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(54) **HYDROXYURETHANE (METH)ACRYLATE PREPOLYMERS FOR USE IN 3D PRINTING**

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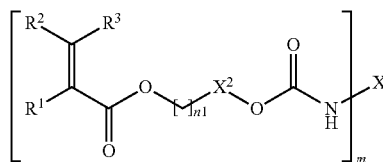
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(57) **ABSTRACT**

The present invention relates to prepolymers of formula (I), a process for the production of the prepolymers, photocurable compositions, comprising the prepolymers of formula (I) and their use in a photopolymerization 3D printing process. In contrast to usual urethane (meth)acrylates. The prepolymers of formula (I) can be prepared without using toxic isocyanates and exhibit pending hydroxyl groups along their molecule backbone which allow for the introduction of further side chains or side groups to improve, for example, the interaction with inorganic fillers.



### HYDROXYURETHANE (METH)ACRYLATE PREPOLYMERS FOR USE IN 3D PRINTING

**[0001]** The present invention relates to prepolymers of formula (I), a process for the production of the prepolymers, photocurable compositions, comprising the prepolymers of formula (I) and their use in a photopolymerization 3D printing process. In contrast to usual urethane (meth)acrylates. The prepolymers of formula (I) can be prepared without using toxic isocyanates and exhibit pending hydroxyl groups along their molecule backbone which allow for the introduction of further side chains or side groups to improve, for example, the interaction with inorganic fillers, or to increase the (meth)acrylate functionality.

**[0002]** Additive manufacturing (3D printing) describes a layer by layer construction of three-dimensional objects and as opposed to subtractive manufacturing methods, like milling or cutting, it allows for the preparation of highly complex shapes with no waste from unused build material. 3D printing techniques like stereolithography (SLA) or digital light processing (DLP) make use of UV-curable polymer resins and a respective light source to selectively cure the resin in a layer by layer fashion.

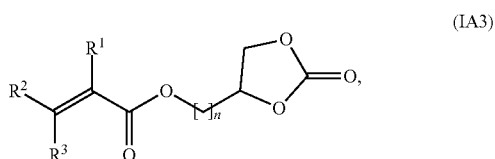
**[0003]** Such resins consist of (meth)acrylate-based building blocks which readily undergo radical chain growth polymerization at the exposure of UV-light. They usually comprise various components like stiff building blocks, flexible and low-viscosity reactive diluents, prepolymers and photoinitiators. The material properties of a given photoresin strongly depend on the structure and size of the used building blocks. This allows for a design of material properties through the use of a modular construction system comprising a broad variety of (meth)acrylate building blocks.

**[0004]** (Meth)acrylate prepolymers, in particular, are most commonly prepared by the reaction of a polyol, like hydroxyl-terminated polyether, polyester or polycarbonate, with an excess of a diisocyanate and the subsequent addition of 2-hydroxyethyl (meth)acrylate to attach the UV-reactive group. This method requires the use of isocyanates which demand special safety precautions due to their high toxicity and water sensitivity.

**[0005]** Carbonation of glycidyl methacrylate affords glycerol carbonate methacrylate (GCMA) which readily reacts with amines under cyclic carbonate aminolysis to form hydroxyurethane linkages and thereby allows for introducing UV-reactive methacrylate groups to amine bearing scaffolds.

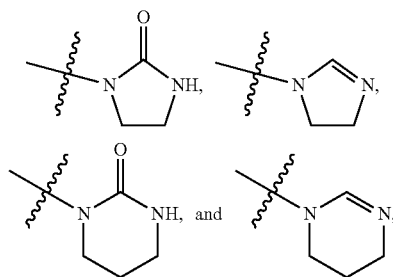
**[0006]** WO12095293 discloses a method of preparing a monomer, macromer or oligomer comprising the steps of:

**[0007]** (a) providing a cyclic carbonate of Formula (IA3):

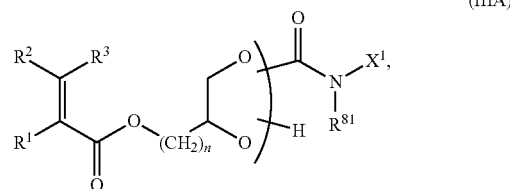


wherein  $R^1$ ,  $R^2$  and  $R^3$  are independently H or methyl, and  $n=1-12$ ;

**[0008]** (b) adding, with control of temperature, an amine of formula (IIA):  $R^{81}NHX^1$  (IIA) wherein  $R^{81}$  is hydrogen or  $C_1-C_{12}$ alkyl optionally substituted with one or more hydroxy,  $C_1-C_4$ alkoxy, halogen or  $C_1-C_4$ haloalkoxy groups;  $X^1$  is  $(CH_2)_nR^{82}$ , wherein  $n=1-12$ , and  $R^{82}$  is haloalkyl,  $SiR^{83}$ ,  $OSiR^{83}$ , or heterocyclyl, wherein  $R^{83}$  are independently  $C_1-C_{12}$ alkyl,  $C_1-C_6$ alkoxy, trimethylsilyloxy (OTMS),  $C_3-C_6$ cycloalkyl,  $C_3-C_6$ cycloalkoxy,  $[OSi(Me)_2]_z(CH_2)_nNH_2$ ,  $[OSi(Me)_2]_zOSiR^{85}$ , where  $z=1-1000$ , and  $R^{85}$  is independently  $C_1-C_{12}$ alkyl, or aryl or heteroaryl, optionally substituted with hydroxy,  $C_1-C_4$ alkyl,  $C_1-C_4$ alkoxy, halogen,  $C_1-C_4$ hydroxyalkyl,  $C_1-C_4$ alkoxyl- $C_1-C_4$ alkyl; and wherein heterocyclyl is selected from the group consisting of



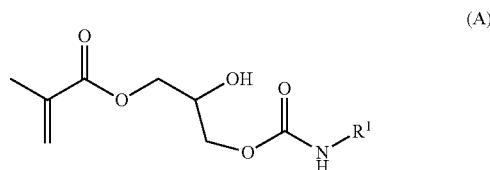
**[0009]** to form a ring-opened monomer of Formula (IIIA):



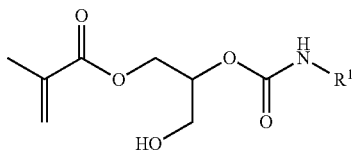
**[0010]** (c) optionally, distilling said monomer; (d) optionally, further reacting said ring-opened monomer, optionally in the presence of a catalyst, to introduce functionality comprising Si, F, N, and/or O atoms; and (e) optionally, removing said catalyst and/or distilling.

**[0011]** The compounds of formula (IIIA) and hydrogel polymers are useful for the preparation of contact lenses.

**[0012]** CN108084059A discloses a class of compounds and their synthesis and application of polyurethane, the polyurethane-based compound having the formula

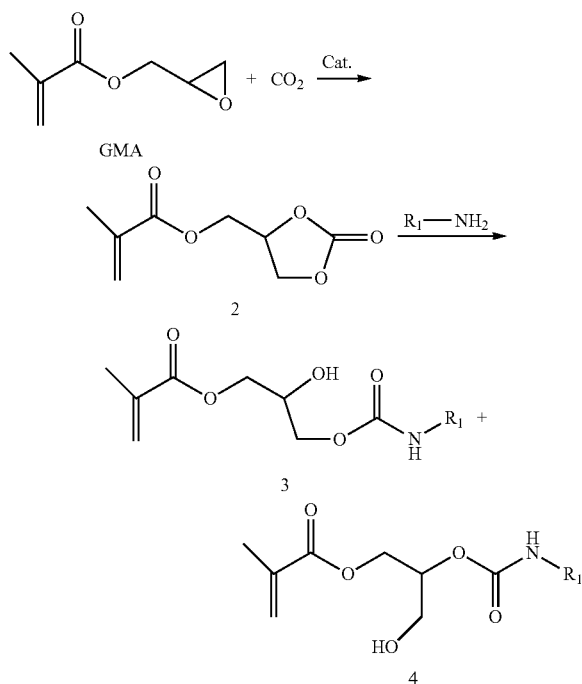


or formula

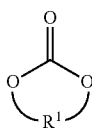


(II)

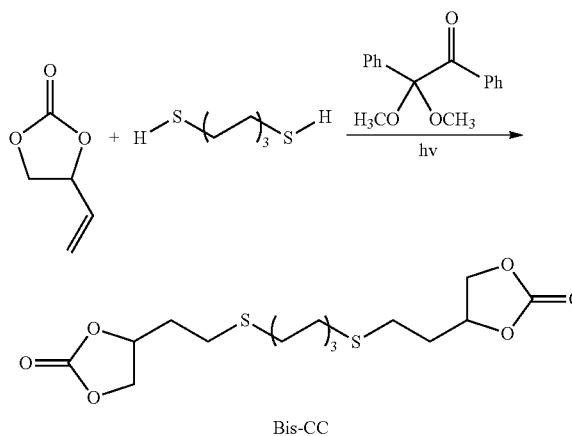
as shown in structure, wherein  $R^1$  is  $C_2$ - $C_{18}$ alkyl group,  $C_2$ - $C_{18}$ haloalkyl,  $C_2$ - $C_{18}$ fatty acid group, or a  $C_2$ - $C_{18}$ fatty alcohol. The synthesis method is glycidyl methacrylate and  $CO_2$  synthesized cyclic carbonate intermediate, then mono-amino compound ring-opening reaction to obtain a polyurethane-based compounds.



[0013] US2014182784 relates to compositions comprising a reaction product of: 1) one or more compounds having at least one cyclic carbonate group, wherein the cyclic carbonate comprises one or more functional groups having one or more carbon-carbon double bonds or triple bonds; 2) one or more compounds having two or more thiol groups; and, 3) one or more compounds having two or more amine functional groups, wherein the product is a cross-linked poly(hydroxyl urethane). The cyclic carbonate group has the structure



wherein  $R^1$  is  $-(CR^2R^3)_n-$ , wherein  $2 \leq n \leq 4$ , and wherein  $R^2$  and  $R^3$  are each independently hydrogen, straight chain or branched alkane, alkene or alkyne, optionally substituted with at least one member selected from the group consisting of  $NH_2$ ,  $SH$ ,  $COO$  and  $OH$ , and further wherein at least one  $R^2$  or  $R^3$  is a straight chain or branched alkene or alkyne.



[0014] WO17001172A1 relates to isocyanate-free polyurethane compositions comprising polymers (A) carrying cyclic carbonate groups, which do not comprise or are not based on isocyanates, obtained by reaction of polymers which carry carboxyl groups, selected from the group encompassing polyesters based on diols or polyols and on dicarboxylic or polycarboxylic acids and/or derivatives thereof, or poly(meth)acrylates, with five-membered cyclic carbonates that are functionalised with hydroxyl groups, and a curing agent (B) having at least one amino group and at least one further functional group, with the proviso that the further functional group is not an isocyanate group. In the production of an adhesive a bifunctional polyester is reacted with glycerol carbonate and diaminoethane.

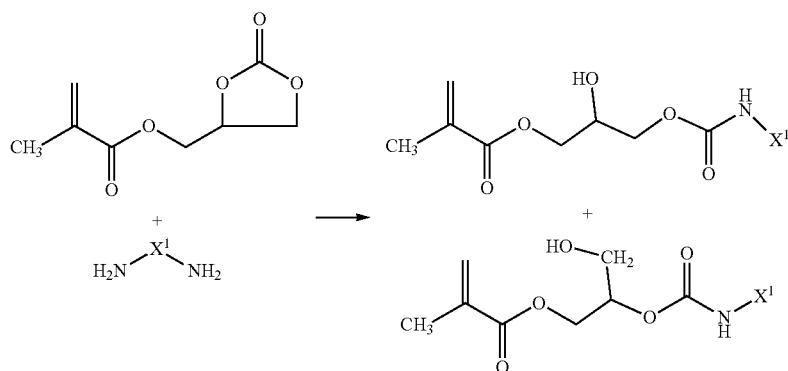
[0015] WO2015092467 relates to polymer compositions to manufacture a transparent ophthalmic lens characterized in that it is obtained by polymerization of a polymerizable composition comprising at least:

[0016] a monomer or oligomer (A) comprising at least a reactive group selected from epoxy, thioepoxy, epoxysilane, (meth)acrylate, thio(meth)acrylate, vinyl, urethane, thiourethane, isocyanate, mercapto, and alcohol, wherein said monomer (A) shrinks during polymerization;

[0017] a monomer (B) comprising at least a non-aromatic cyclic group wherein during polymerization said cyclic group opens and reacts with another molecule of monomer (B) and/or with a reactive group of monomer or oligomer (A), and

[0018] wherein said monomer (B) expands during polymerization.

[0019] The present invention relates to the preparation of hydroxyurethane (meth)acrylate prepolymers from carbonate (meth)acrylates, such as, for example, glycerol carbonate methacrylate (GCMA) and di- or polyfunctional amines as well as their use in UV-curable 3D printing resins. Ring-opening of GMAC with  $H_2N-X^1-NH_2$  can result in two products:

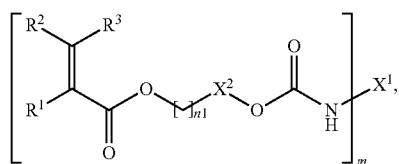


The formation of secondary OH groups is preferred.

