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SPECIFICATION

Scope of the invention

The invention relates to uniformly illuminated light conducting plates which are illuminated from the side, made up of a matrix plastic A having a high, non-wavelength-selective transmission, preferably in the range of visible light, and transparent particles incorporated therein consisting of a cross-linked polymer B having a refractive index $n_p(B)$, which is at least 0.02 units higher than the refractive index $n_p(A)$ of polymer A.

Prior art

There are numerous methods known in the art for obtaining uniformly illuminated light conducting plates. EP-A 533 301, for example, describes disc-shaped light distribution bodies consisting of non-scattering and transparent material, in which the radiant surface and/or the surface opposite it has over its entire surface or part of its surface an at least partially reflective coating, lamination, texturing or structure which interrupts the total reflection in order to improve the distribution of light in the light distribution body.

EP-PS 371 073 relates to an apparatus consisting of a light conducting plate in which light, emanating from a light source, is guided by means of components parallel to the large surfaces of the plate and emerges from elevated portions on a surface of the plate, characterised in that the smooth surface of the plate is covered with a continuous, transparent intermediate

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layer which is provided with the elevated portions on one of its sides, these elevated portions being arranged close to one another and ranging from 1 to 500 μm in height and width.

German Utility Model 93 00 991 describes plate-shaped light conducting plates the light-receiving area of which is formed by a circumferential area extending perpendicularly to the plane of the plate and the surface of which is provided, at at least one point, with recesses and/or texturing and/or applied elements the surfaces of which, facing the surroundings, form the light-emitting area, whilst all the other areas of material are constructed to conduct light.

German Utility Model 89 13 036 refers to light conducting plates in which light from a light source is channelled in over a smooth edge surface, this light flowing invisibly through the light conducting plate and becoming visible by light refraction in the region of rough decorative surfaces of the light conducting plate, characterised in that the smooth edge surface which channels the light in is constructed as an edge recess extending into the light conducting plate and the light from the light source is directed on to the ingoing edge surface of the edge recess.

Apart from these methods of illuminating light conducting plates which concentrate on manipulating the surfaces of the light conducting plates, the prior art also provides other possible ways of preparing illuminated light conducting plates, for example by incorporating scatter particles in the light conducting plate matrix.

Thus, for example, EP-A 269 324 describes a special composition which is suitable for incorporation in thermoplastic polymers and contains core-shell polymer particles with diameters of between 2 and 15 μm . The



core of the core-shell polymer consists of cross-linked alkylacrylate polymer and has a refractive index which deviates by a maximum of 0.2 units from that of the matrix polymer. The shell of the core-shell polymer is compatible with the matrix polymer, is not cross-linked and makes up 5 to 40% by weight of the weight of the particles. EP-A 342 283 also describes particles having diameters of between 2 and 15 μm in light-scattering thermoplastic polymer compositions, the proportion of particles being 0.1 to 10% by weight, based on the polymer compositions, whilst core-shell polymer particles according to EP-A 269 324 are excluded by a disclaimer.

EP-A 497 502 describes multi-layer light conducting plates which comprise a translucent plate having a light transmittance of more than 80%, the translucent plate comprising proportions of 0.1 to 40% by weight, based on the thermoplastic matrix polymer of the plate, of polymer particles having particle diameters of between 2 and 15 μm . The light source the light from which is scattered diffusely, is mounted behind the main surface of the light conducting plates.

Objective and solution

If the scatter particles described in EP-A 342 283 or EP-A 259 324 are used in edge-illuminated light conducting elements, it is impossible to obtain uniform illumination of the light conducting element owing to the high scattering effect of the particles. According to EP-A 342 283 (Example 9), even 2.5% by weight of polymers substantially reduce the light transmittance of PMMA and result in considerable clouding. In contrast to this, the endeavour here is to prepare light conducting elements which on the one hand can be illuminated from the side and on the other hand do not

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require any expensive surface structuring.

Surprisingly, it has been found that the resulting objective of preparing edge-illuminated light conducting elements with uniform illumination can be achieved by incorporating scatter particles of a specific configuration in the light conducting matrix.

The scatter particles, consisting of a cross-linked polymer B, are present in amounts of 0.01 to 1% by weight, preferably 0.02 to 0.5% by weight, more preferably 0.05 to 0.2% by weight, based on the matrix plastic A in the light conducting element, and have refractive indices $n_D(B)$ which are at least 0.01 and preferably at least 0.02 units above the refractive indices $n_D(A)$ of the matrix plastic A. The cross-linked polymer B is incompatible with the matrix plastic A, the scatter particles consisting of polymer B in the matrix plastic A forming distinct phase interfaces on the surface of the scatter particles. Generally, the cross-linked polymer B is made up of:

- b1) 0 to 60 parts by weight of an acrylic and/or methacrylic acid ester having 1 to 12 carbon atoms in the aliphatic ester group,
- b2) 25 to 99 parts by weight of comonomers which contain aromatic groups as substituents and which are copolymerisable with the monomers b1), and
- b3) 1 to 15 parts by weight of cross-linking comonomers which contain at least two ethylenically unsaturated groups which are radically copolymerisable with b1) and b2),

the sum of the groups b1), b2) and b3) constituting 100 parts by weight.

