 100 parts by mass of the styrene-based resin;

the phenol antioxidant (B-2) and the phosphorus/phenol antioxidant (B-3) in total are contained by 0.001 to 0.5 parts by mass with respect to 100 parts by mass of the styrene-based resin;

the light diffuser (C) is contained by 0.1 to 10 parts by mass with respect to 100 parts by mass of the styrene-based resin; and

t-butyl catechol is contained by 0.1 to 10 $\mu\text{g/g}$ in the styrene-based resin composition.

2. The light diffusion plate of Claim 1, wherein the phosphorus antioxidant (B-1) is at least one selected from:

2,2'-methylenebis(4,6-di-tert-butyl-1-phenyloxy) (2 - ethylhexyloxy)phosphorus,
tris(2,4-di-tert-butylphenyl)phosphite,
3,9-bis(2,6-di-tert-butyl-4-methylphenoxy)-2,4,8,10-tetraoxa-3,9-diphoshaspiro[5,5]undecane,
tetrakis(2,4-di-tert-butylphenyl) [1,1-biphenyl]-4,4'-diylbisphosphonite, and
bis(2,4-di-tert-butyl-6-methylphenyl)ethyl phosphite.

3. The light diffusion plate of Claim 1 or 2, wherein the phenol antioxidant (B-2) is at least one selected from:

6-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propoxy]-2,4,8,10-tetra-tert-butyl-dibenzo[d,f][1,3,2]dioxaphosphine,
octadecyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate,
ethylenebis(oxyethylene)bis[3-(5-tert-butyl-4-hydroxy-m-tolyl)propionate],

pentaerythritol tetrakis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate], and

3,9-bis[2-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propionyloxy]-1,1-dimethylethyl]-2,4,8,10-tetraoxaspiro[5,5]undecane.

4. The light diffusion plate of any one of Claims 1 to 3, wherein the phosphorus/phenol antioxidant (B-3) is 6-[3-(3-tert-butyl-4-hydroxy-5-methylphenyl)propoxy]-2,4,8,10-tetra-tert-butylldibenzo[d,f][1,3,2]dioxaphosphepine.

5. The light diffusion plate of any one of Claims 1 to 4, wherein the light diffuser (C) is at least one selected from cross-linked acryl-based polymer particles, cross-linked styrene-based polymer particles, and cross-linked siloxane-based polymer particles.

6. The light diffusion plate of any one of Claims 1 to 5, wherein the styrene-based resin (A) has a weight average molecular weight (Mw) of 200,000 to 400,000, and a ratio of the weight average molecular weight (Mw) and number average molecular weight (Mn) (Mw/Mn) is 1.0 to 3.0.

7. The light diffusion plate of any one of Claims 1 to 6 used for LED light source.

8. A direct surface light source unit comprising the light diffusion plate of any one of Claims 1 to 7.