**[0020]** GCMA reacts with amines under cyclic carbonate aminolysis to form hydroxy urethane linkages but also shows a significant side reaction from Michael addition of the amine to the methacrylate group yielding a secondary amine which is known to have much lower reactivity towards cyclic carbonates. This side reaction accounts for roughly 10% of the amine consumption. Consequently, when setting the reaction parameters to an equimolar ratio of GCMA and amine groups around 10% of the cyclic carbonate remains as an end group in the prepolymer. Applying a 20% excess of amine groups significantly reduces the amount of the cyclic carbonate end groups in the product, thereby increasing the functionality (=number of acrylate groups per molecule) of the prepolymer. This also causes an increase in molar mass, which is known to benefit the shrinkage behavior during UV-curing.

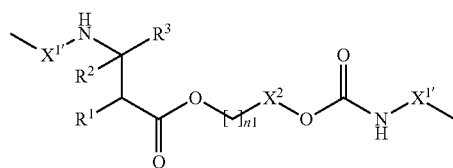
**[0021]** Furthermore, the prepolymers of the present invention exhibit nucleophilic hydroxy and amine groups in the prepolymer backbone, which is unusual for common urethane acrylate prepolymers and can be exploited to further functionalize these compounds or improve, for example, the interaction of the photoresin with inorganic fillers through hydrogen bonding, or through use of coupling agents. Based on the great variety of commercial di- and triamines such as hydroxyurethane methacrylates (HUMA) may represent flexible building blocks containing long-chain methylene or polyether sequences as well as stiff, low-molecular weight compounds containing rigid cycloaliphatic or aromatic structures. In a basic resin formulation comprising roughly 40 wt % HUMA and 60 wt % of a reactive diluent material properties such as the Young's Modulus, tensile strength, elongation at break and the glass transition temperature are tunable in the range of 869-5700 MPa, 20.5-85 MPa, 1.2-90% and 84-120° C., respectively.

**[0022]** Accordingly, the present invention is directed to prepolymers of formula



wherein

**[0023]** X<sup>1</sup> is a linking group, or a group of formula



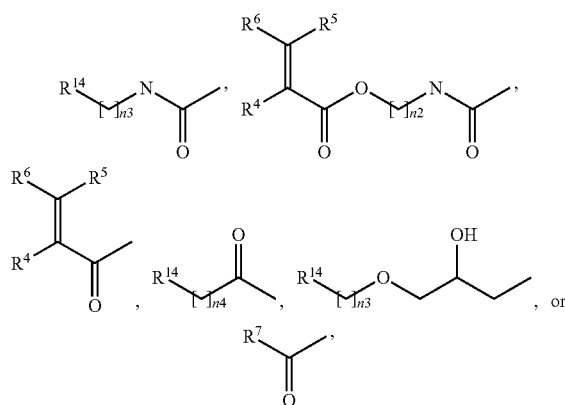
**[0024]** X<sup>1'</sup> is a linking group,

**[0025]** X<sup>2</sup> is independently in each occurrence a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—,

**[0026]** R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are independently of each other H, or a C<sub>1</sub>-C<sub>4</sub>-alkyl group, especially a methyl group;

**[0027]** n<sub>1</sub> is an integer of 1 to 12;

**[0028]** m is an integer of 1 to 4; wherein optionally the hydrogen atom of the hydroxy groups and/or the amino groups of the prepolymer may be replaced by a group of formula



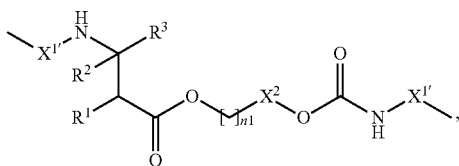
wherein

**[0029]** R<sup>4</sup>, R<sup>5</sup> and R<sup>6</sup> are independently of each other H, or a C<sub>1</sub>-C<sub>4</sub>-alkyl group, especially a methyl group;

**[0030]** R<sup>7</sup> is a C<sub>1</sub>-C<sub>25</sub>alkyl group, a C<sub>2</sub>-C<sub>25</sub>alkenyl group, or a phenyl group, which can be substituted by one, or more C<sub>1</sub>-C<sub>8</sub>alkyl groups, C<sub>1</sub>-C<sub>8</sub>alkoxy groups,

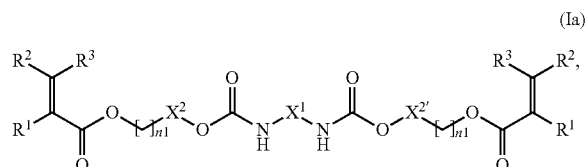
**[0031]** R<sup>14</sup> is a group of formula —SiR<sup>15</sup>(R<sup>16</sup>)<sub>2</sub>,

- [0032]  $R^{15}$  is a  $C_1$ - $C_8$ alkoxy group,  
 [0033]  $R^{16}$  is a  $C_1$ - $C_8$ alkyl group, or a  $C_1$ - $C_8$ alkoxy group,  
 [0034]  $n_2$  is an integer of 1 to 12 and  
 [0035]  $n_3$  and  $n_4$  are an integer of 1 to 12.  
 [0036] For groups substituted with  $R^{14}$  the following preferences apply:  
 [0037]  $n_3$  and  $n_4$  are 3,  $R^{15}$  is a methoxy group, or an ethoxy group and  $R^{16}$  is a methyl group,  
 [0038] an ethyl group, a methoxy group, or an ethoxy group.  
 [0039] The viscosity of the photocurable compositions is in the range 10 to 3000 mPa·s, preferably 10 to 1500 mPa·s at 30° C. In case of photopolymer jetting the viscosity of the photocurable composition is adjusted to be in the range of 10 to 150 mPa·s at 30° C. In case of vat-based photopolymerization the viscosity of the photocurable composition is adjusted to be in the range of 50 to 1500 mPa·s at 30° C. Most commercial print heads require heating to reduce ink viscosity which is typically in the range of 10 to 20 mPa·s.  
 [0040] If  $X^1$  is a linking group, i.e. is different from a group of formula

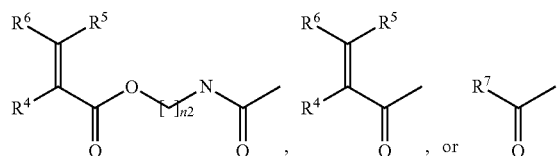


$X^{1'}$  has the meaning of  $X^1$ . For  $X^{1'}$  the same preferences apply as for  $X^1$ .

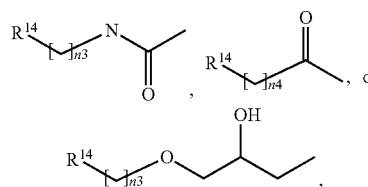
- [0041] In addition, the present invention is directed to photocurable compositions, comprising  
 [0042] (A) the prepolymer of formula (I), or the prepolymer obtainable by the process according to the present invention,  
 [0043] (B) a diluent (B),  
 [0044] (C) optionally an oligomer (C), and  
 [0045] (D) a photoinitiator (D).  
 [0046] The present invention is directed to the use of the photocurable composition according to the present invention, or the prepolymers of formula (I), or the prepolymer obtainable by the process according to the present invention in a photopolymerization 3D printing process, coatings, inks, varnishes, adhesives, composite materials and solder resists.  
 [0047] The photopolymerization 3D printing process is preferably vat photopolymerisation, or photopolymer jetting.  
 [0048] The prepolymer is preferably a prepolymer of formula



- [0049] wherein  
 [0050]  $X^1$  is a linking group,  
 [0051]  $R^1$ ,  $R^2$  and  $R^3$  are independently of each other H, a  $C_1$ - $C_4$ -alkyl group, especially a methyl group;  
 [0052]  $n_1$  is an integer of 1 to 12;  
 [0053]  $X^2$  is a group of formula  $-\text{CH}(\text{CH}_2\text{OH})-$ , or  $-\text{CH}(\text{OH})-(\text{CH}_2)-$ , and  
 [0054]  $X^{2'}$  is a group of formula  $-\text{CH}(\text{CH}_2\text{OH})-$ , or  $-\text{CH}(\text{OH})-(\text{CH}_2)-$ , wherein optionally the hydrogen atom of the hydroxy groups and/or the amino groups of the prepolymer may be replaced by a group of formula

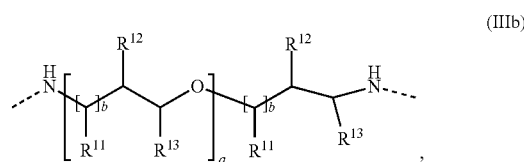


- [0055] wherein  $R^4$ ,  $R^5$ ,  $R^6$ ,  $R^7$  and  $n_2$  are defined above, or below, or a group of formula



wherein

- [0056]  $R^{14}$ ,  $n_3$  and  $n_4$  are defined above, or below.  
 [0057]  $R^2$  and  $R^3$  are preferably H, or a methyl group; more preferably H.  
 [0058]  $R^1$  is preferably H, or a methyl group, more preferably a methyl group.  
 [0059]  $n_1$  is preferably 1.  
 [0060]  $R^{14}$  is a group of formula  $-\text{SiR}^{15}(\text{R}^{16})_2$ , wherein  
 [0061]  $n_3$  and  $n_4$  are preferably 3,  $R^{15}$  is preferably a methoxy group, or an ethoxy group and  $R^{16}$  is preferably a methyl group, an ethyl group, a methoxy group, or an ethoxy group.  
 [0062] In a preferred embodiment of the present invention the linking group  $X^1$  is derived from polyetheramines. When the polyetheramines are prepared by using polyetherdiols, preference is given to using those which are propylene oxide- and/or ethylene oxide- and/or butylene oxide- and/or pentylene oxide-based.  
 [0063] In said embodiment the groups  $\dots \text{HNX}^1\text{NH} \dots$  may be derived from a polyether diamine are groups of formula

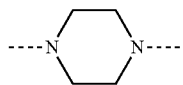


- [0064]  $R^{11}$  is hydrogen, or a  $C_1$ - $C_4$ alkyl group;  
 [0065]  $R^{12}$  and  $R^{13}$  are the same or different and are each independently hydrogen, or a methyl group;

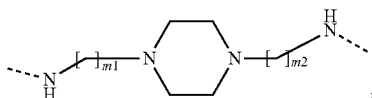
[0066] b is 0, or 1; and

[0067] a is an integer from 1 to 50. It should be noted that, for example, units with identical or different R<sup>11</sup>; R<sup>12</sup> and R<sup>13</sup> groups occur, in which case units with different substitution, i.e. propylene oxide- and/or ethylene oxide-based, are present in any sequence and repetition in the particular unit of formula (IIIb).

[0068] Examples of preferred groups . . . HNX<sup>1</sup>NH . . . are shown below:



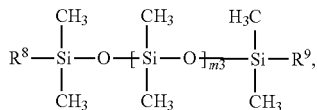
a group of formula



wherein

[0069] m<sub>1</sub> and m<sub>2</sub> are an integer of 1 to 25, especially 1 to 8, very especially 1 to 4, such as, for example, a group derived from 1,4-bis(3-aminopropyl)piperazine;

[0070] a group of formula

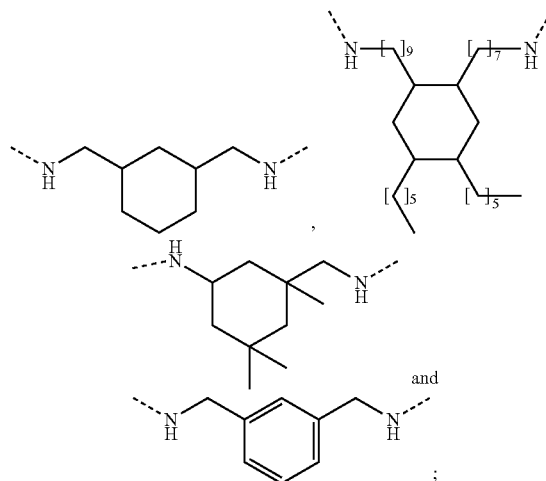


wherein

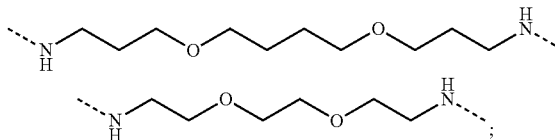
[0071] R<sup>8</sup> and R<sup>9</sup> are a group of formula —(CH<sub>2</sub>)<sub>m4</sub>—NH . . . , m<sub>3</sub> is 2 to 200 and m<sub>4</sub> is an integer of 1 to 8;

[0072] a group of formula . . . HN—(CH<sub>2</sub>)<sub>n4</sub>—NH . . . , wherein part of the hydrogen atoms may be replaced by a C<sub>1</sub>–C<sub>4</sub>alkyl group and n<sub>4</sub> is an integer of 1 to 25, such as, for example, groups derived from diaminoethane, diaminopropane, 1,2-diamino-2-methylpropane, 1,3-diamino-2,2-dimethylpropane, diaminobutane, diaminopentane, 1,5-diamino-2-methylpentane, neopentyl diamine, diaminohexane, 1,6-diamino-2,2,4-trimethylhexane, 1,6-diamino-2,4,4-trimethylhexane, diaminoheptane, diaminooctane, diamiononane, diaminodecane, diaminoundecane, diaminododecane, especially diaminopentane, diaminohexane, diaminododecane, or mixtures thereof;