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The matrix plastic A is a highly transparent polymer having a spectral decade absorption level according to DIN 1349 of not more than 0.035, wherein the matrix plastic A may be a thermoplastic plastics or preferably a cured casting resin. It is particularly preferable for the matrix plastic A to contain at least 50% by weight (based on A) of methacrylic acid ester units; it is most particularly preferred for A to contain at least 50% by weight of methyl methacrylate.

Performing the invention

The matrix plastic A

The essential condition for the matrix plastic A, which consists of a highly transparent polymer, is that the polymer must have a spectral decade absorption level according to DIN 1349 of not more than 0.035.

Preferably, matrix plastic A are used which contain at least 50% by weight of methacrylic acid ester units, based on A. Most preferably, the matrix plastic A contain at least 50% by weight of methylmethacrylate units. Comonomers for the methacrylic acid esters may consist of ethylenically unsaturated monomers which are radically copolymerisable therewith, such as esters of acrylic acid, acrylo- or methacrylonitrile, vinyl esters of carboxylic acids, such as vinyl acetate, amides of acrylic or methacrylic acid and olefins.

The preparation of thermoplastic matrix plastic A is known. Thus, the preparation of the preferred polymethacrylate plastic A as thermoplastic moulding compositions has been described in detail in the literature (cf. for example Vieweg, Esser, Plastics Handbook, Volume IX, Polymethacrylates, pages 22 to 42, published by Carl Hanser, Munich, 1975). The scatter particles from the cross-linked polymer B are introduced

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into the thermoplastic matrix plastic A by means of known thermoplastic mixing techniques, such as melt mixing in an extruder or in a mixing kneader, the scatter particles being distributed as homogeneously as possible after the mixing process.

Preferably, the matrix plastic A consist of cured casting resins, most preferably cured polymethacrylate casting resins, the preparation of which is described, for example, in Vieweg-Esser, Plastics Handbook, Volume IX, Polymethacrylates, pages 15 to 21 and 43 to 56, published by Carl Hanser, Munich, 1975. Preferably, the casting moulds are selected so that their form and dimensions correspond to the desired shape of the light conducting elements, the most suitable moulds consisting of plates and round bars. One method of producing light conducting elements from casting resins A with scatter particles of polymer B incorporated therein may run as follows, for example: a preliminary solution of 80 to 100 parts by weight of methacrylate monomers and 0 to 20 parts by weight of polymethacrylate prepolymer is homogeneously mixed with 0 to 1 parts by weight, optionally 0.05 to 0.3 parts by weight, of a cross-linking monomer having at least two ethylenically unsaturated, radically polymerisable groups, as well as 0.01 to 1 part by weight of scatter particles consisting of polymer B. Conventional polymerisation initiators are added to this preliminary solution, the mixture is poured into a polymerisation chamber and polymerised preferably in a water bath and/or in an air chamber.

The scatter particles consisting of polymer B

The cross-linked polymer B which constitutes the scatter particles has a refractive index $n_D(B)$ which is 0.01, preferably 0.02 units above the refractive index $n_D(A)$ of the matrix plastic A. The proportion of scatter

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particles in the light conducting elements is from 0.01 to 1% by weight, based on the matrix plastic A, preferably 0.02 to 0.5% by weight, most preferably 0.05 to 0.2% by weight. Generally, the cross-linked polymer B is made up of:

- b1) 0 to 60 parts by weight of an acrylic and/or methacrylic acid ester having 1 to 12 carbon atoms in the aliphatic ester group, examples of these being: methyl(meth)acrylate, ethyl(meth)acrylate, n-propyl(meth)acrylate, i-propyl(meth)acrylate, n-butyl(meth)acrylate, i-butyl(meth)acrylate, tert.-butyl(meth)acrylate, cyclohexyl(meth)acrylate, 3,3,5-trimethylcyclohexyl(meth)acrylate, 2-ethylhexyl(meth)acrylate, norbornyl(meth)acrylate or isobornyl(meth)acrylate;
- b2) 25 to 99 parts by weight of comonomers which contain aromatic groups as substituents and which are copolymerisable with the monomers b1), such as for example styrene, α -methylstyrene, ring-substituted styrenes, phenyl(meth)acrylate, benzyl(meth)acrylate, 2-phenylethyl(meth)acrylate, 3-phenylpropyl(meth)acrylate or vinylbenzoate; and
- b3) 1 to 15 parts by weight of cross-linking comonomers which have at least two ethylenically unsaturated groups which are radically copolymerisable with b1) and b2), such as for example divinylbenzene, glycoldi(meth)acrylate, 1,4-butandioldi(meth)-acrylate, allyl(meth)acrylate, triallylcyanurate, diallylphthalate, diallylsuccinate, pentaerythritol-tetra(meth)acrylate or trimethylolpropanetri(meth)acrylate,

the comonomers b1), b2) and b3) adding up to 100 parts by weight.

