

Molding compounds for the production of solar cell modules

The present invention relates to moulding compositions, to the use of the moulding compositions for the production of solar-cell modules, and also to the corresponding solar-cell modules.

PRIOR ART

A solar cell or photovoltaic cell is an electrical module which converts the radiant energy in light, in particular that in sunlight, directly into electrical energy. The physical basis of this conversion is the photovoltaic effect, which is a specific instance of the internal photoelectric effect.

Figure 3 is a cross-sectional diagram showing the fundamental structure of a solar-cell module. 501 in Figure 3 indicates a photovoltaic element, 502 indicates a fixing means, 503 indicates a pane, and 504 indicates a rear wall. Radiation from sunlight impacts the light-sensitive surface of the photovoltaic element 501 by passing through the pane 503 and the fixing means 502, and is converted into electrical energy. Output terminals (not shown) serve for output of the resultant electricity.

The photovoltaic element cannot withstand extreme outdoor conditions, because it readily corrodes and is very fragile. It therefore has to be covered and protected by a suitable material. In most instances, this is achieved by using a suitable fixing means to insert and laminate the photovoltaic element between a transparent weathering-resistant pane, e.g. a pane of glass, and a rear wall which has excellent moisture resistance and high electrical resistance.

Materials often used as fixing means for solar cells are polyvinyl butyral and ethylene-vinyl acetate copolymers (EVA). In particular, crosslinkable EVA compositions exhibit excellent properties here, examples being good heat resistance, high weathering resistance, high transparency and good cost-efficiency.

The solar-cell module is intended to have high stability because it is intended for

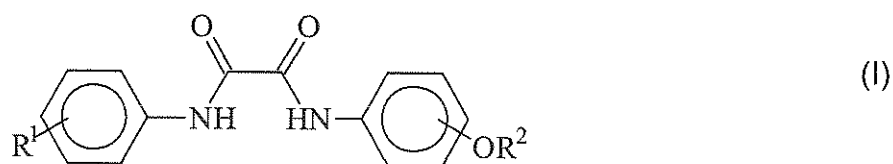
long-term outdoor use. Accordingly, the fixing means must inter alia have excellent weathering resistance and high heat resistance. However, a phenomenon frequently observed when the module is in long-term outdoor use, for example for a period of ten years, is light-induced and/or heat-induced degradation of the fixing means, leading to yellowing of the fixing means and/or peeling from the photovoltaic element. The yellowing of the fixing means leads to a reduction in the utilizable proportion of the incident light, with a consequent reduction in electrical power level. Secondly, peeling from the photovoltaic element allows penetration of moisture, and this can lead to corrosion of the photovoltaic element itself or of metallic parts in the solar-cell module, and likewise reduces the power obtained from the solar-cell module.

Although the EVAs usually used are good fixing means per se, they are gradually degraded by hydrolysis and/or pyrolysis. Over the course of time, acetic acid is liberated by the action of heat or moisture. This leads to yellowing of the fixing means, to a reduction in mechanical strength and to a reduction in the adhesion of the fixing means. Furthermore, the acetic acid liberated acts as catalyst and further accelerates degradation. A further problem arising is that the acetic acid corrodes the photovoltaic element and/or other metal parts in the solar-cell module.

To solve the said problems, European Patent Application EP 1 065 731 A2 proposes the use of a solar-cell module which encompasses a photovoltaic element and a polymeric fixing means, where the polymeric fixing means is intended to comprise an ethylene-acrylate-acrylic acid terpolymer, an ethylene-acrylate-maleic anhydride terpolymer, an ethylene-methacrylate-acrylate terpolymer, an ethylene-acrylate-methacrylic acid terpolymer, an ethylene-methacrylate-methacrylic acid terpolymer and/or an ethylene-methacrylate-maleic anhydride terpolymer. However, solar-cell modules of this type have restricted weathering resistance and also restricted effectiveness.

The prior art also discloses improvement of the weathering resistance of acrylic moulding compositions by use of suitable UV absorbers.

DE 103 11 641 A1 , for example, describes tanning aids which encompass a polymethyl methacrylate moulding which comprises from 0.005% by weight to 0.1% by weight of a UV stabilizer according to formula (I)



in which the moieties R^1 and R^2 are independently an alkyl or cycloalkyl moiety having from 1 to 20 carbon atoms.

However, the publication reveals nothing about the use of the moulding compositions for the production of solar-cell modules.

DE 38 38 480 A1 discloses methyl methacrylate polymers and methyl methacrylate copolymers, both of which comprise

- a) an oxanilide or 2,2,6,6-tetramethylpiperidine compound as stabilizer for protection from damage caused by light, and
- b) a flame-retardant organophosphorus compound.

However, the publication reveals nothing about the use of the composition for the production of solar-cell modules.

JP 2005-298748 A provides mouldings composed of a methacrylic resin, and these preferably comprise 100 parts by weight of methacrylic resin, encompassing from 60 to 100% by weight of methyl methacrylate units and from 0 to 40% by weight of other copolymerizable vinyl monomer units, and from 0.005-0.15% by weight of 2-(2-hydroxy-4-n-octyloxyphenyl)-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine and/or 2-hydroxy-4-octyloxybenzophenone. The mouldings are intended to have a significant barrier for UV radiation and to have transparency of at most 20% at 340 nm and transparency of at least 70% at 380 nm, measured on mouldings of thickness in the range from 0.5 to 5 mm.

The mouldings are in particular intended to be used as covers for lighting systems. However, the publication reveals nothing about the use of the moulding compositions for the production of solar-cell modules.

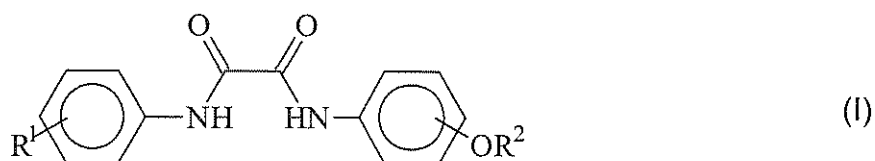
BRIEF DESCRIPTION OF THE INVENTION

It is therefore an object of the present invention to provide possibilities for mitigating the reduction in power from a solar cell during long-term outdoor use, in particular at high temperature and/or high humidity. The intention was in particular to provide, for this purpose, a fixing means which can be used for a solar-cell module and which exhibits excellent weathering resistance, maximum heat resistance and maximum permeability to light, and also minimum water absorption. Other desirable features are minimum liberation of substances that promote corrosion, in particular of acids, and maximum adhesion to the various substrate elements of a solar-cell module.