[0073] a group of formula . . . HN—(CH<sub>2</sub>)<sub>n5</sub>—Y<sup>1</sup>—(CH<sub>2</sub>)<sub>n6</sub>—NH . . . , wherein Y<sup>1</sup> is a C<sub>3</sub>–C<sub>8</sub>cycloalkylen group, or a phenylene group, which may be substituted by one, or more C<sub>1</sub>–C<sub>8</sub>alkyl groups, and n<sub>5</sub> and n<sub>6</sub> independently of each other 0, or an integer 1 to 4, such as, for example, groups derived from 1,4-cyclohexane-diamine, 4,4'-methylenebis(cyclohexylamine), 4,4'-isopropylenebis(cyclohexylamine), isophoronediamine, m-xylylenediamine, 1,2-(bisaminomethyl)cyclohexane, 1,3-(bisaminomethyl)cyclohexane, 1,4-(bisaminomethyl)cyclohexane, bis(4-aminocyclohexyl)methane, especially groups of formula

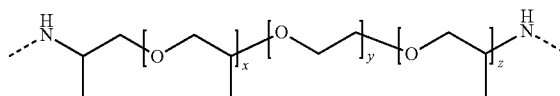


[0074] a group of formula . . . HN—(CH<sub>2</sub>)<sub>n7</sub>—O(CH<sub>2</sub>)<sub>n8</sub>—O(CH<sub>2</sub>)<sub>n9</sub>—NH . . . , wherein n<sub>7</sub>, n<sub>8</sub> and n<sub>9</sub> are independently of each other an integer 2 to 4, such as, for example,



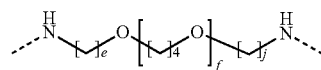
[0075] a group of formula . . . HN—(CH<sub>2</sub>)<sub>n10</sub>—O(CH<sub>2</sub>)<sub>2</sub>—O(CH<sub>2</sub>)<sub>n11</sub>—NH . . . , wherein n<sub>10</sub> and n<sub>11</sub> are independently of each other an integer 2 to 4; or

[0076] a group of formula



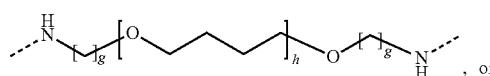
wherein y=0-39, x+z=1-68; or

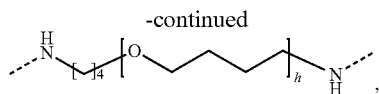
[0077] a group of formula



[0078] wherein e and j are independently of each other an integer of 2 to 6 and f is an integer of 2 to 30;

[0079] a group of formula

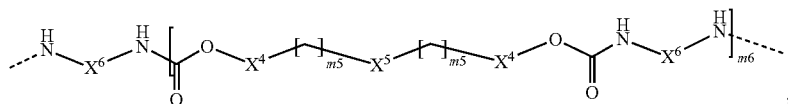




wherein g is an integer of 1 to 12;

[0080] h is 3 to 50, especially 10 to 30; or

[0081] a group of formula



[0082] wherein X<sup>2</sup> is a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—,

[0083] X<sup>4</sup> is independently in each occurrence a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—,

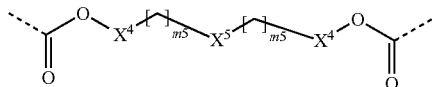
[0084] X<sup>5</sup> is a linking group,

[0085] X<sup>6</sup> is a linking group,

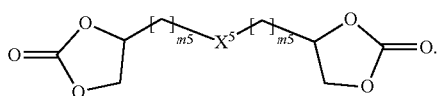
[0086] m<sub>5</sub> is 0, or an integer of 1 to 12;

[0087] m<sub>6</sub> is 1 to 20, especially 1 to 6.

[0088] The group of formula

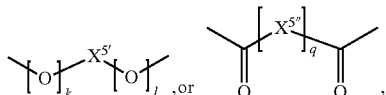


can be derived from dicarbonates of formula

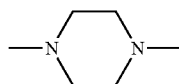


(IVa)

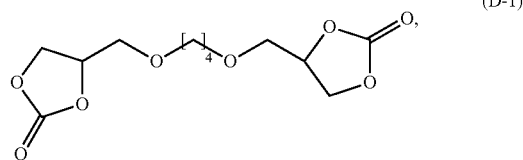
wherein X<sup>5</sup> is a group of formula



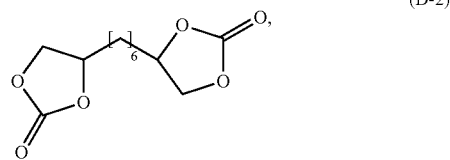
wherein k is 0, or 1, l is 0, or 1, X<sup>5'</sup> is a single bond, a phenyl group, which may be substituted by one, or more C<sub>1</sub>-C<sub>4</sub>alkyl, or C<sub>1-4</sub>alkoxy groups, or a C<sub>1</sub>-C<sub>12</sub>alkylen group, which may be substituted by one, or more C<sub>1</sub>-C<sub>4</sub>alkyl groups, X<sup>5''</sup> is a group



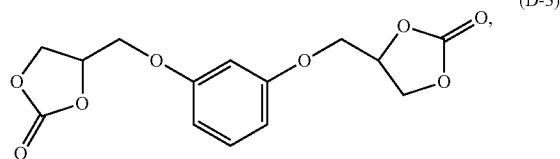
and q is 1, or X<sup>5''</sup> is a group —CH<sub>2</sub>— and q is 1 to 12, wherein part of the hydrogen atoms of the CH<sub>2</sub>-groups may be replaced by C<sub>1</sub>-C<sub>4</sub>alkyl groups, or X<sup>5''</sup> is a group —NR<sup>104</sup>—X<sup>5'''</sup>—NR<sup>104</sup>—, wherein R<sup>104</sup> is a C<sub>1</sub>-C<sub>8</sub>alkyl group and X<sup>5'''</sup> is a C<sub>1</sub>-C<sub>12</sub>alkylen group, which may be substituted by one, or more C<sub>1</sub>-C<sub>4</sub>alkyl groups. Examples of such dicarbonates are shown below:



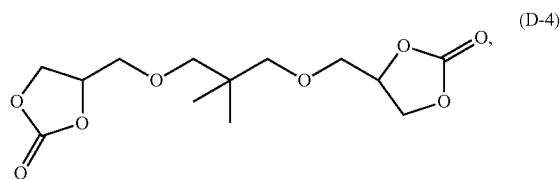
(D-1)



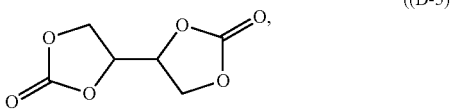
(D-2)



(D-3)



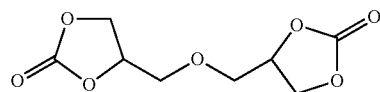
(D-4)



((D-5)

Stanislaus Schmidt et al., *Macromolecules* 50 (2017) 2296-2303),

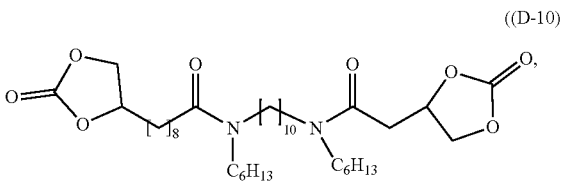
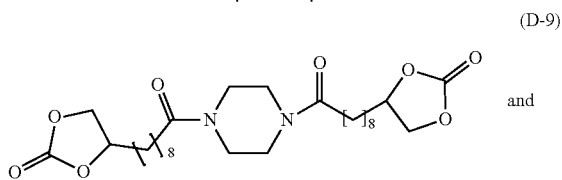
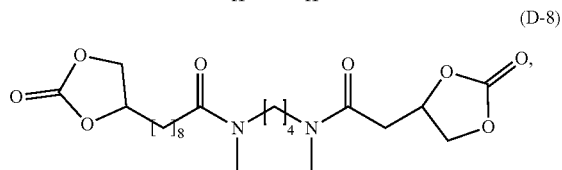
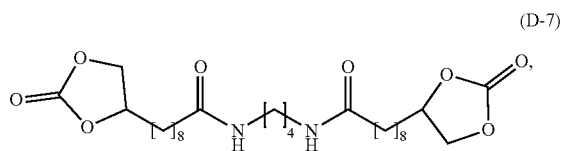
[0089]



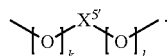
((D-6)

Mariusz Tryznowski et al., Polymer 80 (2015) 228-236,

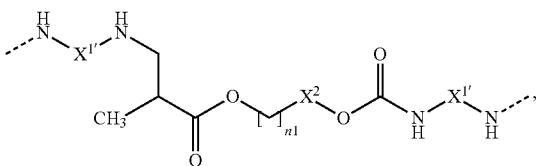
[0090]



Lise Maisonneuve et al., RSC Adv. 4 (2014) 25795-25803). Dicarbonates are preferred, wherein X<sup>5</sup> is a group of formula



[0091] In another preferred embodiment . . . HNX<sup>1</sup>NH . . . is a group of formula



wherein

[0092] X<sup>1</sup> has the meaning of the linking group X<sup>1</sup>,

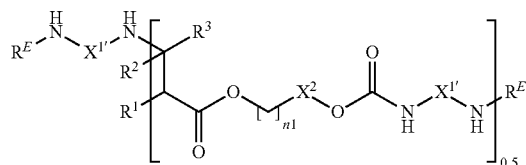
[0093] X<sup>2</sup> is a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—,

[0094] n<sub>1</sub> is an integer of 1 to 12, and

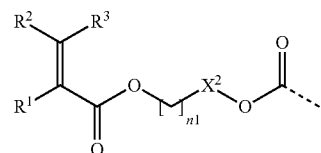
[0095] . . . HNX<sup>1</sup>NH . . . has the meaning of . . . HNX<sup>1</sup>NH . . .

[0096] In said embodiment the same preferences for the linking group X<sup>1</sup> apply as for the linking group X<sup>1</sup>.

[0097] In said embodiment the prepolymer is a prepolymer of formula



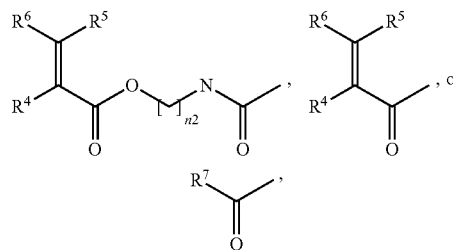
wherein R<sup>E</sup> is a group of formula



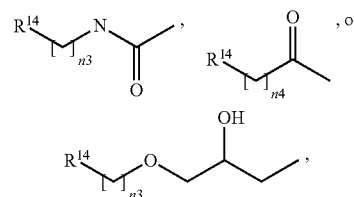
wherein

[0098] X<sup>1'</sup> is a linking group,

[0099] R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, n<sub>1</sub>; are defined above, or below. The hydrogen atom of the hydroxy groups and/or the amino groups of the prepolymer may be replaced by a group of formula



wherein R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup> and n<sub>2</sub> are defined above, or below, or by a group of formula



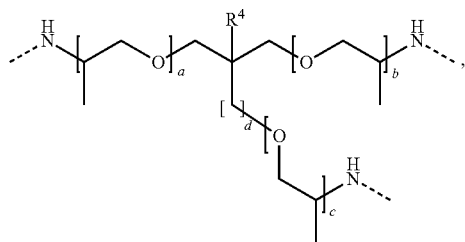
wherein

[0100] R<sup>14</sup>, n<sub>3</sub> and n<sub>4</sub> are defined above, or below.

[0101] However, the linking group X<sup>1</sup> may also be derived from amines having more than two functionalities. These include, for example, diethylenetriamine, triethylenetetramine and tetraethylenepentamine.

[0102] In another preferred embodiment X<sup>1</sup>(NH . . . )<sub>3</sub> is a group of formula

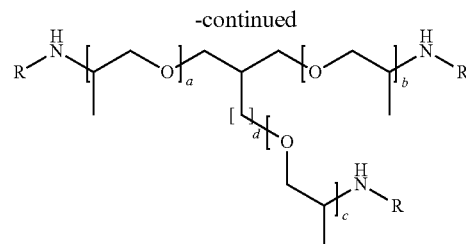
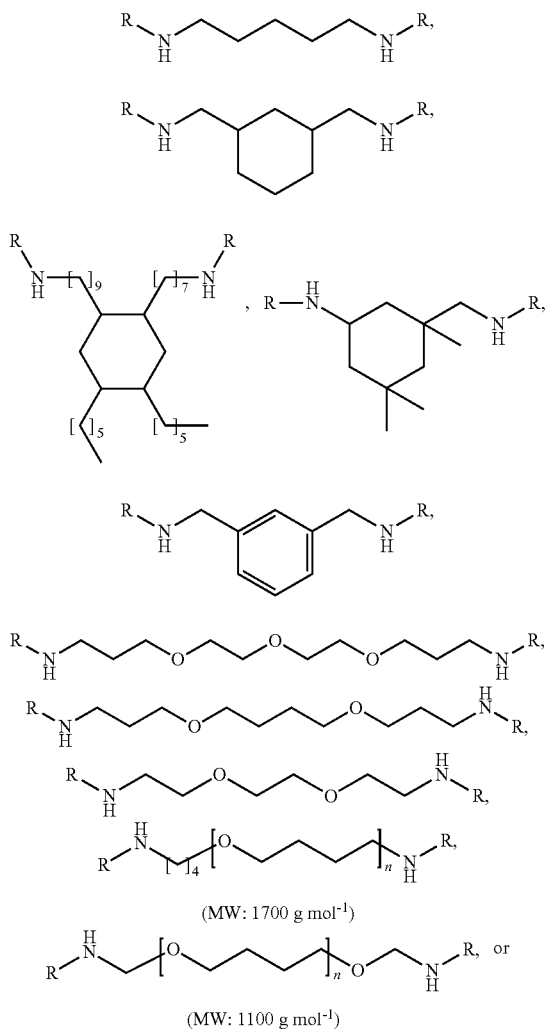




wherein R<sup>4</sup> is H, or C<sub>2</sub>H<sub>5</sub>, d is 0, or 1, a+b+c=5-85. Examples of corresponding triamines are Jeffamine® T-403, T-3000 and T-5000 (commercially available from Huntsman).