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The average particle diameter of the scatter particles made up of the cross-linked polymer B is between 2 and 20 μm , preferably between 3 and 10 μm , at least 80% by weight of the scatter particles, based on all the scatter particles, having a maximum deviation in particle diameter from the average particle diameter of $\pm 20\%$.

Preferably, the scatter particles are produced by emulsion polymerisation as described, for example, in EP-A 342 283 or EP-A 269 324, most preferably by polymerisation in the organic phase, as described for example in German Patent Application P 43 27 464.1; in the latter polymerisation technique, particularly narrow distributions of particle size or, in other words, particularly small deviations in particle diameter from the average particle diameter are obtained.

Polymer B which constitutes the scatter particles is incompatible with the matrix plastic A, irrespective of the degree of cross-linking, the scatter particles incorporated in the plastics matrix A forming clearly marked phase interfaces at which the light is scattered with minimum losses. Preferably, this marking of the phase interfaces is achieved by having proportions of cross-linking monomers b3) in the polymer B of more than 2 parts by weight, more preferably more than 4 parts by weight, based on the monomers used.

The light conducting elements

The light conducting elements consist of the matrix plastic A and the homogeneously distributed scatter particles of polymer B incorporated therein. The light conducting elements are illuminated at their edge surfaces. The edge-illuminated light conducting element, which may be in the form of a plate or round

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bar, for example, emits the light in a plane at right angles to the edge where the lighting source is mounted. The illumination of the surfaces of the light conducting elements according to the invention is highly uniform, whilst as a result of the clearly marked phase interfaces of the scatter particles, caused by the incompatibility between polymers A and B, there is very little loss in intensity of the light irradiated in. Moreover, because of the special construction of the scatter particles, there are no spectral intensity losses in the light scattering such as often occur with scatter particles of the prior art, caused by light-absorbent properties of the scatter particles at specific wavelengths or, more particularly, by indistinct phase interfaces between the scatter particles and the matrix plastics.

The light conducting elements according to the invention are illuminated from the edge by means of light sources which are preferably integrated in frame elements which enclose the light conducting elements. If the light conducting elements are plate-shaped in geometry, the light source is preferably a tubular lighting member, whereas in the case of light conducting elements in the shape of round bars the light source is preferably in point form. The light sources used are conventional lighting members such as incandescent lamps or fluorescent tubes.

In another preferred embodiment of the invention the unilluminated edges of the light conducting elements are covered with thin coatings which reflect the scattered light arriving at the edge back into the light conducting element. Such reflective coatings may, for example, be applied by means of adhesive foil with a directional reflecting effect or a scattered reflecting effect or by painting on formulations containing

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reflective pigments.

Other preferred plate-shaped light conducting elements comprise a disc with a diffuse scattering effect which is mounted behind the light conducting element in plan view, this disc uniformly reflecting the light which radiates backwards in the direction of observation and thereby increases the intensity of light irradiated forwards without affecting the uniform illumination of the surfaces.

One particularly preferred embodiment using the light conducting elements according to the invention comprises a reflector provided behind the light conducting plate described above and a light-scattering information carrier plate which in turn has a low light transmittance and at the same time high reflection on the surface facing the light conducting plate.

Moreover, the light conducting plate may be provided with the above-mentioned information carrier plates on both sides.

The following Examples are intended to illustrate the invention:

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EXAMPLES

Example 1

Preparation of the scatter particles from polymer B

136.5 g of Cyclohexane

34.5 g of Methylmethacrylate

25.1 g of Benzylmethacrylate

3.1 g of Allylmethacrylate

0.8 g of Styrene-isopren block copolymer
(Shellvis® 50), hydrogenated,

are placed in a 500 ml reactor fitted with condenser, nitrogen inlet, temperature sensor, thermostat and stirrer.