Provision of a moulding composition with all of the properties of the present Patent Claim 1 achieves the said objects, and also achieves other objects which although not specifically mentioned are obvious from the circumstances discussed in the introduction. The dependent claims that refer back to Claim 1 describe particularly advantageous embodiments of the moulding composition. Protection is also provided for the use of the moulding composition for the production of solar-cell modules, and also for the corresponding solar-cell modules.

Provision of a moulding composition which encompasses

- a) at least one polyalkyl (meth)acrylate and
- b) at least one compound according to formula (I)



in which the moieties R^1 and R^2 are independently an alkyl or cycloalkyl moiety having from 1 to 20 carbon atoms,

where the moulding composition further comprises

- c) at least one infrared absorber,

where the transmittance of the moulding composition

- at 500 nm is smaller than 89%,
- at 1000 nm is smaller than 80%,
- at 1150 nm is smaller than 70% and

- at 1600 nm is smaller than 77%, in each case measured by means of infrared spectroscopy at 25°C on 3 mm plaques

is a successful, but not readily foreseeable, method of optimizing mitigation of any reduction in the power from a solar cell during long-term outdoor use, in particular at high temperature and/or high humidity. In particular, a fixing means is provided which can be used for a solar-cell module and which exhibits excellent weathering resistance, very high heat resistance and very high permeability to light, and also very low water absorption. Furthermore, even long-term outdoor use results in no liberation of substances that promote corrosion, while the adhesion achieved of the fixing means to the various substrate elements of a solar-cell module is very good.

The moulding composition presented here permits efficient utilization of "useful" light in the visible wavelength range. At the same time, other wavelength ranges, in particular in the UV region, which cannot be utilized to generate electricity, are effectively absorbed. The said absorption increases the weathering resistance of the solar-cell modules. The absorption moreover inhibits disadvantageous heating of the light collectors, without a need to use cooling elements for the said purposes, and the lifetime of the solar-cell modules is prolonged, and their total output and their effectiveness is increased.

The procedure according to the invention in particular gives the following advantages:

Access is provided to a solar-cell module with excellent weathering resistance, heat resistance and moisture resistance. Since the adhesion of the fixing means is improved, no peeling occurs, even when the module is exposed to outdoor conditions for a long period. Weathering resistance is moreover improved, since the protective material does not decompose to liberate acid at high temperatures and high humidity. Since there is no corrosion of the photovoltaic element caused by acid, a long-lasting stable power level is maintained by the solar cell over a long period.

The fixing means used moreover comprises one whose weathering resistance, heat resistance and moisture resistance are excellent, and which has excellent permeability to light, and which permits the production of very good solar-cell modules.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional diagram of a preferred solar-cell module according to the present invention.

Figures 2a and 2b are cross-sectional diagrams showing the fundamental structure of a photovoltaic element preferably used in the solar-cell module according to Figure 1, and, respectively, a plan view of the light-sensitive area of the photovoltaic element.

Figure 3 is a cross-sectional diagram of a conventional solar cell.

Key

Figure 1

101	Photovoltaic element
102	Fixing means
103	Pane
104	Fixing means
105	Rear wall

Figure 2a

201	Conductive substrate
202	Reflective layer
203	Photoactive semiconductor layer
204	Transparent conductive layer
205	Collector electrode
206a	Crocodile clip
206b	Crocodile clip
207	Conductive, adhesive paste
208	Conductive paste or tin solder

Figure 2b

201	Conductive substrate
202	Reflective layer
203	Photoactive semiconductor layer
204	Transparent conductive layer
205	Collector electrode
206a	Crocodile clip
206b	Crocodile clip
207	Conductive, adhesive pastes

Figure 3

501	Photovoltaic element
502	Fixing means
503	Pane
504	Rear wall

DETAILED DESCRIPTION OF THE INVENTION

The moulding composition according to the invention comprises at least one polyalkyl (meth)acrylate, which can be used alone or else in a mixture of a plurality of different polyalkyl (meth)acrylates. The polyalkyl (meth)acrylate can moreover also take the form of a copolymer.

For the purposes of the present invention, particular preference is given to homo- and copolymers of C_1 - C_{18} -alkyl (meth)acrylates, advantageously of C_1 - C_{10} -alkyl (meth)acrylates, in particular of C_1 - C_4 -alkyl (meth)acrylates, and these can, if appropriate, also comprise monomer units which differ therefrom.

The term (meth)acrylate here means not only methacrylate, e.g. methyl methacrylate, ethyl methacrylate, etc., but also acrylate, e.g. methyl acrylate, ethyl acrylate, etc., and also mixtures composed of these two monomers.

It has proven particularly successful to use copolymers which contain from 70% by weight to 99% by weight, in particular from 70% to 90% by weight, of C_1 - C_{10} -alkyl (meth)acrylates. Preferred C_1 - C_{10} -alkyl methacrylates encompass methyl methacrylate, ethyl methacrylate, propyl methacrylate, isopropyl methacrylate, n-butyl methacrylate, isobutyl methacrylate, tert-butyl methacrylate, pentyl methacrylate, hexyl methacrylate, heptyl methacrylate, octyl methacrylate, isooctyl methacrylate, and ethylhexyl methacrylate, nonyl methacrylate, decyl methacrylate, and also cycloalkyl methacrylates, for example cyclohexyl methacrylate, isobornyl methacrylate or ethylcyclohexyl methacrylate. Preferred C_1 - C_{10} -alkylacrylates encompass methyl acrylate, ethyl acrylate, propyl acrylate, isopropyl acrylate, n-butyl acrylate, isobutyl acrylate, tert-butyl acrylate, pentyl acrylate, hexyl acrylate, heptyl acrylate, octyl acrylate, isooctyl acrylate, nonyl acrylate, decyl acrylate, and ethylhexyl acrylate, and also cycloalkyl acrylates, for example cyclohexyl acrylate, isobornyl acrylate or ethylcyclohexyl acrylate.

Very particularly preferred copolymers encompass from 80% by weight to 99% by weight of methyl methacrylate (MMA) units and from 1% by weight to 20% by weight, preferably from 1% by weight to 5% by weight, of C_1 - C_{10} -alkyl acrylate units, in particular methyl acrylate units, ethyl acrylate units and/or butyl acrylate units. In this

context, it has proven particularly successful to use PLEXIGLAS® 7N polymethyl methacrylate, obtainable from Röhm GmbH.