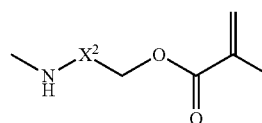
**[0103]** Also possible are mixtures of two or more different groups X<sup>1</sup> in any proportion.

**[0104]** Examples of preferred prepolymers are shown below:



wherein d is 0, a+b+c=50, or 5-6,

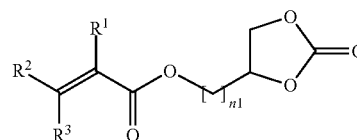
**[0105]** R is a group of formula



and X<sup>2</sup> is a group of formula  $-CH(CH_2OH)-$ , or  $-CH(OH)-(CH_2)-$ .

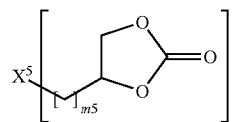
**[0106]** The process for the production of a prepolymer according to the present invention, comprises

**[0107]** a) reacting a cyclic carbonate of formula



(II)

with a polyamine of formula  $(H_2N)_mX^1$  (III), or reacting a diglycidylethercarbonate of formula



(IV)

**[0108]** with a polyamine of formula (III) and the obtained reaction product with a cyclic carbonate of formula (II), wherein

**[0109]** R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are independently of each other H, or a C<sub>1</sub>-C<sub>4</sub>-alkyl group, especially a methyl group;

**[0110]** n<sub>1</sub> is an integer of 1 to 12;

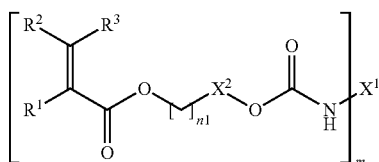
**[0111]** m is an integer of 1 to 4;

**[0112]** X<sup>1</sup> is a linking group,

**[0113]** X<sup>5</sup> is a linking group,

**[0114]** m<sub>5</sub> is 0, or an integer of 1 to 12.

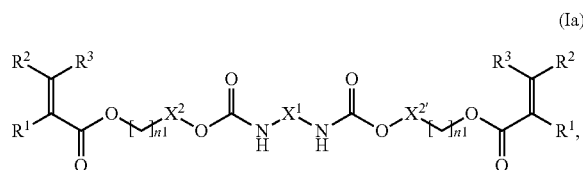
**[0115]** In a preferred embodiment the process is directed to the production of a prepolymer of formula



(I)

and comprises

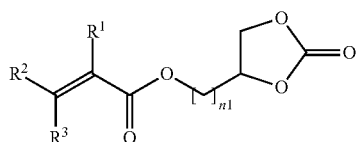
[0116] a) reacting a cyclic carbonate of formula



(Ia)

[0131] comprising

[0132] a) reacting a cyclic carbonate of formula



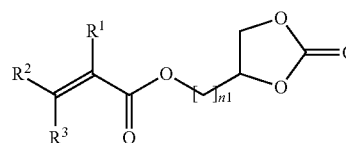
(II)

with

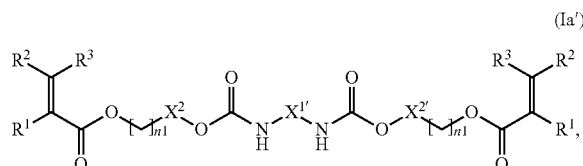
[0117] a polyamine of formula  $(H_2N)_m X^1$  (III), wherein[0118]  $R^1$ ,  $R^2$  and  $R^3$  are independently of each other H, or methyl,[0119]  $n_1$  is an integer of 1 to 12;[0120]  $m$  is an integer of 1 to 4;[0121]  $X^1$  is a linking group,[0122]  $X^2$  is independently in each occurrence a group of formula  $-CH(CH_2OH)-$ , or  $-CH(OH)-(CH_2)-$ .

[0123] In another preferred embodiment the process comprises

[0124] a) reacting a cyclic carbonate of formula



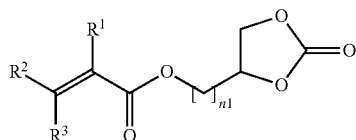
(II)

with a diamine of formula  $(H_2N)_2 X^1$  (IIIa), or the process is directed to the production of the prepolymer of formula

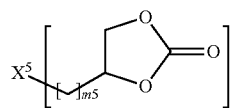
(Ia')

[0133] comprising

[0134] a) reacting a diglycidylethercarbonate of formula

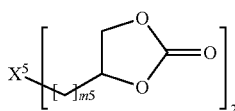


(II)

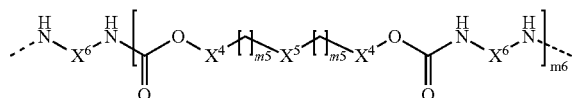
with a diamine of formula  $(H_2N)_2 X^1$  (IIIa), or reacting a diglycidylethercarbonate of formula

(IV)

with a diamine of formula (IIIa) and the obtained reaction product with a cyclic carbonate of formula (II), wherein

[0135]  $X^1$  is a linking group,[0136]  $\dots NHX^1NH \dots$  is a group of formula

(IV)



with a diamine of formula (IIIa) and the obtained reaction product with a cyclic carbonate of formula (II), wherein

[0125]  $X^1$  is a linking group,[0126]  $R^1$ ,  $R^2$  and  $R^3$  are independently of each other H, or methyl,[0127]  $n_1$  is an integer of 1 to 12;[0128]  $m_5$  is 0, or an integer of 1 to 12;[0129]  $X^5$  is a linking group.

[0130] In said embodiment the process is directed to the production of the prepolymer of formula

[0137]  $R^1$ ,  $R^2$  and  $R^3$  are independently of each other H, or methyl,[0138]  $n_1$  is an integer of 1 to 12;[0139]  $X^2$  is a group of formula  $-CH(CH_2OH)-$ , or  $-CH(OH)-(CH_2)-$ ,[0140]  $X^{2'}$  is a group of formula  $-CH(CH_2OH)-$ , or  $-CH(OH)-(CH_2)-$ , and[0141]  $X^4$  is a group of formula  $-CH(CH_2OH)-$ , or  $-CH(OH)-(CH_2)-$ ,

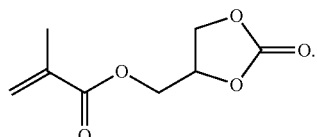
[0142]  $m_5$  is 0, or an integer of 1 to 12;

[0143]  $m_6$  is an integer of 1 to 20, especially 1 to 6;

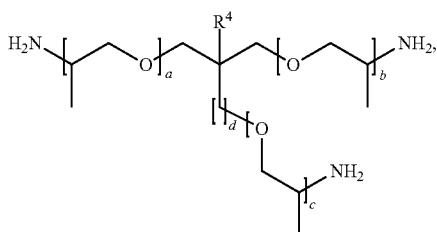
[0144]  $X^5$  is a linking group and  $X^6$  is a linking group.

[0145] The cyclic carbonate of formula (II) is preferably cyclic carbonate of formula (II), wherein  $R^2$  and  $R^3$  are H, or a methyl group; preferably H,

[0146]  $R^1$  is H, or a methyl group, preferably a methyl group and  $n_1$  is 1, especially a compound of formula

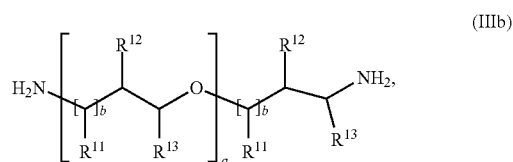


[0147] Examples of amines having more than two functionalities are diethylenetriamine, triethylenetetramine and tetraethylenepentamine, especially an amine of formula



wherein  $R^4$  is H, or  $C_2H_5$ ,  $d$  is 0, or 1,  $a+b+c=5-85$ . Examples of corresponding triamines are Jeffamine® T-403, T-3000 and T-5000 (commercially available from Huntsman).

[0148] Examples of diamines are polyether diamines of formula



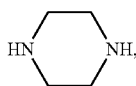
[0149]  $R^{11}$  is hydrogen, or a  $C_1$ - $C_4$ alkyl group;

[0150]  $R^{12}$  and  $R^{13}$  are the same or different and are each independently hydrogen, or a methyl group;

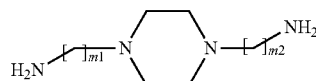
[0151]  $b$  is 0, or 1; and

[0152]  $a$  is an integer from 1 to 50. It should be noted that, for example, units with identical or different  $R^{11}$ ;  $R^{12}$  and  $R^{13}$  groups occur, in which case units with different substitution, i.e. propylene oxide- and/or ethylene oxide-based, are present in any sequence and repetition in the particular polyether diamine of formula (IIIb).

[0153] Examples of preferred diamines are shown below:

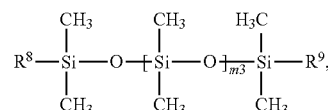


a group of formula



wherein  $m_1$  and  $m_2$  are an integer of 1 to 25, especially 1 to 8, very especially 1 to 4, such as, for example, 1,4-bis(3-aminopropyl)piperazine;

[0154] a group of formula

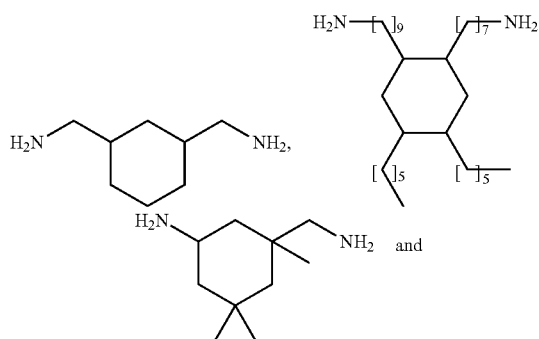


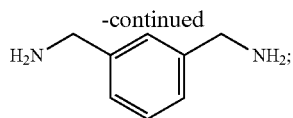
wherein

[0155]  $R^8$  and  $R^9$  are a group of formula  $-(CH_2)_{m_4}-NH_2$ ,  $m_3$  is 2 to 200 and  $m_4$  is an integer of 1 to 8;

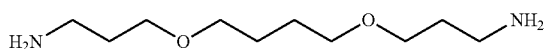
[0156] a group of formula  $H_2N-(CH_2)_{n_4}-NH_2$ , wherein part of the hydrogen atoms may be replaced by a  $C_1$ - $C_4$ alkyl group and  $n_4$  is an integer of 1 to 25, such as, for example, diaminoethane, diaminopropane, 1,2-diamino-2-methylpropane, 1,3-diamino-2,2-dimethylpropane, diaminobutane, diaminopentane, 1,5-diamino-2-methylpentane, neopentylidiamine, diaminohexane, 1,6-diamino-2,2,4-trimethylhexane, 1,6-diamino-2,4,4-trimethylhexane, diaminoheptane, diaminooctane, diaminononane, diaminodecane, diaminoundecane, diaminododecane, especially diaminopentane, diaminohexane, diaminododecane, or mixtures thereof;

[0157] a group of formula  $H_2N-(CH_2)_{n_5}-Y^1-(CH_2)_{n_6}-NH_2$ , wherein  $Y^1$  is a  $C_3$ - $C_8$ cycloalkyl group, or a phenylene group, which may be substituted by one, or more  $C_1$ - $C_8$ alkyl groups, and  $n_5$  and  $n_6$  independently of each other 0, or an integer 1 to 4, such as, for example, 1,4-cyclohexanediamine, 4,4'-methylenebiscyclohexylamine, 4,4'-isopropylenebiscyclohexylamine, isophoronediamine, m-xylylenediamine, 1,2-(bisaminomethyl)cyclohexane, 1,3-(bisaminomethyl)cyclohexane, 1,4-(bisaminomethyl)cyclohexane, bis(4-aminocyclohexyl)methane, especially groups of formula

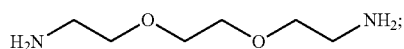




**[0158]** a group of formula  $\text{H}_2\text{N}-(\text{CH}_2)_{n7}-\text{O}(\text{CH}_2)_{n8}-\text{O}(\text{CH}_2)_{n9}-\text{NH}_2$ , wherein  $n7$ ,  $n8$  and  $n9$  are independently of each other an integer 2 to 4, such as, for example,

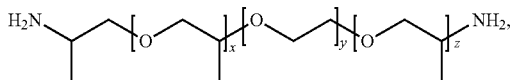


and



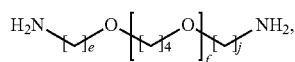
**[0159]** a group of formula  $\text{H}_2\text{N}-(\text{CH}_2)_{n10}-\text{O}(\text{CH}_2)_2-\text{O}(\text{CH}_2)_{n11}-\text{NH}_2$ , wherein  $n10$  and  $n11$  are independently of each other an integer 2 to 4; or

**[0160]** a group of formula



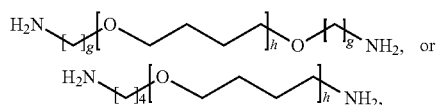
**[0161]** wherein  $y=0-39$ ,  $x+z=1-68$ ; or

**[0162]** a group of formula



wherein  $e$  and  $j$  are independently of each other an integer of 2 to 6 and  $f$  is an integer of 2 to 30; or

**[0163]** a group of formula



wherein  $g$  is an integer of 1 to 12;

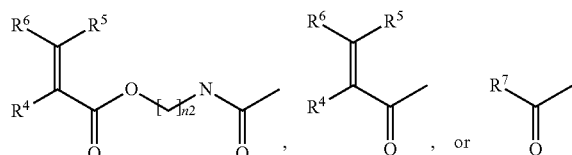
**[0164]**  $h$  is 3 to 50, especially 10 to 30.