Polymerisation is started by the addition of a solution of 0.63 g of bis(4-tert.-butylcyclohexyl)-peroxodicarbonate and 0.06 g of t-butyl-per-2-ethylhexanoate in 6.2 g of cyclohexane. After 75 minutes the internal temperature is increased to 75°C and the mixture is stirred for 2 hours at this temperature. For further reaction, 0.06 g of t-butyl-perneodecanoate in 0.54 g of cyclohexane are added, the mixture is stirred for another hour at 75°C and then cooled. A coagulate-free dispersion is obtained. The dispersion contains < 2% by weight of very fine particles; more than 98% by weight of the particles have a diameter of 7 μm , these particles having a rough surface. The particles are filtered off and dried in vacuo.

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Example 2

Production of a light conducting plate containing scatter particles of polymer B according to Example 1

In order to produce a light conducting plate, 1 part by weight of scatter particles according to Example 1 is mixed with 30 parts by weight of methylmethacrylate in a high speed intensive stirrer using the rotor-stator principle and then added to a mixture of 968 parts by weight of polymethylmethacrylate prepolymer having a viscosity of 1000 mPa s (rotation viscometer according to DIN 53019) and 1 part by weight of 2,2'-azobis-(2,4-dimethylvaleronitrile). The mixture is stirred thoroughly, poured into a polymerisation chamber consisting of silicate glass held at a spacing of 8 mm, and polymerised in a water bath at 25°C for 30 hours. To complete the polymerisation, polymerisation is continued in a temperature-controlled chamber for 12 hours at 120°C. After cooling and removal from the mould, a colourless, slightly cloudy light conducting plate is obtained.

Example 3

Properties of the edge-illuminated light conducting plate

A light conducting plate measuring 500 x 500 x 8 mm, produced according to Example 2, is illuminated from one edge with a fluorescent tube 200 mm long, 7 mm in cross-section and with a power of 11 Watts. The ratio of the maximum lighting density MALD of the light emitted at right angles to the plate surface, determined at a spacing of 50 mm from the fluorescent tube, to the minimum light density MILD, determined at a distance of 450 mm from the fluorescent tube, is $MALD:MILD \leq 2 : 1$.

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PATENT CLAIMS

1. Edge-illuminated light conducting elements, consisting of a matrix plastic A and scatter particles of a polymer B homogeneously distributed therein, characterised in that the matrix plastic A is incompatible with the polymer B, the matrix plastic A has a spectral decade absorption level according to DIN 1349 of not more than 0.035, the proportion of scatter particles consisting of polymer B is 0.01 to 1% by weight, based on the matrix plastic A, the refractive index $n_D(B)$ of polymer B is at least 0.01 units above the refractive index $n_D(A)$ of the matrix plastic A, and polymer B is made of:

- (b1) 0 to 60 parts by weight of an acrylic and/or methacrylic acid ester having 1 to 12 carbon atoms in the aliphatic ester group,
- (b2) 25 to 99 parts by weight of comonomers which contain aromatic groups as substituents and which are copolymerisable with the monomers b1), and
- (b3) 1 to 15 parts by weight of cross-linking comonomers which contain at least two ethylenically unsaturated groups which are radically copolymerisable with b1) and b2),

the sum of the groups b1), b2) and b3) constituting 100 parts by weight.

2. Edge illuminated light conducting elements according to claim 1, characterised in that the matrix plastic A is made up of at least 50% by weight of methacrylic acid ester units.

3. Edge illuminated light conducting elements



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according to claims 1 and 2, characterised in that the refractive index $n_D(B)$ of polymer B is 0.02 units above the refractive index $n_D(A)$ of matrix plastic A.

4. Edge illuminated light conducting elements according to claims 1 to 3, characterised in that the proportion of scatter particles of polymer B is 0.02 to 0.5% by weight, based on the matrix plastic A.

5. Edge illuminated light conducting elements according to claims 1 to 4, characterised in that the matrix plastic A is a cured casting resin.

6. Edge illuminated light conducting elements according to claims 1 to 5, characterised in that the light conducting elements are illuminated from a specific edge.

7. Edge illuminated light conducting elements according to claims 1 to 6, characterised in that the unilluminated edges of the light conducting elements are covered with reflective coatings which reflect the light leaving the edges back into the light conducting elements.

8. Edge illuminated light conducting elements according to claims 1 to 7, characterised in that the light conducting elements are plate-shaped.

9. Edge illuminated light conducting elements according to claim 8, characterised in that, behind the plate-shaped light conducting element, there is a disc with a diffuse scattering action which reflects the light irradiated backwards back into the light conducting element.

10. Edge illuminated light conducting elements



according to claims 8 and 9, characterised in that the plate-shaped light conducting elements are enclosed by frame elements in which the lighting elements are integrated.

11. Edge illuminated light conducting elements according to claims 8 to 10, characterised in that a light scattering information carrier is mounted in front of the light conducting plate.

12. Edge illuminated light conducting elements according to claim 8, characterised in that a light scattering information carrier is mounted in front of and behind the light conducting plate.

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