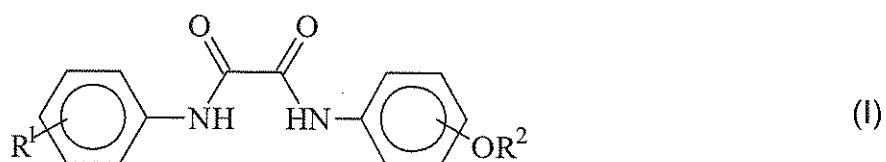
The polyalkyl (meth)acrylate can be produced by polymerization processes known per se, and particular preference is given here to free-radical polymerization processes, in particular bulk polymerization, solution polymerization, suspension polymerization and emulsion polymerization processes. Initiators particularly suitable for these purposes encompass in particular azo compounds, such as 2,2'-azobis(isobutyronitrile) or 2,2'-azobis(2,4-dimethylvaleronitrile), redox systems, e.g. the combination of tertiary amines with peroxides or sodium disulphite and persulphates of potassium, sodium or ammonium, or preferably peroxides (in which connection cf. for example H. Rauch-Puntigam, Th. Völker, "Acryl- und Methacrylverbindungen" [Acrylic and methacrylic compounds], Springer, Heidelberg, 1967, or Kirk-Othmer, Encyclopedia of Chemical Technology, Vol. 1, pages 386ff, J. Wiley, New York, 1978). Examples of particularly suitable peroxide polymerization initiators are dilauroyl peroxide, tert-butyl peroctoate, tert-butyl perisononanoate, dicyclohexyl peroxodicarbonate, dibenzoyl peroxide and 2,2-bis(tert-butylperoxy)butane. It is also possible and preferred to carry out the polymerization reaction using a mixture of various polymerization initiators of different half-lifetime, examples being dilauroyl peroxide and 2,2-bis(tert-butylperoxy)butane, in order to maintain a constant stream of free radicals during the course of the polymerization reaction, and also at various polymerization temperatures. The amounts used of polymerization initiator are generally from 0.01% by weight to 2% by weight, based on the monomer mixture.

The polymerization reaction can be carried out continuously or else batchwise. After the polymerization reaction, the polymer is obtained by way of conventional steps of isolation and separation, e.g. filtration, coagulation and spray drying.

The chain lengths of the polymers or copolymers can be adjusted by polymerizing the monomer or monomer mixture in the presence of molecular-weight regulators, a particular example being the mercaptans known for this purpose, e.g. n-butyl mercaptan, n-dodecyl mercaptan, 2-mercaptoethanol or 2-ethylhexyl thioglycolate, pentaerythritol tetrathioglycolate; the amounts used of the molecular-weight regulators generally being from 0.05% by weight to 5% by weight, preferably from 0.1

to 2% by weight and particularly preferably from 0.2% by weight to 1% by weight, based on the monomer or monomer mixture (cf., for example, H. Rauch-Puntigam, Th. Völker, "Acryl- und Methacrylverbindungen" [Acrylic and methacrylic compounds], Springer, Heidelberg, 1967; Houben-Weyl, Methoden der organischen Chemie [Methods of organic chemistry], Vol. XIV/1, page 66, Georg Thieme, Heidelberg, 1961, or Kirk-Othmer, Encyclopedia of Chemical Technology, Vol. 1, pages 296ff, J. Wiley, New York, 1978). n-Dodecyl mercaptan is particularly preferably used as molecular-weight regulator.

For the purposes of the present invention, the moulding composition comprises at least one compound according to formula (I)

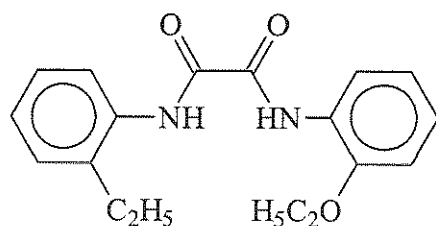


in which the moieties R^1 and R^2 are independently an alkyl or a cycloalkyl moiety having from 1 to 20 carbon atoms, particularly preferably having from 1 to 8 carbon atoms. The aliphatic moieties are preferably linear or branched, and can have substituents, examples being halogen atoms.

Among the preferred alkyl groups are the methyl, ethyl, propyl, isopropyl, 1-butyl, 2-butyl, 2-methylpropyl, tert-butyl, pentyl, 2-methylbutyl, 1,1-dimethylpropyl, hexyl, heptyl, octyl, 1,1,3,3-tetramethylbutyl, nonyl, 1-decyl, 2-decyl, undecyl, dodecyl, pentadecyl, and eicosyl groups.

Among the preferred cycloalkyl groups are the cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, and cyclooctyl group, which can optionally have substitution by branched or unbranched alkyl groups.

It is particularly preferable to use the compound of the formula (II)



(II).

This compound is available commercially from Clariant with trade mark [®]Sanduvor VSU and from Ciba Geigy with trade mark [®]Tinuvin 312.

A particular feature of the moulding composition according to the invention is that its transmittance

- at 500 nm is smaller than 89%, in particular in the range from 80% to smaller than 89%,
- at 1000 nm is smaller than 80%, in particular in the range from 75% to smaller than 80%,
- at 1150 nm is smaller than 70%, in particular in the range from 55% to smaller than 70%, and
- at 1600 nm is smaller than 77%, in each case measured by means of infrared spectroscopy at 25°C on plaques of thickness 3 mm.

The infrared spectroscopy here can be carried out in a manner known per se. However, particular preference is given to a procedure in which the transmittance spectrum is measured with the aid of a Lambda 19 spectrophotometer from Perkin Elmer.

In order to achieve the transparency properties, the moulding composition according to the invention encompasses at least one infrared absorber. For the purposes of the present invention, "infrared absorbers" is the term used for substances which absorb light in the infrared region, i.e. in the range from 780 nm to 1 mm.

Infrared absorbers preferred for the present purpose are those which absorb light at 500 nm, 1000 nm, 1150 nm and/or 1600 nm. These can be used alone or else in a mixture of two or more compounds which, if appropriate, have different levels of absorption of light at various wavelengths.

Particular preference is given to infrared absorbers which absorb light at 500 nm, 1000 nm, 1150 nm and at 1600 nm.

Infrared absorbers very particularly preferred for the purposes of the present invention absorb light in such a way that the ratio of the transparency of the moulding composition at 500 nm to the transparency of the moulding composition at 1150 nm is in the range 88:65 to 69, measured in each case by means of infrared spectroscopy at 25°C on plaques of thickness 3 mm.

For the purposes of the present invention, it has moreover proven very particularly advantageous to use polyalkyl (meth)acrylates whose transparency in the infrared spectrum in the range from 250 nm to 2500 nm, in each case measured by means of infrared spectroscopy at 25°C on plaques of thickness 3 mm, differs at each wavelength by at most 5%, particularly preferably by at most 2.5%, in particular by at most 1%, from the transparency in the reference spectrum given below ("polyalkyl (meth)acrylate standard"), based in each case on the transparency of the reference.