**[0165]** The dicarbonate is preferably a dicarbonate of formula (IVa), especially a compound (D-1), (D-2), (D-3), (D-4), (D-5), or (D-6).

**[0166]** The amines of formula (III) are employed in amounts such that the ratio of the number of all the amino groups in the amines of formula (III) to the number of all the carbonate groups in the cyclic carbonate of formula (II) is 2:1 to 1:1, preferably 1.6:1 to 1:1, and more particularly 1.2:1.

**[0167]** The diamine of formula (IIIa) is used in an amount of 0.5 to 0.8, especially 0.5 to 0.6 equivalents based on 1 equivalent of cyclic carbonate of formula (II).

**[0168]** The process may comprise an additional step b), in which the hydrogen atoms of the hydroxy groups and/or the amino groups of the prepolymer are replaced by a group of formula

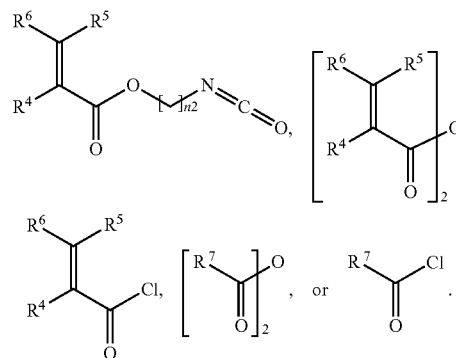


wherein

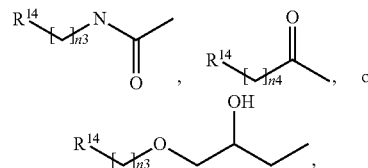
**[0169]**  $\text{R}^4$ ,  $\text{R}^5$  and  $\text{R}^6$  are independently of each other H, or a  $\text{C}_1$ - $\text{C}_4$ -alkyl group, especially a methyl group;

**[0170]**  $\text{R}^7$  is a  $\text{C}_1$ - $\text{C}_{25}$ alkyl group, a  $\text{C}_2$ - $\text{C}_{25}$ alkenyl group, or a phenyl group, which can be substituted by one, or more  $\text{C}_1$ - $\text{C}_8$ alkoxy groups,

**[0171]**  $n2$  is an integer of 1 to 12; by reacting the prepolymer obtained in step a) with a compound of formula

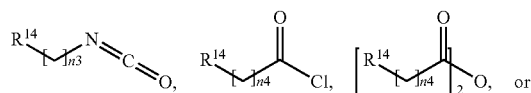


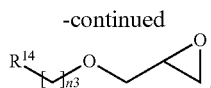
**[0172]** In addition, the hydrogen atoms of the hydroxy groups and/or the amino groups of the prepolymer may be replaced by a group of formula



wherein

**[0173]**  $\text{R}^{14}$ ,  $n3$  and  $n4$  are defined above, or below; by reacting the prepolymer obtained in step a) with a compound of formula





**[0174]** Preferably, no solvent or co-solvent is used in steps a) and/or b).

**[0175]** Catalysts may be used in step a). Said catalysts are any catalysts suitable for the reaction of carbonates with polyamines, such as, for example, inorganic lewis acids (e.g. MgBr<sub>2</sub>, Yb(OTf)<sub>3</sub>, Fe(OTf)<sub>3</sub>, FeCl<sub>3</sub>, Bi(OTf)<sub>3</sub>, LiOTf), organocatalysts, such as, for example, phosphines (e.g. triphenylphosphine), amine bases (e.g. 1,8-diazabicyclo[5.4.0]undec-7-en (DBU), 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD), 1,4-diazabicyclo[2.2.2]octane (DABCO), 4-dimethylaminopyridine (DMAP), thioureas and phosphazene. Combination of these catalysts are also possible (e.g. LiOTf with TBD or DBU).

**[0176]** The catalyst is added in an amount of 0.1-20 mol %, preferably 1-5 mol % based on mol of cyclic carbonate of formula (II).

**[0177]** Step a) is carried out at elevated temperature, such as a temperature of 80 to 120° C., preferably 90 to 110° C. Step a) can also be carried out at a higher temperature, provided no decomposition, or degradation, of the resulting product occurs, and/or provided that no premature polymerization occurs. Lower temperatures are also feasible in the presence of a suitable catalyst. In case of a reaction in bulk the viscosity of the reaction mixture typically demands elevated temperatures. The reaction time is 1 h to 6 d.

**[0178]** Inhibitors may be used in step a). Said inhibitors are any inhibitors suitable for preventing the thermal polymerization, decomposition, or degradation of the resulting products. Examples of conventional inhibitors include butylated hydroxytoluene, hydroquinone, hydroquinone monomethyl ether, or derivatives thereof; 4-hydroxy-2,2,6,6-tetramethyl-1-piperidinyloxy (4-hydroxy-TEMPO), and phenothiazine. Other known types of polymerisation inhibitors include diaryl amines, sulphur-coupled olefins, or hindered phenols. The presence of oxygen in the atmosphere is also a well-known to prevent radical polymerization and therefore the reaction is preferably performed under air atmosphere. In addition, the reaction mixture should be stirred vigorously in order to promote the interaction with the oxygen.

**[0179]** The inhibitor is added in an amount of 0.01-1 wt %, preferably 0.1-0.6 wt %.

**[0180]** Diluent (B)

**[0181]** The reactive diluent (B) may be a single diluent, or a mixture of two, or more diluents.

**[0182]** The diluent (B) is contained in an amount of 20 to 80% by weight, especially 30 to 70% by weight, very especially 40 to 60% by weight based on the amount of components (A), (B), (C) and (D).

**[0183]** The diluent (B) is preferably selected from acrylamides, methacrylamides, acrylates, methacrylates, vinylamides, difunctional acrylates and methacrylates and mixtures thereof.

**[0184]** Suitable monofunctional, difunctional, or tetrafunctional acrylate, methacrylate, or vinylamide components are listed below. Monofunctional refers to the fact that the molecule of the compound exhibits only one acrylate, methacrylate, or vinylamide functional group.

**[0185]** Examples of monofunctional vinylamide components include such as N-vinyl-pyrrolidone, vinyl-imidazole, N-vinylcaprolactame, N-(hydroxymethyl)vinylamide, N-hydroxyethyl vinylamide, N-isopropylvinylamide, N-isopropylmethvinylamide, N-tert-butylvinylamide, N,N'-methylenebisvinylamide, N-(isobutoxymethyl)vinylamide, N-(butoxymethyl)vinylamide, N-[3-(dimethylamino)propyl]methvinylamide, N,N-dimethylvinylamide, N,N-diethylvinylamide and N-methyl-N-vinylacetamide.

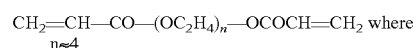
**[0186]** Examples of monofunctional methacrylate include isobornyl methacrylate, tetrahydrofurfuryl methacrylate, ethoxylated phenyl methacrylate, cyclohexylmethacrylate, lauryl methacrylate, stearyl methacrylate, octyl methacrylate, isodecyl methacrylate, tridecyl methacrylate, caprolactone methacrylate, nonyl phenol methacrylate, cyclic trimethylolpropane formal methacrylate, methoxy polyethyleneglycol methacrylates, methoxy polypropyleneglycol methacrylates, hydroxyethyl methacrylate, hydroxypropyl methacrylate and glycidyl methacrylate.

**[0187]** The photocurable composition of the present invention may contain a difunctional, or tetrafunctional diluent having two unsaturated carbon-carbon bonds, such as, for example, difunctional, or tetrafunctional (meth)acrylates.

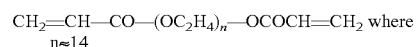
**[0188]** Examples of the bifunctional monomer include 1,3-butylene glycol di(meth)acrylate, 1,4-butanediol di(meth)acrylate, diethylene glycol di(meth)acrylate, 1,6-hexanediol di(meth)acrylate, polyethylene glycol (200) di(meth)acrylate, tetraethylene glycol di(meth)acrylate, triethylene glycol di(meth)acrylate, tripropylene glycol di(meth)acrylate, polyethylene glycol (400) di(meth)acrylate, ethoxylated (3) bisphenol A di(meth)acrylate, dipropylene glycol di(meth)acrylate, alkoxyated hexanediol di(meth)acrylate, ethoxylated (4) bisphenol A di(meth)acrylate, ethoxylated (10) bisphenol A di(meth)acrylate, polyethylene glycol (600) di(meth)acrylate, tricyclodecane dimethanol di(meth)acrylate, 1,9-nonanediol di(meth)acrylate, 1,10-decanediol di(meth)acrylate, neopentyl glycol di(meth)acrylate, polytetramethylene glycol di(meth)acrylate, 3-methyl-1,5-pentanediol di(meth)acrylate, and dimethylol-tricyclodecane di(meth)acrylate. One of these may be used alone, or two or more of these may be used in combination.

**[0189]** Polyethylene glycol (200) diacrylate, polyethylene glycol (400) diacrylate, and polyethylene glycol (600) diacrylate mentioned above are represented by the chemical formulae below.

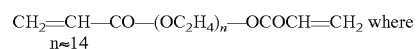
**[0190]** Polyethylene glycol (200) diacrylate



**[0191]** Polyethylene glycol (400) diacrylate



**[0192]** Polyethylene glycol (600) diacrylate



**[0193]** Examples of tetrafunctional (meth)acrylates are bistrimethylolpropane tetraacrylate, pentaerythritol tetraacrylate, tetramethylolmethane tetramethacrylate, pentaerythritol tetramethacrylate, bistrimethylolpropane tetramethacrylate, ethoxylated pentaerythritol tetraacrylate, propoxylated pentaerythritol tetraacrylate, dipentaerythritol tetraacrylate, ethoxylated dipentaerythritol tetraacrylate, propoxylated

dipentaerythritol tetraacrylate, aryl urethane tetraacrylates, aliphatic urethane tetraacrylates, melamine tetraacrylates, epoxy novolac tetraacrylates and polyester tetraacrylates.

**[0194]** The photocurable composition of the present invention may contain monofunctional acrylamides or methacrylamides. Examples include acryloylmorpholine, methacryloylmorpholine, N-(hydroxymethyl)acrylamide, N-hydroxyethyl acrylamide, N-isopropylacrylamide, N-isopropylmethacrylamide, N-tert-butylacrylamide, N,N'-methylenebisacrylamide, N-(isobutoxymethyl)acrylamide, N-(butoxymethyl)acrylamide, N-[3-(dimethylamino)propyl]methacrylamide, N,N-dimethylacrylamide, N,N-diethylacrylamide, N-(hydroxymethyl)methacrylamide, N-hydroxyethyl methacrylamide, N-isopropylmethacrylamide, N-isopropylmethmethacrylamide, N-tert-butylmethacrylamide, N,N'-methylenebismethacrylamide, N-(isobutoxymethyl)methacrylamide, N-(butoxymethyl)methacrylamide, N-[3-(dimethylamino)propyl]methmethacrylamide, N,N-dimethylmethacrylamide and N,N-diethylmethacrylamide.

**[0195]** Oligomer (C)

**[0196]** The photocurable composition may contain an oligomer (C). The oligomer (C) is selected from polyester (meth)acrylates, polyether (meth)acrylates, carbonate (meth)acrylates, epoxy (meth)acrylates and urethane (meth)acrylates, including amine-modified oligomers. The oligomer (C) may be single oligomer, or a mixture of two, or more oligomers.

**[0197]** Urethane (meth)acrylates are obtainable for example by reacting polyisocyanates with hydroxyalkyl (meth)acrylates and optionally chain extenders such as diols, polyols, diamines, polyamines, dithiols or polythiols.

**[0198]** Urethane (meth)acrylates of this kind comprise as synthesis components substantially:

**[0199]** (1) at least one organic aliphatic, aromatic or cycloaliphatic di- or polyisocyanate,

**[0200]** (2) at least one compound having at least one isocyanate-reactive group and at least one radically polymerizable unsaturated group, and

**[0201]** (3) optionally, at least one compound having at least two isocyanate-reactive groups.

**[0202]** Suitable components (1) are, for example, aliphatic, aromatic, and cycloaliphatic diisocyanates and polyisocyanates having an NCO functionality of at least 2, preferably 2 to 5, and more preferably more than 2 to 4.

**[0203]** Polyisocyanates contemplated include polyisocyanates containing isocyanurate groups, uretdione diisocyanates, polyisocyanates containing biuret groups, polyisocyanates containing urethane groups or allophanate groups, polyisocyanates comprising oxadiazinetrione groups, uretonimine-modified polyisocyanates of linear or branched C<sub>4</sub>-C<sub>20</sub> alkylene diisocyanates, cycloaliphatic diisocyanates having a total of 6 to 20 C atoms, or aromatic diisocyanates having a total of 8 to 20 C atoms, or mixtures thereof.

**[0204]** Examples of customary diisocyanates are aliphatic diisocyanates such as tetramethylene diisocyanate, hexamethylene diisocyanate (1,6-diisocyanatohexane), trimethylhexamethylene diisocyanate, octamethylene diisocyanate, decamethylene diisocyanate, dodecamethylene diisocyanate, tetradecamethylene diisocyanate, derivatives of lysine diisocyanate, tetramethylxylylene diisocyanate, trimethylhexane diisocyanate or tetramethylhexane diisocyanate, cycloaliphatic diisocyanates such as 1,4-, 1,3- or 1,2-diisocyanatocyclohexane, 4,4'- or 2,4'-di(isocyanatocyclohexyl)methane, 1-isocyanato-3,3,5-trimethyl-5-(isocyanatom-

ethyl)cyclohexane (isophorone diisocyanate), 1,3- or 1,4-bis(isocyanatomethyl)cyclohexane or 2,4- or 2,6-diisocyanato-1-methylcyclohexane, and also aromatic diisocyanates such as tolylene 2,4- or 2,6-diisocyanate and the isomer mixtures thereof, m- or p-xylylene diisocyanate, 2,4'- or 4,4'-diisocyanato-diphenylmethane and the isomer mixtures thereof, phenylene 1,3- or 1,4-diisocyanate, 1-chlorophenylene 2,4-diisocyanate, naphthylene 1,5-diisocyanate, diphenylene 4,4'-diisocyanate, 4,4'-diisocyanato-3, 3'-dimethylbiphenyl, 3-methyldiphenylmethane 4,4'-diisocyanate, tetramethylxylylene diisocyanate, 1,4-diisocyanatobenzene or diphenyl ether 4,4'-diisocyanate.

**[0205]** Mixtures of the stated diisocyanates may also be present.

**[0206]** Contemplated as component (2) in accordance with the invention is at least one compound (2) which carries at least one isocyanate-reactive group and at least one radically polymerizable group.

**[0207]** The compounds (2) preferably have precisely one isocyanate-reactive group and 1 to 5, more preferably 1 to 4, and very preferably 1 to 3 radically polymerizable groups.

**[0208]** The components (2) preferably have a molar weight of below 10 000 g/mol, more preferably below 5000 g/mol, very preferably below 4000 g/mol, and more particularly below 3000 g/mol. Special components (b) have a molar weight of below 1000 or even below 600 g/mol.

**[0209]** Isocyanate-reactive groups may be, for example, —OH, —SH, —NH<sub>2</sub>, and —NHR<sup>100</sup>, where R<sup>100</sup> is hydrogen or an alkyl group containing 1 to 4 carbon atoms, such as methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl or tert-butyl, for example. Components (2) may be, for example, monoesters of α,β-unsaturated carboxylic acids, such as acrylic acid, methacrylic acid, crotonic acid, itaconic acid, fumaric acid, maleic acid, acrylamidoglycolic acid and methacrylamidoglycolic acid, and polyols, which have preferably 2 to 20 C atoms and at least two hydroxyl groups, such as ethylene glycol, diethylene glycol, triethylene glycol, propylene 1,2-glycol, propylene 1,3-glycol, 1,1-dimethyl-1,2-ethanediol, dipropylene glycol, triethylene glycol, tetraethylene glycol, pentaethylene glycol, tripropylene glycol, 1,2-, 1,3- or 1,4-butanediol, 1,5-pentanediol, neopentyl glycol, 1,6-hexanediol, 2-methyl-1,5-pentanediol, 2-ethyl-1,4-butanediol, 1,4-dimethylolcyclohexane, 2,2-bis(4-hydroxycyclohexyl)propane, glycerol, trimethylolthane, trimethylolpropane, trimethylolbutane, pentaerythritol, ditrimethylolpropane, erythritol, sorbitol, polyethylene glycol having a molar mass of between 106 and 2000, polypropylene glycol having a molar weight of between 134 and 2000, polyTHF having a molar weight of between 162 and 2000 or poly-1,3-propanediol having a molar weight of between 134 and 400. In addition it is also possible to use esters or amides of (meth)acrylic acid with amino alcohols such as 2-aminoethanol, 2-(methylamino)ethanol, 3-amino-1-propanol, 1-amino-2-propanol or 2-(2-aminoethoxy)ethanol, for example, 2-mercaptoethanol or polyaminoalkanes, such as ethylenediamine or diethylenetriamine, or vinylacetic acid.

**[0210]** Also suitable, furthermore, albeit less preferably, are unsaturated polyetherols or polyesterols or polyacrylate polyols having an average OH functionality of 2 to 10.

**[0211]** Examples of amides of ethylenically unsaturated carboxylic acids with amino alcohols are hydroxyalkyl (meth)acrylamides such as N-hydroxymethylacrylamide, N-hydroxymethylmethacrylamide, N-hydroxyethylacrylamide, N-hydroxyethylmethacrylamide, 5-hydroxy-3-oxapen-

tyl(meth)acrylamide, N-hydroxyalkylcrotonamides such as N-hydroxymethylcrotonamide, or N-hydroxyalkylmaleimides such as N-hydroxyethylmaleimide.

**[0212]** Preference is given to using 2-hydroxyethyl (meth)acrylate, 2- or 3-hydroxypropyl (meth)acrylate, 1,4-butanediol mono(meth)acrylate, neopentyl glycol mono(meth)acrylate, 1,5-pentanediol mono(meth)acrylate, 1,6-hexanediol mono(meth)acrylate, glycerol mono(meth)acrylate and di(meth)acrylate, trimethylolpropane mono(meth)acrylate and di(meth)acrylate, pentaerythritol mono(meth)acrylate, di(meth)acrylate, and tri(meth)acrylate, and also 2-aminoethyl (meth)acrylate, 2-aminopropyl (meth)acrylate, 3-aminopropyl (meth)acrylate, 4-aminobutyl (meth)acrylate, 6-aminohexyl (meth)acrylate, 2-thioethyl (meth)acrylate, 2-aminoethyl(meth)acrylamide, 2-amino-propyl(meth)acrylamide, 3-aminopropyl(meth)acrylamide, 2-hydroxyethyl(meth)acrylamide, 2-hydroxypropyl(meth)acrylamide, or 3-hydroxypropyl(meth)acrylamide. Particularly preferred are 2-hydroxyethyl acrylate, 2-hydroxyethyl methacrylate, 2- or 3-hydroxypropyl acrylate, 1,4-butanediol monoacrylate, 3-(acryloyloxy)-2-hydroxypropyl (meth)acrylate, and also the monoacrylates of polyethylene glycol with a molar mass of 106 to 238.

**[0213]** Contemplated as component (3) are compounds which have at least two isocyanate-reactive groups, examples being —OH, —SH, —NH<sub>2</sub> or —NH R<sup>101</sup>, in which R<sup>101</sup> therein, independently of one another, may be hydrogen, methyl, ethyl, isopropyl, n-propyl, n-butyl, isobutyl, sec-butyl or tert-butyl.

**[0214]** Compounds (3) having precisely 2 isocyanate-reactive groups are preferably diols having 2 to 20 carbon atoms, examples being ethylene glycol, 1,2-propanediol, 1,3-propanediol, 1,1-dimethylethane-1,2-diol, 2-butyl-2-ethyl-1,3-propanediol, 2-ethyl-1,3-propanediol, 2-methyl-1,3-propanediol, neopentyl glycol, neopentyl glycol hydroxypivalate, 1,2-, 1,3- or 1,4-butanediol, 1,6-hexanediol, 1,10-decanediol, bis(4-hydroxycyclohexane)isopropylidene, tetramethylcyclobutanediol, 1,2-, 1,3- or 1,4-cyclohexanediol, cyclooctanediol, norbornanediol, pinanediol, decalindiol, 2-ethyl-1,3-hexanediol, 2,4-diethyloctane-1,3-diol, hydroquinone, bisphenol A, bisphenol F, bisphenol B, bisphenol S, 2,2-bis(4-hydroxycyclohexyl)propane, 1,1-, 1,2-, 1,3-, and 1,4-cyclohexanedimethanol, 1,2-, 1,3-, or 1,4-cyclohexanediol, polyTHF having a molar mass of between 162 and 2000, poly-1,2-propanediol or poly-1,3-propanediol having a molar mass of between 134 and 1178 or polyethylene glycol having a molar mass of between 106 and 2000, and also aliphatic diamines, such as methylene- and isopropylidene-bis(cyclohexylamine), piperazine, 1,2-, 1,3- or 1,4-diaminocyclohexane, 1,2-, 1,3-, or 1,4-cyclohexanebis(methylamine), etc., dithiols or polyfunctional alcohols, secondary or primary amino alcohols, such as ethanolamine, monopropylamine, etc. or thio alcohols, such as thioethylene glycol.

**[0215]** Particularly suitable here are the cycloaliphatic diols, such as, for example, bis(4-hydroxycyclohexane)isopropylidene, tetramethylcyclobutanediol, 1,2-, 1,3-, or 1,4-cyclohexanediol, 1,1-, 1,2-, 1,3-, and 1,4-cyclohexanedimethanol, cyclooctanediol or norbornanediol.

**[0216]** Further compounds (3) may be compounds having at least three isocyanate-reactive groups.

**[0217]** For example, these components may have 3 to 6, preferably 3 to 5, more preferably 3 to 4, and very preferably 3 isocyanate-reactive groups.

**[0218]** The molecular weight of these components is generally not more than 2000 g/mol, preferably not more than 1500 g/mol, more preferably not more than 1000 g/mol, and very preferably not more than 500 g/mol.

**[0219]** The urethane (meth)acrylates preferably have a number-average molar weight  $M_n$  of 500 to 20 000, in particular of 500 to 10 000 and more preferably 600 to 3000 g/mol (determined by gel permeation chromatography using tetrahydrofuran and polystyrene as standard).

**[0220]** Epoxy (meth)acrylates are obtainable by reacting epoxides with (meth)acrylic acid. Examples of suitable epoxides include epoxidized olefins, aromatic glycidyl ethers or aliphatic glycidyl ethers, preferably those of aromatic or aliphatic glycidyl ethers.

**[0221]** Examples of possible epoxidized olefins include ethylene oxide, propylene oxide, iso-butylene oxide, 1-butene oxide, 2-butene oxide, vinyloxirane, styrene oxide or epichlorohydrin, preference being given to ethylene oxide, propylene oxide, isobutylene oxide, vinyloxirane, styrene oxide or epichlorohydrin, particular preference to ethylene oxide, propylene oxide or epichlorohydrin, and very particular preference to ethylene oxide and epichlorohydrin.

**[0222]** Aromatic glycidyl ethers are, for example, bisphenol A diglycidyl ether, bisphenol F diglycidyl ether, bisphenol B diglycidyl ether, bisphenol S diglycidyl ether, hydroquinone diglycidyl ether, alkylation products of phenol/dicyclopentadiene, e.g., 2,5-bis[(2,3-epoxypropoxy)phenyl]octahydro-4,7-methano-5H-indene (CAS No. [13446-85-0]), tris[4-(2,3-epoxypropoxy)phenyl]methane isomers (CAS No. [66072-39-7]), phenol-based epoxy novolaks (CAS No. [9003-35-4]), and cresol-based epoxy novolaks (CAS No. [37382-79-9]).

**[0223]** Examples of aliphatic glycidyl ethers include 1,4-butanediol diglycidyl ether, 1,6-hexanediol diglycidyl ether, trimethylolpropane triglycidyl ether, pentaerythritol tetraglycidyl ether, 1,1,2,2-tetrakis[4-(2,3-epoxypropoxy)phenyl]ethane (CAS No. [27043-37-4]), diglycidyl ether of polypropylene glycol ( $\alpha,\omega$ -bis(2,3-epoxypropoxy)poly(oxypropylene), CAS No. [16096-30-3]) and of hydrogenated bisphenol A (2,2-bis[4-(2,3-epoxypropoxy)cyclohexyl]propane, CAS No. [13410-58-7]).

**[0224]** The epoxy (meth)acrylates preferably have a number-average molar weight  $M_n$  of 200 to 20 000, more preferably of 200 to 10 000 g/mol, and very preferably of 250 to 3000 g/mol; the amount of (meth)acrylic groups is preferably 1 to 5, more preferably 2 to 4, per 1000 g of epoxy (meth)acrylate (determined by gel permeation chromatography using polystyrene as standard and tetrahydrofuran as eluent).