For the purposes of the present invention, it has moreover proven very particularly successful to use infrared-absorber-polyalkyl(meth)acrylate combinations whose transparency in the infrared spectrum in the range from 250 nm to 2500 nm, in each case measured by means of infrared spectroscopy at 25°C on plaques of thickness 3 mm, differs at each wavelength by at most 5%, particularly preferably by at most 2.5%, in particular by at most 1%, from the transparency in the reference spectrum given below ("polyalkyl (meth)acrylate + infrared absorber standard"), based in each case on the transparency of the reference.

Wavelength [nm]	"Polyalkyl (meth)acrylate + infrared absorber standard" Transparency [%]	"Polyalkyl (meth)acrylate standard" Transparency [%]
250	0.04	0.04
255	0.27	0.34
260	2.19	2.74
265	6.51	7.91

270	13.73	16.66
275	22.92	27.28
280	32.11	37.61
285	39.39	46.11
290	47.05	54.50
295	52.96	61.26
300	60.08	67.56
305	64.74	73.33
310	69.82	78.12
315	72.35	80.87
320	74.99	82.74
325	76.32	84.58
330	77.97	86.00
335	78.90	86.82
340	80.09	87.36
345	80.33	88.47
350	80.91	88.85
355	81.30	89.70
360	81.58	90.24
365	82.67	90.06
370	82.32	91.03
375	82.75	91.02
380	83.58	91.13
385	83.66	91.62
390	83.99	91.80
395	83.92	91.45
400	84.48	91.74
405	84.87	91.71
410	84.97	91.69
415	85.05	91.59
420	85.35	91.67
425	85.22	91.87
430	85.66	91.86
435	85.94	91.80

440	86.13	92.08
445	86.10	91.87
450	86.52	92.16
455	86.70	92.01
460	86.73	92.08
465	87.16	92.04
470	87.28	92.22
475	87.28	92.02
480	87.73	92.10
485	87.70	91.81
490	87.99	91.90
495	88.07	92.13
500	88.15	92.07
505	88.36	92.23
510	88.52	92.03
515	88.72	92.22
520	88.69	92.17
525	89.07	92.32
530	89.04	92.21
535	89.36	92.33
540	89.38	92.07
545	89.68	92.24
550	89.64	92.25
555	89.63	92.03
560	89.70	91.97
565	89.83	92.31
570	89.60	92.42
575	89.89	92.47
580	90.02	92.41
585	89.84	92.40
590	89.81	92.44
595	89.82	92.27
600	89.77	92.23
605	89.62	92.15

610	89.42	92.41
615	89.36	92.47
620	89.11	92.27
625	88.66	92.18
630	88.46	92.50
635	88.19	92.16
640	88.13	92.37
645	87.76	92.36
650	87.42	92.34
655	87.20	92.42
660	86.95	92.41
665	86.80	92.41
670	86.71	92.35
675	86.56	92.32
680	86.48	92.52
685	86.34	92.53
690	86.37	92.31
695	86.06	92.63
700	86.27	92.11
705	86.13	92.30
710	86.01	92.13
715	85.54	92.26
720	85.74	92.25
725	85.63	92.31
730	85.52	92.20
735	85.33	92.29
740	85.16	92.39
745	85.30	92.63
750	84.83	92.37
755	84.90	92.34
760	84.51	92.02
765	84.44	92.50
770	83.99	92.52
775	84.06	92.69

780	84.23	93.15
785	83.87	91.87
790	83.69	92.31
795	83.44	92.49
800	85.09	91.91
805	84.38	91.56
810	83.66	91.21
815	83.11	92.92
820	82.56	94.63
825	83.04	92.67
830	83.51	90.72
835	83.48	91.09
840	83.44	91.46
845	83.25	91.75
850	83.05	92.04
855	82.87	92.46
860	82.69	92.88
865	82.15	92.34
870	81.60	91.80
875	81.22	91.54
880	80.83	91.28
885	80.62	91.06
890	80.41	90.83
895	80.13	90.82
900	79.84	90.80
905	79.82	90.99
910	79.79	91.19
915	80.00	91.45
920	80.21	91.72
925	80.27	92.00
930	80.33	92.28
935	80.30	92.37
940	80.27	92.47
945	80.20	92.43

950	80.12	92.38
955	80.02	92.36
960	79.92	92.34
965	79.73	92.20
970	79.54	92.06
975	79.30	91.95
980	79.07	91.83
985	78.81	91.64
990	78.56	91.45
995	78.39	91.34
1000	78.21	91.24
1005	78.11	91.22
1010	78.01	91.20
1015	78.02	91.24
1020	78.03	91.28
1025	78.03	91.30
1030	78.02	91.32
1035	78.04	91.45
1040	78.05	91.59
1045	78.10	91.69
1050	78.16	91.80
1055	78.22	91.93
1060	78.29	92.07
1065	78.31	92.12
1070	78.32	92.18
1075	78.34	92.21
1080	78.36	92.25
1085	78.27	92.18
1090	78.17	92.12
1095	77.98	91.89
1100	77.79	91.66
1105	77.31	91.12
1110	76.83	90.59
1115	75.98	89.57

1120	75.13	88.55
1125	73.81	87.00
1130	72.48	85.44
1135	71.18	83.84
1140	69.87	82.24
1145	68.48	80.65
1150	67.09	79.05
1155	65.36	77.00
1160	63.62	74.94
1165	62.39	73.48
1170	61.15	72.02
1175	61.80	72.74
1180	62.44	73.46
1185	64.61	75.95
1190	66.77	78.45
1195	68.73	80.72
1200	70.69	82.98
1205	72.26	84.74
1210	73.83	86.50
1215	74.91	87.70
1220	76.00	88.91
1225	76.51	89.44
1230	77.03	89.97
1235	77.34	90.30
1240	77.66	90.64
1245	77.91	90.87
1250	78.16	91.09
1255	78.34	91.22
1260	78.53	91.34
1265	78.61	91.36
1270	78.68	91.39
1275	78.74	91.40
1280	78.79	91.41
1285	78.84	91.36

1290	78.88	91.32
1295	78.90	91.29
1300	78.92	91.26
1305	78.85	91.08
1310	78.78	90.89
1315	78.47	90.42
1320	78.17	89.94
1325	76.76	88.22
1330	75.36	86.50
1335	72.32	82.95
1340	69.29	79.40
1345	66.89	76.55
1350	64.49	73.70
1355	62.99	71.98
1360	61.48	70.27
1365	60.58	69.14
1370	59.67	68.02
1375	59.76	67.99
1380	59.84	67.96
1385	60.73	68.86
1390	61.63	69.76
1395	63.16	71.31
1400	64.68	72.86
1405	65.74	73.88
1410	66.80	74.91
1415	66.82	74.89
1420	66.85	74.87
1425	66.95	74.94
1430	67.04	75.01
1435	67.80	75.86
1440	68.56	76.70
1445	70.06	78.39
1450	71.56	80.09
1455	73.03	81.67