**[0225]** Carbonate (meth)acrylates comprise on average preferably 1 to 5, especially 2 to 4, more preferably 2 to 3 (meth)acrylic groups, and very preferably 2 (meth)acrylic groups.

**[0226]** The number-average molecular weight  $M_n$  of the carbonate (meth)acrylates is preferably less than 3000 g/mol, more preferably less than 1500 g/mol, very preferably less than 800 g/mol (determined by gel permeation chromatography using polystyrene as standard, tetrahydrofuran as solvent).

**[0227]** The carbonate (meth)acrylates are obtainable in a simple manner by transesterifying carbonic esters with polyhydric, preferably dihydric, alcohols (diols, hexanediol for example) and subsequently esterifying the free OH groups

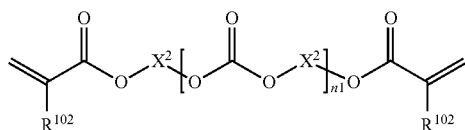
with (meth)acrylic acid, or else by transesterification with (meth)acrylic esters, as described for example in EP-A 92 269. They are also obtainable by reacting phosgene, urea derivatives with polyhydric, e.g., dihydric, alcohols.

[0228] Also conceivable are (meth)acrylates of polycarbonate polyols, such as the reaction product of one of the aforementioned diols or polyols and a carbonic ester and also a hydroxyl-containing (meth)acrylate.

[0229] Examples of suitable carbonic esters include ethylene carbonate, 1,2- or 1,3-propylene carbonate, dimethyl carbonate, diethyl carbonate or dibutyl carbonate.

[0230] Examples of suitable hydroxyl-containing (meth)acrylates are 2-hydroxyethyl (meth)acrylate, 2- or 3-hydroxypropyl (meth)acrylate, 1,4-butanediol mono(meth)acrylate, neopentyl glycol mono(meth)acrylate, glyceryl mono- and di(meth)acrylate, trimethylolpropane mono- and di(meth)acrylate, and pentaerythritol mono-, di-, and tri(meth)acrylate.

[0231] Particularly preferred carbonate (meth)acrylates are those of the formula:



[0232] in which  $R^{102}$  is H or  $CH_3$ ,  $X^2$  is a  $C_2$ - $C_{18}$  alkylene group, and  $n$  is an integer from 1 to 5, preferably 1 to 3.

[0233]  $R^{102}$  is preferably H and  $X^2$  is preferably  $C_2$  to  $C_{10}$  alkylene, examples being 1,2-ethylene, 1,2-propylene, 1,3-propylene, 1,4-butylene, and 1,6-hexylene, more preferably  $C_4$  to  $C_8$  alkylene. With very particular preference  $X^2$  is  $C_6$  alkylene.

[0234] The carbonate (meth)acrylates are preferably aliphatic carbonate (meth)acrylates.

[0235] Among the oligomers (B) urethane (meth)acrylates are particularly preferred.

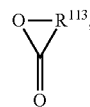
[0236] A urethane (meth)acrylate may refer to a single urethane (meth)acrylate or to a mixture of different urethane (meth)acrylates. Suitable urethane (meth)acrylates can be monofunctional, but preferably are difunctional, or of higher functionality. The functionality refers to the number of (meth)acrylate functional groups exhibited by the compound.

[0237] Preferred are urethane (meth)acrylates made from polyetherdiols, or polyester diols, aliphatic, aromatic, or cyclic diisocyanates and hydroxyalkyl (meth)acrylates. More preferred are urethane (meth)acrylates made from polyester diols, aromatic, or cyclic diisocyanates and hydroxyalkyl (meth)acrylates.

[0238] The diisocyanates are preferably selected from 4,4'-, 2,4'- and/or 2,2'-methylene-dicyclohexyl diisocyanate (H12MDI), isophorone diisocyanates (IPDI) and tolylene 2,4- and/or 2,6-diisocyanate (TDI).

[0239] The hydroxyalkyl (meth)acrylates are preferably selected from 2-hydroxyethyl acrylate, 2-hydroxyethyl methacrylate, 2- or 3-hydroxypropyl acrylate, 2- or 3-hydroxypropyl methacrylate, 4-hydroxybutyl methacrylate, and 4-hydroxybutyl acrylate.

[0240] Also preferred are urethane (meth)acrylates made from lactones of formula



(B)

aliphatic, aromatic, or cyclic diisocyanates and hydroxyalkyl (meth)acrylates. More preferred are urethane (meth)acrylates made from caprolactone, aliphatic, or cyclic diisocyanates and hydroxyalkyl (meth)acrylates.

[0241] The diisocyanates are preferably selected from di(isocyanatocyclohexyl)methane, 2,2,4- and 2,4,4-trimethylhexane diisocyanate, and especially 4,4'-, 2,4'- and/or 2,2'-methylene-dicyclohexyl diisocyanate (H12MDI).

[0242] The hydroxyalkyl (meth)acrylates are preferably selected from 2-hydroxyethyl acrylate, 2-hydroxyethyl methacrylate, 2- or 3-hydroxypropyl acrylate, 2- or 3-hydroxypropyl methacrylate, 4-hydroxybutyl methacrylate, and 4-hydroxybutyl acrylate.

[0243] Also preferred are those having polyfunctionality of (meth)acrylates or mixed acrylic and methacrylic functionality.

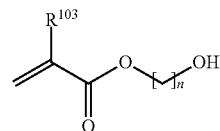
[0244] In a preferred embodiment the polyester urethane (meth)acrylate (B) is obtained by reacting

[0245] (B1) a hydroxyalkylacrylate, or hydroxyalkylmethacrylate,

[0246] (B2) an aliphatic diisocyanate, an aliphatic polyisocyanate, a cycloaliphatic diisocyanate, a cycloaliphatic polyisocyanate, an aromatic diisocyanate, or an aromatic polyisocyanate, or mixtures thereof, especially an aliphatic diisocyanate, cycloaliphatic diisocyanate, or an aromatic diisocyanate, or mixtures thereof,

[0247] (B3) a polyester polyol, which is derived from aliphatic dicarboxylic acids and aliphatic diols, and (B4) optionally a secondary polyol, especially glycerol.

[0248] The hydroxyalkylacrylate, or hydroxyalkylmethacrylate (B1) is preferably a compound of formula



wherein  $R^{103}$  is a hydrogen atom, or a methyl group, and  $n$  is 2 to 6, especially 2 to 4. Examples of (B1) include 2-hydroxyethyl acrylate, 2-hydroxyethyl methacrylate, 2- or 3-hydroxypropyl acrylate, 2- or 3-hydroxypropyl methacrylate, 4-hydroxybutyl methacrylate and 4-hydroxybutyl acrylate. 2-Hydroxyethyl acrylate is most preferred.

[0249] Hydroxyalkylacrylates, or hydroxyalkylmethacrylates (B1) having shorter alkyl chains ( $n$  is 2 to 4, especially 2) lead to a higher E modulus of the UV cured composition. Hydroxyalkyl-methacrylates (B1) lead to a higher E modulus as compared to hydroxyalkylacrylates.

[0250] The organic diisocyanate (B2) used for making the polyester urethane acrylate is either an aliphatic, a cycloaliphatic, or an aromatic diisocyanate.

[0251] Examples of customary aliphatic and cycloaliphatic diisocyanates are tri-, tetra-, penta-, hexa-, hepta- and/or octamethylene diisocyanate, 2-methylpentamethylene 1,5-diisocyanate, 2-ethyltetramethylene 1,4-diisocya-



nate, hexamethylene 1,6-diisocyanate (HDI), pentamethylene 1,5-diisocyanate, butylene 1,4-diisocyanate, trimethylhexamethylene 1,6-diisocyanate, 1-isocyanato-3,3,5-trimethyl-5-isocyanatomethylcyclohexane (isophorone diisocyanate, IPDI), 1,4- and/or 1,3-bis(isocyanatomethyl)cyclohexane (HXDI), 1,4-cyclohexane diisocyanate, 1-methyl-2,4- and/or 1-methyl-2,6-cyclohexane diisocyanate, 4,4'-, 2,4'- and/or 2,2'-methylenedicyclohexyl diisocyanate (H12MDI).

**[0252]** Preferred aliphatic and cycloaliphatic polyisocyanates are hexamethylene 1,6-diisocyanate (HDI), 1-isocyanato-3,3,5-trimethyl-5-isocyanatomethylcyclohexane (isophorone diisocyanate, IPDI) and 4,4'-, 2,4'- and/or 2,2'-methylenedicyclohexyl diisocyanate (H12MDI); particular preference is given to H12MDI and IPDI or mixtures thereof. Suitable aromatic diisocyanates include naphthylene 1,5-diisocyanate (NDI), tolylene 2,4- and/or 2,6-diisocyanate (TDI), diphenylmethane 2,2'-, 2,4'- and/or 4,4'-diisocyanate (MDI), 3,3'-dimethyl-4,4'-diisocyanatodiphenyl (TODI), p-phenylene diisocyanate (PDI), diphenylethan-4,4'-diisocyanate (EDI), diphenylmethandiiisocyanate, 3,3'-dimethyl-diphenyl-diisocyanate, 1,2-diphenylethandiisocyanate and/or phenylene diisocyanate.

**[0253]** The at present most preferred diisocyanates are 4,4'-, 2,4'- and/or 2,2'-methylenedicyclohexyl diisocyanate (H12MDI), isophorone diisocyanates (IPDI), or tolylene 2,4- and/or 2,6-diisocyanate (TDI).

**[0254]** Polyester polyols (B3) derived from dicarboxylic acid and diols are preferred and, for example, described in US20160122465. The dicarboxylic acids used for making the polyester polyol include aliphatic, or cycloaliphatic dicarboxylic acids, or combinations thereof. Among them, aliphatic dicarboxylic acids are preferred. Suitable aliphatic dicarboxylic acids which can be used alone or in mixture typically contain from 4 to 12 carbon atoms and include: succinic acid, glutaric acid, adipic acid, pimelic acid, suberic acid, and the like. Adipic acid is preferred.

**[0255]** The diols used for making the polyester polyol include aliphatic, or cycloaliphatic diols, or combinations thereof, preferably aliphatic diols containing 2 to 8 carbon atoms and more preferably 2 to 6 carbon atoms. Some representative examples of aliphatic diols that can be used include ethylene glycol, 1,3-propanediol, 1,4-butanediol, 1,5-pentanediol, 1,6-hexanediol and the like.

**[0256]** In a preferred embodiment, only one kind of aliphatic dicarboxylic acid is used in making the polyester polyol. In another preferred embodiment, one or two kinds of aliphatic diols are used in making the polyester polyol. Most preferably, the polyester polyol is derived from adipic acid and ethylene glycol and 1,4-butanediol (poly(ethylene 1,4-butylene adipate) diol, PEBA). In the PEBA, the molar ratio of ethylene glycol to 1,4-butanediol is from 0.05:1 to 10:1, preferably from 0.2:1 to 5:1, more preferably 0.5:1 to 1.5:1, most preferred from 0.75:1 to 1.25:1.

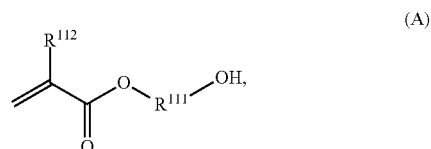
**[0257]** The linear polyester polyol will typically have a number average molecular weight within the range of  $4 \times 10^2$  to  $7.0 \times 10^3$ , preferably  $8 \times 10^2$  to  $6.0 \times 10^3$ , more preferably  $1 \times 10^3$  to  $5.0 \times 10^3$ . In a preferred embodiment, the linear polyol is polyester polyol derived from one kind of aliphatic dicarboxylic acid and two kinds of aliphatic diols and has a number average molecular weight of from  $2.0 \times 10^3$  to  $4.0 \times 10^3$ . In another preferred embodiment, the linear polyol is polyester polyol derived from one kind of aliphatic dicarboxylic acid and one kind of aliphatic diol and has a number

average molecular weight of from  $1.5 \times 10^3$  to  $4.0 \times 10^3$ , and more preferably from  $1.8 \times 10^3$  to  $3.5 \times 10^3$ . All molecular weights specified in this text have the unit of [g/mol] and refer, unless indicated otherwise, to the number average molecular weight (Mn).

**[0258]** The polyester urethane acrylates, or methacrylates (A) have viscosities in the range of 2000 to 20000 mPas at 60° C.

**[0259]** A secondary polyol, such as, for example, glycerol, may be used, to fine tune the mechanical properties of the inventive urethane (meth)acrylates by introducing linear or branched structural elements.

**[0260]** In another preferred embodiment the polyester urethane (meth)acrylate (B) is obtained by reacting a hydroxyalkyl(meth)acrylate of formula



with a lactone of formula



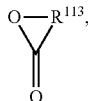
and at least one cycloaliphatic or asymmetric aliphatic diisocyanate, wherein  $R^{111}$  is a divalent alkylene radical having 2 to 12 carbon atoms and which may optionally be substituted by  $C_1$ - $C_4$ alkyl groups and/or interrupted by one or more oxygen atoms,  $R^{112}$  in each case independently of any other is methyl or hydrogen,  $R^{113}$  is a divalent alkylene radical having 1 to 12 carbon atoms and which may optionally be substituted by  $C_1$  to  $C_4$  alkyl groups and/or interrupted by one or more oxygen atoms. Reference is made to WO14191228A1

**[0261]**  $R^{111}$  is preferably selected from the group consisting of 1,2-ethylene, 1,2- or 1,3-propylene, 1,2-, 1,3-, or 1,4-butylene, 1,1-dimethyl-1,2-ethylene, 1,2-dimethyl-1,2-ethylene, 1,5-pentylene, 1,6-hexylene, 1,8-octylene, 1,10-decylene, and 1,12-dodecylene.