1460	74.51	83.25
1465	75.19	83.96
1470	75.86	84.67
1475	76.34	85.11
1480	76.81	85.54
1485	77.25	86.03
1490	77.68	86.52
1495	78.16	86.92
1500	78.64	87.32
1505	79.01	87.65
1510	79.39	87.99
1515	79.67	88.19
1520	79.96	88.39
1525	80.12	88.46
1530	80.27	88.53
1535	80.26	88.47
1540	80.24	88.42
1545	80.10	88.22
1550	79.96	88.02
1555	79.68	87.69
1560	79.40	87.36
1565	79.12	86.97
1570	78.85	86.58
1575	78.52	86.15
1580	78.19	85.73
1585	77.74	85.15
1590	77.30	84.56
1595	76.61	83.75
1600	75.92	82.93
1605	74.90	81.76
1610	73.88	80.59
1615	72.65	79.19
1620	71.42	77.78
1625	70.00	76.17

1630	68.59	74.56
1635	66.02	71.76
1640	63.45	68.96
1645	57.81	62.75
1650	52.18	56.54
1655	44.08	47.70
1660	35.98	38.85
1665	29.12	31.42
1670	22.26	23.99
1675	19.50	21.07
1680	16.74	18.14
1685	17.34	18.73
1690	17.93	19.32
1695	18.80	20.24
1700	19.66	21.16
1705	19.93	21.51
1710	20.20	21.86
1715	20.83	22.41
1720	21.45	22.96
1725	22.92	24.61
1730	24.39	26.26
1735	26.95	28.89
1740	29.51	31.52
1745	32.61	34.83
1750	35.71	38.14
1755	38.41	40.99
1760	41.11	43.84
1765	42.49	45.31
1770	43.86	46.78
1775	44.21	47.16
1780	44.56	47.55
1785	45.69	48.63
1790	46.82	49.70
1795	49.08	52.13

1800	51.34	54.56
1805	53.45	56.73
1810	55.57	58.89
1815	56.82	60.13
1820	58.06	61.37
1825	58.37	61.90
1830	58.69	62.44
1835	58.39	61.95
1840	58.09	61.46
1845	57.49	60.73
1850	56.89	60.00
1855	56.74	59.88
1860	56.58	59.75
1865	57.03	60.10
1870	57.49	60.45
1875	57.66	60.14
1880	57.83	59.83
1885	57.18	58.51
1890	56.53	57.19
1895	55.41	55.28
1900	54.29	53.36
1905	54.05	52.89
1910	53.81	52.42
1915	54.72	54.08
1920	55.62	55.74
1925	55.66	56.28
1930	55.70	56.81
1935	54.00	55.26
1940	52.30	53.71
1945	51.52	53.33
1950	50.74	52.95
1955	52.54	54.74
1960	54.35	56.54
1965	56.52	58.96

1970	58.70	61.38
1975	59.78	62.48
1980	60.85	63.58
1985	61.03	63.85
1990	61.21	64.13
1995	60.97	63.68
2000	60.74	63.23
2005	60.55	63.13
2010	60.36	63.03
2015	60.13	62.60
2020	59.90	62.16
2025	59.50	61.86
2030	59.10	61.56
2035	58.92	60.90
2040	58.74	60.24
2045	57.47	59.46
2050	56.20	58.68
2055	55.58	57.60
2060	54.97	56.53
2065	53.88	56.09
2070	52.80	55.66
2075	51.00	53.31
2080	49.20	50.96
2085	46.04	47.59
2090	42.87	44.23
2095	37.87	39.46
2100	32.86	34.69
2105	29.70	30.80
2110	26.53	26.91
2115	24.04	24.77
2120	21.56	22.63
2125	20.38	20.95
2130	19.20	19.28
2135	18.97	18.60

2140	18.74	17.92
2145	20.00	19.79
2150	21.27	21.66
2155	22.02	22.81
2160	22.76	23.95
2165	23.02	23.83
2170	23.27	23.70
2175	21.30	21.97
2180	19.34	20.24
2185	17.27	17.89
2190	15.20	15.54
2195	12.90	12.90
2200	10.60	10.26
2205	8.17	7.91
2210	5.74	5.57
2215	3.80	3.66
2220	1.86	1.75
2225	1.21	0.93
2230	0.55	0.11
2235	0.26	0.12
2240	-0.02	0.13
2245	0.36	0.31
2250	0.74	0.48
2255	0.55	0.21
2260	0.36	-0.06
2265	0.44	-0.32
2270	0.53	-0.57
2275	0.47	-0.32
2280	0.40	-0.06
2285	0.19	0.11
2290	-0.03	0.28
2295	0.25	0.32
2300	0.52	0.35
2305	0.32	0.12

2310	0.12	-0.11
2315	0.18	0.14
2320	0.23	0.39
2325	0.46	0.25
2330	0.68	0.10
2335	0.41	0.06
2340	0.14	0.01
2345	0.18	0.06
2350	0.23	0.10
2355	0.10	0.01
2360	-0.02	-0.08
2365	0.03	-0.12
2370	0.09	-0.16
2375	0.00	-0.02
2380	-0.09	0.12
2385	-0.07	-0.12
2390	-0.05	-0.37
2395	-0.14	-0.22
2400	-0.22	-0.08
2405	0.01	-0.16
2410	0.24	-0.24
2415	0.18	-0.17
2420	0.13	-0.10
2425	0.02	-0.13
2430	-0.09	-0.16
2435	0.02	-0.46
2440	0.13	-0.76
2445	0.14	-0.27
2450	0.15	0.23
2455	0.37	0.50
2460	0.58	0.76
2465	0.77	0.46
2470	0.95	0.16
2475	0.92	0.37

2480	0.89	0.57
2485	0.37	1.02
2490	-0.14	1.46
2495	0.41	0.75
2500	0.96	0.05

Infrared absorbers very particularly suitable for the purposes of the present invention are hybrid organic-inorganic nanoparticles, e.g. LUMOGEN IR 1050 from BASF.

The moulding composition according to the invention can, if appropriate, comprise further additives well known to the person skilled in the art. Preference is given to external lubricants, antioxidants, flame retardants, further UV stabilizers, flow aids, metal additives for shielding from electromagnetic radiation, antistatic agents, mould-release agents, dyes, pigments, adhesion promoters, weathering stabilizers, plasticizers, fillers and the like.

For the purposes of one particularly preferred embodiment of the present invention, the moulding composition comprises at least one sterically hindered amine, giving a further improvement in weathering resistance. A further reduction can be achieved in yellowing or a degradation of the moulding composition exposed to outdoor conditions for long periods.

Particularly preferred sterically hindered amines include dimethyl succinate-1-(2-hydroxyethyl)-4-hydroxy-2,2,6,6-tetramethylpiperazine polycondensate, poly[{6-(1,1,3,3-tetramethylbutyl)amino-1,3,5-triazine-2,4-diyl}{(2,2,6,6-tetramethyl-4-piperidyl)imino}hexamethylene{(2,2,6,6-tetramethyl-4-piperidyl)imino}], N,N'-bis(3-aminopropyl)ethylenediamine-2,4-bis[N-butyl-N-(1,2,2,6,6-pentamethyl-4-piperidyl)amino]-6-chloro-1,3,5-triazine condensate, bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate and bis(1,2,2,6,6-pentamethyl-4-piperidyl) 2-(3,5-di-tert-butyl-4-hydroxybenzyl)-2-n-butylmalonate.

The moulding composition according to the invention preferably comprises moreover at least one silane adhesion promoter or one organic titanium compound, thus giving a further improvement in adhesion to inorganic materials.

Suitable silane adhesion promoters include vinyltrichlorosilane, vinyltris(β -methoxyethoxy)silane, vinyltriethoxysilane, vinyltrimethoxysilane, γ -methacryloxypropyltrimethoxysilane, β -(3,4-epoxycyclohexyl)ethyltrimethoxysilane, γ -glycidoxypropylmethyldiethoxysilane, N- β -(aminoethyl)- γ -aminopropyltrimethoxysilane, N- β -(aminoethyl)- γ -aminopropylmethyldimethoxysilane, γ -aminopropyltriethoxysilane, N-phenyl- γ -aminopropyltrimethoxysilane, γ -mercaptopropyltrimethoxysilane, and γ -chloropropyltrimethoxysilane.

The relative proportions of the polyalkyl (meth)acrylate, of the compound according to formula (I) and of the infrared absorber can in principle be freely selected.

However, particularly preferred moulding compositions encompass, in each case based on their total weight,

- a) from 90% by weight to 99.9989% by weight of polyalkyl (meth)acrylate
- b) from 0.001% by weight to 0.03% by weight of compound according to formula (I) and
- c) from 0.0001% by weight to 0.04% by weight of infrared absorber.

The compounds can be incorporated into the moulding composition according to the invention by the processes known from the literature, for example by mixing with the polymer prior to further processing at a relatively high temperature, by addition to the melt of the polymer or by addition to suspended or dissolved polymer during its processing. They can also, if appropriate, be added to the starting materials for the production of the polymer, and they do not lose their absorption capability even in the presence of other conventional light stabilizers and heat stabilizers, oxidants and reducing agents and the like.

The softening point of the moulding composition according to the invention is preferably not lower than 80°C (Vicat softening point VST (ISO 306-B50)). It is therefore particularly suitable as fixing means for solar-cell modules, since it does not exhibit any onset of creep even when the module is exposed to high temperatures during use.

The total light permeability of the moulding composition according to the invention is comparatively high, and when the moulding composition is used as fixing means in solar-cell modules it therefore mitigates any reduction in the power level of the solar cell that could be caused by optical loss in the fixing means. Total permeability to

light is preferably at least 90% over the wavelength range from 400 nm to less than 500 nm. Total permeability to light is preferably at least 80% over the wavelength range from 500 nm to less than 1000 nm (measured with the aid of a Lambda 19 spectrophotometer from Perkin Elmer).

The moulding composition according to the invention is particularly suitable for the production of solar-cell modules, in particular as fixing means in solar-cell modules.

One particularly advantageous structure of a solar-cell module is described below, with occasional reference to figures 1 to 2B.

The solar-cell module according to the invention preferably encompasses a photovoltaic element 101, a pane 103, covering the frontal side of the photovoltaic element 101, a first fixing means 102 between the photovoltaic element 101 and the pane 103, a rear wall 105, covering the reverse side 104 of the photovoltaic element 101, and a second fixing means 104 between the photovoltaic element 101 and the rear wall 105.

The photovoltaic element preferably encompasses a photoactive semiconductor layer on a conductive substrate as a first electrode for conversion of light, and a transparent conductive layer as a second electrode, formed thereon.

The conductive substrate preferably encompasses in this context stainless steel, giving a further improvement in the adhesion of the fixing means to the substrate.

The dissipation resistance of the moulding composition according to the invention is preferably from 1 to 500 $\text{k}\Omega \times \text{cm}^2$. This optimizes avoidance of any reduction in the power level from the solar cell caused by short circuits.

On the light-sensitive side of the photovoltaic element, there is preferably a collector electrode comprising copper and/or silver as constituent, and the moulding composition according to the invention is preferably brought into contact with the collector electrode.

The light-sensitive surface of the photovoltaic element is advantageously covered

with the moulding composition according to the invention, and it is preferable that a thin fluoride polymer film is then arranged as outermost layer thereon.

The first fixing means 102 is intended to protect the photovoltaic element 101 from external effects, by covering any unevenness of the light-sensitive surface of the element 101. It also serves to bond the pane 103 to the element 101. It is therefore intended to have high weathering resistance, high adhesion and high heat resistance, in addition to high transparency. It is moreover intended to exhibit low water absorption and to liberate no acid. In order to meet these requirements, it is preferable to use a moulding composition according to the invention as first fixing means.

In order to minimize the reduction in the amount of light reaching the photovoltaic element 101, it is preferable that the permeability of the first fixing means 102 to light in the visible wavelength range from 400 nm to 800 nm is at least 80%, and particularly preferably at least 90% in the wavelength range from 400 nm to less than 500 nm (measured with the aid of a Lambda 19 spectrophotometer from Perkin Elmer). It also advantageously has a refractive index of from 1.1 to 2.0, advantageously from 1.1 to 1.6, in order to maximize the amount of light incident from air (measured to ISO 489).

The second fixing means 104 is used in order to protect the photovoltaic element 101 from external effects, by covering any unevenness on the reverse side of the element 101. It also serves to bond the rear wall 105 to the element 101. The second fixing means, like the first fixing means, is therefore intended to have high weathering resistance, high adhesion and high heat resistance. It is therefore preferable that the moulding composition according to the invention is also used as second fixing means. It is preferable that the material used for the first fixing means is the same as that used for the second fixing means. However, since the transparency is optional, it is possible, if necessary, to add a filler, e.g. an organic oxide, to the second fixing means, in order to achieve a further improvement in weathering resistance and mechanical properties, or to add a pigment in order to colour the fixing means.

The photovoltaic element 101 used preferably comprises known elements, in particular monocrystalline silicon cells, multicrystalline silicon cells, amorphous silicon

and microcrystalline silicon, these also being used in thin-layer silicon cells. Copper-indium-selenide compounds and semiconductor compounds are moreover particularly suitable.

Figures 2a and 2b show a block diagram of a preferred photovoltaic element. Figure 2a is a cross-sectional diagrammatic view of a photovoltaic element, whereas Figure 2b is a diagrammatic plan view of a photovoltaic element. The numeral 201 in these figures indicates a conductive substrate, 202 indicates a reflective layer on the reverse side, 203 indicates a photoactive semiconductor layer, 204 indicates a transparent, conductive layer, 205 indicates a collector electrode, 206a and 206b indicate crocodile clips, and 207 and 208 indicate conductive, adhesive pastes or conductive pastes.

The conductive substrate 201 serves not merely as substrate of the photovoltaic element but also as second electrode. The material of the conductive substrate 201 preferably encompasses silicon, tantalum, molybdenum, tungsten, stainless steel, aluminium, copper, titanium, a carbon foil, a lead-plated steel sheet, a resin film and/or a ceramic material, with a conductive layer thereon.

On the conductive substrate 201, there is preferably a metal layer provided, or a metal oxide layer, or both, as reflective layer 202 on the reverse side. The metal layer preferably encompasses Ti, Cr, Mo, B, Al, Ag and/or Ni, whereas the metal oxide layer preferably comprises ZnO, TiO₂ and SnO₂. The metal layer and the metal oxide layer are advantageously formed by gas-phase deposition, by heating, or by electron beam or by sputtering.

The photoactive semiconductor layer 203 serves to carry out the photoelectric conversion process. In this context, preferred materials are multicrystalline silicon with pn transition, pin junction types composed of amorphous silicon, pin junction types composed of microcrystalline silicon and semiconductor compounds, in particular CuInSe₂, CuInS₂, GaAs, CdS/Cu₂S, CdS/CdTe, CdS/InP and CdTe/Cu₂Te. Particular preference is given here to the use of pin junction types composed of amorphous silicon.

The preferred method of production of a photoactive semiconductor layer uses

forming of molten silicon to give a foil, or uses heat treatment of amorphous silicon in the case of polycrystalline silicon, or uses plasma gas-phase deposition with use of a silane gas as starting material in the case of amorphous silicon and of microcrystalline silicon, or uses ion plating, ion beam deposition, vacuum evaporation, sputtering or electroplating in the case of a semiconductor compound.

The transparent conductive layer 204 serves as upper electrode of the solar cell. It preferably encompasses In_2O_3 , SnO_2 , $\text{In}_2\text{O}_3\text{-SnO}_2$ (ITO), ZnO , TiO_2 , Cd_2SnO_4 or a crystalline semiconductor layer which has been doped with a high concentration of impurities. It can be formed by resistance-heating vapour deposition, sputtering, spraying, gas-phase deposition, or diffusion of impurities.

Another aspect of the photovoltaic element on which the transparent conductive layer 204 has been formed is that some degree of short circuit can arise between the conductive substrate and the transparent, conductive layer, due to the unevenness of the surface of the conductive substrate 201 and/or to non-uniformity at the juncture of formation of the photoactive semiconductor layer. The result here is a large current loss, proportional to the output voltage. This means that the leakage resistance (shunt resistance) is low. It is therefore desirable to eliminate the short circuits and to subject the photovoltaic element to a treatment for the removal of defects, after formation of the transparent conductive layer. US Patent 4,729,970 describes this type of treatment in detail. The said treatment adjusts the shunt resistance of the photovoltaic element to from 1 to $500 \text{ k}\Omega \times \text{cm}^2$, preferably from 10 to $500 \text{ k}\Omega \times \text{cm}^2$.

The collector electrode (grid) can be formed on the transparent conductive layer 204. It preferably takes the form of a grid, of a cone, or of a line or the like, in order to be an effective electrical collector. Preferred examples of the material forming the collector electrode 205 are Ti, Cr, Mo, W, Al, Ag, Ni, Cu, Sn, or a conductive paste, which is termed silver paste.

The collector electrode 205 is preferably formed by a sputtering using a masking pattern, by resistance heating, by gas-phase deposition, by a process encompassing the steps of forming a metal film by gas deposition over the entire layer and using etching to remove superfluous portions of the film, by a process which uses photochemical gas-phase deposition to form a grid-electrode pattern, by a process

encompassing the steps of producing a marked pattern of the grid electrode in negative form and plating the patterned surface, by a process in which a conductive paste is applied by printing, or by a process in which metal wires are soldered onto a printed conductive paste. The conductive paste used is preferably a binder polymer comprising silver, gold, copper, nickel, carbon or the like dispersed in the form of a fine powder. The binder polymer preferably includes polyester resins, ethoxy resins, acrylic resins, alkyd resins, polyvinyl acetate resins, rubbers, urethane resins and/or phenolic resins.

Finally, tapping terminals 206 are preferably secured on the conductive substrate 201 or on the collector electrode 205, in order to tap the electromotive force. In a preferred method of fixing the tapping terminals 206 on the conductive substrate, a metal body, e.g. a copper tag, is secured by spot welding or soldering on the conductive substrate, while the tapping terminals are preferably secured on the collector electrode by using a conductive paste or tin solder 207 and 208 to make an electrical connection between a metal body and the collector electrode.

The photovoltaic elements can be connected in series or in parallel, in accordance with the desired voltage or current level. The voltage or current level can also be controlled by introducing the photovoltaic elements into an insulating substrate.

The pane 103 in Figure 1 is intended to have maximum weathering resistance, maximum dirt repellency and maximum mechanical strength, since it is the outermost layer of the solar-cell module. It is moreover intended to ensure that the solar-cell module is reliable in long-term outdoor use. Panes suitable for use for the purposes of the present invention include (reinforced) glass foils and fluoride polymer films. The glass foil preferably used is a glass foil with high permeability to light. Suitable fluoride polymer foils encompass in particular ethylene tetrafluoride-ethylene copolymer (ETFE), polyvinyl fluoride resin (PVF), polyvinylidene fluoride resin (PVDF), tetrafluoroethylene resin (TFE), ethylene tetrafluoride-propylene hexafluoride copolymer (FEP) and chlorotrifluoroethylene (CTFE). The polyvinylidene fluoride resin is particularly suitable with regard to weathering resistance, while ethylene tetrafluoride ethylene copolymer is particularly advantageous with regard to combination of weathering resistance and mechanical strength. In order to improve adhesion between the fluoride polymer foil and the fixing means, it is desirable to

subject the foil to a corona treatment or a plasma treatment. It is also preferable to use stretched foil, in order to achieve a further improvement in mechanical strength.

For the purposes of one particularly preferred embodiment of the present invention, the pane is manufactured from the moulding composition according to the invention.

The rear wall 105 serves for electrical insulation between the photovoltaic element 101 and the environment, and for improving weathering resistance, and acts as reinforcing material. It is preferably composed of a material which provides reliably adequate electrical insulation properties, and which has excellent long-term stability and which can withstand thermal expansion and thermal contraction, and which is flexible. Materials particularly suitable for these purposes include nylon foils, polyethylene terephthalate (PET) foils and polyvinyl fluoride foils. If moisture resistance is demanded, it is preferable to use aluminium-laminated polyvinyl fluoride foils, aluminium-coated PET foils, or silicon-oxide-coated PET foils. The fire resistance of the module can moreover be improved by using, as rear wall, a foil-laminated, electroplated iron foil or a foil composed of stainless steel.

For the purposes of one particularly preferred embodiment of the present invention, the rear wall has been manufactured from the moulding composition according to the invention.

There can be a supportive plate secured on the external surface of the rear wall, in order to achieve a further improvement in the mechanical strength of the solar-cell module or in order to inhibit buckling and deflection of the rear wall caused by temperature changes. Particularly preferred rear walls are stainless-steel sheets, plastics sheets, and FRP (fibre-reinforced plastics) sheets. There can also be a construction material secured on the rear pane.

This type of solar-cell module can be produced in a manner known per se. However, a particularly advantageous procedure is described below.

A preferred procedure for covering the photovoltaic element with the fixing means uses heat to melt the fixing means and extrudes this through a slot in order to form a foil, which is then secured thermally on the element. The fixing-means foil is

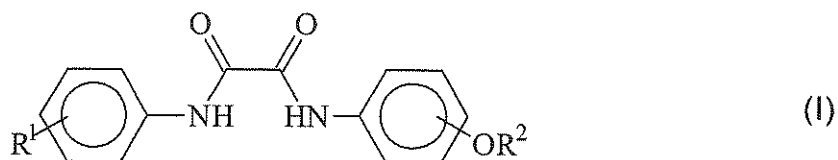
preferably introduced between the element and the pane and between the element and the rear wall, and then consolidated.

The thermal consolidation process can be carried out using known processes, e.g. vacuum lamination and roller lamination.

The operating temperature of the solar-cell module according to the invention is preferably up to 80°C or higher, and it is in particular high temperatures here which permit effective utilization of the heat-resistance effect of the moulding composition according to the invention.

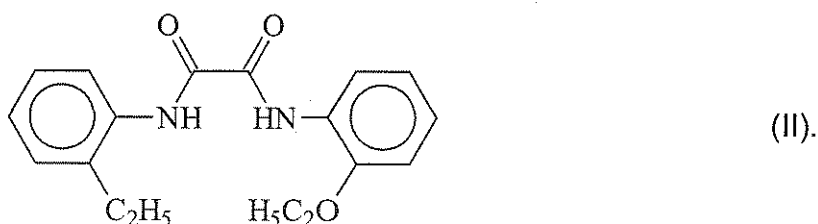
Patent claims:

1. Moulding composition, encompassing
 - a) at least one polyalkyl (meth)acrylate, and
 - b) at least one compound according to formula (I)



- in which the moieties R^1 and R^2 are independently an alkyl or cycloalkyl moiety having from 1 to 20 carbon atoms,
- characterized in that the moulding composition further comprises
- c) at least one infrared absorber,
- where the transmittance of the moulding composition
- at 500 nm is smaller than 89%,
 - at 1000 nm is smaller than 80%,
 - at 1150 nm is smaller than 70% and
 - at 1600 nm is smaller than 77%, in each case measured by means of infrared spectroscopy at 25°C on 3 mm plaques.
2. Moulding composition according to Claim 1, characterized in that it comprises at least one C_1 - C_{18} -alkyl (meth)acrylate homopolymer or C_1 - C_{18} -alkyl (meth)acrylate copolymer.
 3. Moulding composition according to Claim 2, characterized in that it comprises at least one copolymer which encompasses from 80% by weight to 99% by weight of methyl methacrylate units and from 1% by weight to 20% by weight of C_1 - C_{10} -alkyl acrylate units.
 4. Moulding composition according to Claim 3, characterized in that the copolymer encompasses methyl acrylate units and/or ethyl acrylate units.
 5. Moulding composition according to at least one of the preceding claims, characterized in that the moieties R^1 and R^2 in formula (I) are independently an alkyl or cycloalkyl moiety having from 1 to 8 carbon atoms.

6. Moulding composition according to at least one of the preceding claims, characterized in that the moieties R^1 and R^2 in formula (I) are a methyl, ethyl, propyl, isopropyl, 1-butyl, 2-butyl, 2-methylpropyl, tert-butyl, pentyl, 2-methylbutyl, 1,1-dimethylpropyl, hexyl, heptyl, octyl, 1,1,3,3-tetramethylbutyl, nonyl, 1-decyl, 2-decyl, undecyl, dodecyl, pentadecyl or eicosyl group.
7. Moulding composition according to at least one of the preceding claims, characterized in that the moieties R^1 and R^2 in formula (I) are a cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl or cyclooctyl group, optionally substituted with branched or unbranched alkyl groups.
8. Moulding composition according to at least one of the preceding claims, characterized in that it comprises a compound according to formula (II)



9. Moulding composition according to at least one of the preceding claims, characterized in that its transmittance at 500 nm is in the range from 80% to smaller than 89%.
10. Moulding composition according to at least one of the preceding claims, characterized in that its transmittance at 1000 nm is in the range from 75% to smaller than 80%.
11. Moulding composition according to at least one of the preceding claims, characterized in that its transmittance at 1150 nm is in the range from 55% to smaller than 70%.
12. Moulding composition according to at least one of the preceding claims, characterized in that it encompasses at least one sterically hindered amine.

13. Moulding composition according to at least one of the preceding claims, characterized in that it encompasses at least one silane adhesion promoter.
14. Use of a moulding composition according to at least one of the preceding claims for the production of solar-cell modules.
15. Solar-cell module, encompassing a moulding composition according to at least one of claims 1 to 13.