**[0262]**  $R^{113}$  is preferably selected from the group consisting of methylene, 1,2-ethylene, 1,2-propylene, 1,3-propylene, 1,2-butylene, 1,3-butylene, 1,4-butylene, 1,5-pentylene, 1,5-hexylene, 1,6-hexylene, 1,8-octylene, 1,10-decylene, 1,12-dodecylene, 2-oxa-1,4-butylene, 3-oxa-1,5-pentylene, and 3-oxa-1,5-hexylene.

**[0263]** The hydroxyalkyl(meth)acrylate of formula (A) is preferably selected from the group consisting of 2-hydroxyethyl(meth)acrylate, 2- or 3-hydroxypropyl(meth)acrylate, 1,4-butanediol mono(meth)acrylate, neopentyl glycol mono(meth)acrylate, 1,5-pentanediol mono(meth)acrylate, and 1,6-hexanediol mono(meth)acrylate.

[0264] The lactone of formula



(B)

is preferably selected from the group consisting of  $\beta$ -propiolactone,  $\gamma$ -butyrolactone,  $\gamma$ -ethyl-gamma-butyrolactone,  $\gamma$ -valerolactone, delta-valerolactone,  $\epsilon$ -caprolactone, 7-methyloxepan-2-one, 1,4-dioxepan-5-one, oxacyclotridecan-2-one, and 13-butyl-oxacyclotridecan-2-one.

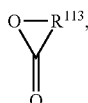
[0265] Cycloaliphatic diisocyanates are 1,4-, 1,3-, or 1,2-diisocyanatocyclohexane, 4,4'-, 2,4'- and/or 2,2'-methylenedicyclohexyl diisocyanate (H12MDI), bis(isocyanatomethyl)bicyclo[2.2.1]heptane (NBDI), 1-isocyanato-3,3,5-trimethyl-5-(isocyanatomethyl)cyclohexane(isophorone diisocyanate), 1,3- or 1,4-bis(isocyanatomethyl)cyclohexane or 2,4- or 2,6-diisocyanato-1-methylcyclohexane, and also 3(or 4),8(or 9)-bis(isocyanatomethyl)tricyclo[5.2.1.0<sup>2,6</sup>]decane isomer mixtures.

[0266] Asymmetric aliphatic diisocyanates are derivatives of lysine diisocyanate, or tetramethylxylene diisocyanate, trimethylhexane diisocyanate, or tetramethylhexane diisocyanate.

[0267] Very particular preference is given to di(isocyanatocyclohexyl)methane, 2,2,4- and 2,4,4-trimethylhexane diisocyanate, and especially 4,4'-, 2,4'- and/or 2,2'-methylenedicyclohexyl diisocyanate (H12MDI).

[0268] The urethane (meth)acrylates can be in particular produced by reacting  $\epsilon$ -caprolactone, 4,4'-, 2,4'- and/or 2,2'-methylenedicyclohexyl diisocyanate (H12MDI) and hydroxyethylacrylate.

[0269] In another preferred embodiment the polyester urethane (meth)acrylate (B) is obtained by reacting a polyalkylene glycol with a lactone of formula



(B)

at least one cycloaliphatic or asymmetric aliphatic diisocyanate, and an hydroxyalkyl(meth)acrylate of formula (A).

[0270] The hydroxyalkyl(meth)acrylate of formula (A) is preferably selected from the group consisting of 2-hydroxyethyl(meth)acrylate, 2- or 3-hydroxypropyl(meth)acrylate, 1,4-butanediol mono(meth)acrylate, neopentyl glycol mono(meth)acrylate, 1,5-pentanediol mono(meth)acrylate, and 1,6-hexanediol mono(meth)acrylate.

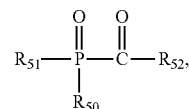
[0271] The urethane (meth)acrylates can be in particular produced by reacting a polyalkylene glycol, preferably a polyethylene glycol, with  $\epsilon$ -caprolactone, 4,4'-, 2,4'- and/or 2,2'-methylenedicyclohexyl diisocyanate (H12MDI) and hydroxyethylacrylate.

[0272] Photoinitiator (D)

[0273] The photoinitiator (D) may be a single compound, or a mixture of compounds. Examples of photoinitiators (D) are known to the person skilled in the art and for example published by Kurt Dietliker in "A compilation of photoini-

tiators commercially available for UV today", Sita Technology Textbook, Edinburgh, London, 2002.

[0274] Examples of suitable acylphosphine oxide compounds are of the formula XII



(XII)

wherein

[0275]  $\text{R}_{50}$  is unsubstituted cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl; or is cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl substituted by one or more halogen,  $\text{C}_1$ - $\text{C}_{12}$ alkyl,  $\text{C}_1$ - $\text{C}_{12}$ alkoxy,  $\text{C}_1$ - $\text{C}_{12}$ alkylthio or by  $\text{NR}_{53}\text{R}_{54}$ ;

[0276] or  $\text{R}_{50}$  is unsubstituted  $\text{C}_1$ - $\text{C}_{20}$ alkyl or is  $\text{C}_1$ - $\text{C}_{20}$ alkyl which is substituted by one or more halogen,  $\text{C}_1$ - $\text{C}_{12}$ alkoxy,  $\text{C}_1$ - $\text{C}_{12}$ alkylthio,  $\text{NR}_{53}\text{R}_{54}$  or by  $\text{---}(\text{CO})\text{---O---C}_1\text{---C}_{24}$ alkyl;

[0277]  $\text{R}_{51}$  is unsubstituted cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl; or is cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl substituted by one or more halogen,  $\text{C}_1$ - $\text{C}_{12}$ alkyl,  $\text{C}_1$ - $\text{C}_{12}$ alkoxy,  $\text{C}_1$ - $\text{C}_{12}$ alkylthio or by  $\text{NR}_{53}\text{R}_{54}$ ; or  $\text{R}_{51}$  is  $\text{---}(\text{CO})\text{R}'_{52}$ ; or  $\text{R}_{51}$  is  $\text{C}_1$ - $\text{C}_{12}$ alkyl which is unsubstituted or substituted by one or more halogen,  $\text{C}_1$ - $\text{C}_{12}$ alkoxy,  $\text{C}_1$ - $\text{C}_{12}$ alkylthio, or by  $\text{NR}_{53}\text{R}_{54}$ ;

[0278]  $\text{R}_{52}$  and  $\text{R}'_{52}$  independently of each other are unsubstituted cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl, or are cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl substituted by one or more halogen,  $\text{C}_1$ - $\text{C}_4$ alkyl or  $\text{C}_1$ - $\text{C}_4$ alkoxy; or  $\text{R}_{52}$  is a 5- or 6-membered heterocyclic ring comprising an S atom or N atom;

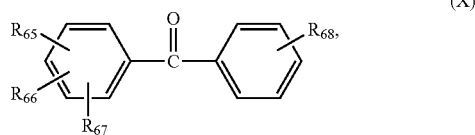
[0279]  $\text{R}_{53}$  and  $\text{R}_{54}$  independently of one another are hydrogen, unsubstituted  $\text{C}_1$ - $\text{C}_{12}$ alkyl or  $\text{C}_1$ - $\text{C}_{12}$ alkyl substituted by one or more OH or SH wherein the alkyl chain optionally is interrupted by one to four oxygen atoms; or  $\text{R}_{53}$  and  $\text{R}_{54}$  independently of one another are  $\text{C}_2$ - $\text{C}_{12}$ -alkenyl, cyclopentyl, cyclohexyl, benzyl or phenyl;

[0280] In a particularly preferred embodiment the photoinitiator (C) is a compound of the formula (XII), such as, for example, bis(2,4,6-trimethylbenzoyl)-phenylphosphine oxide; 2,4,6-trimethylbenzoyl-diphenyl-phosphine oxide; ethyl (2,4,6 trimethylbenzoyl phenyl) phosphinic acid ester; (2,4,6-trimethylbenzoyl)-2,4-dipentoxyphenylphosphine oxide and bis(2,6-dimethoxybenzoyl)-2,4,4-trimethylpentylphosphine oxide.

[0281] Interesting further are mixtures of the compounds of the formula (XII) with compounds of the formula (XI) as well as mixtures of different compounds of the formula (XII).

[0282] Examples are mixtures of bis(2,6-dimethoxybenzoyl)-2,4,4-trimethylpentylphosphine oxide with 1-hydroxy-cyclohexyl-phenyl-ketone, of bis(2,4,6-trimethylbenzoyl)-phenylphosphine oxide with 2-hydroxy-2-methyl-1-phenyl-propan-1-one, of bis(2,4,6-trimethylbenzoyl)-phenylphosphine oxide with ethyl (2,4,6 trimethylbenzoyl phenyl) phosphinic acid ester, etc.

[0283] Examples of suitable benzophenone compounds are compounds of the formula

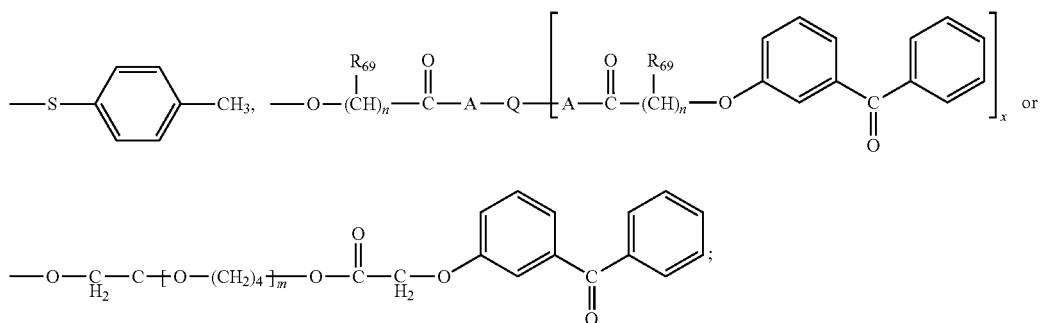


wherein

[0284]  $R_{65}$ ,  $R_{66}$  and  $R_{67}$  independently of one another are hydrogen,  $C_1$ - $C_4$ alkyl,  $C_1$ - $C_4$ -halogenalkyl,  $C_1$ - $C_4$ alkoxy, Cl or  $N(C_1$ - $C_4$ alkyl) $_2$ ;

[0285]  $R_{68}$  is hydrogen,  $C_1$ - $C_4$ alkyl,  $C_1$ - $C_4$ halogenalkyl, phenyl,  $N(C_1$ - $C_4$ alkyl) $_2$ ,  $COOCH_3$ ,

benzoylphenoxy)- $N,N,N$ -trimethyl-1-propanaminium chloride monohydrate, 4-(13-acryloyl-1,4,7,10,13-pentaoxatridecyl)benzophenone, 4-benzoyl- $N,N$ -dimethyl- $N$ -[2-(1-oxo-2-propenyl)oxy]ethylbenzenemethanaminium chloride; [4-(2-hydroxy-ethylsulfanyl)-phenyl]-(4-isopropylphenyl)-methanone; biphenyl-[4-(2-hydroxy-ethylsulfanyl)-phenyl]-methanone; biphenyl-4-yl-phenyl-methanone; biphenyl-4-yl-p-tolyl-methanone; biphenyl-4-yl-m-tolyl-methanone; [4-(2-hydroxy-ethylsulfanyl)-phenyl]-p-tolyl-methanone; [4-(2-hydroxy-ethylsulfanyl)-phenyl]-(4-isopropyl-phenyl)-methanone; [4-(2-hydroxy-ethylsulfanyl)-phenyl]-(4-methoxy-phenyl)-methanone; 1-(4-benzoyl-phenoxy)-propan-2-one; [4-(2-hydroxy-ethylsulfanyl)-phenyl]-(4-phenoxy-phenyl)-methanone; 3-(4-benzoyl-phenyl)-2-dimethylamino-2-methyl-1-phenyl-propan-1-one; (4-chloro-phenyl)-(4-octylsulfanyl-phenyl)-methanone; (4-chloro-phenyl)-(4-dodecylsulfanyl-phenyl)-methanone;



[0286] Q is a residue of a polyhydroxy compound having 2 to 6 hydroxy groups;

[0287] x is a number greater than 1 but no greater than the number of available hydroxyl groups in Q;

[0288] A is  $-[O(CH_2)_bCO]_y-$  or  $-[O(CH_2)_bCO]_{(y-1)}-[O(CHR_{69}CHR_{69'})_a]_y-$ ;

[0289]  $R_{69}$  and  $R_{69'}$  independently of one another are hydrogen, methyl or ethyl; and if n (or a) is greater than 1 the radicals  $R_{69}$  may be the same as or different from each other;

[0290] a is a number from 1 to 2;

[0291] b is a number from 4 to 5;

[0292] y is a number from 1 to 10;

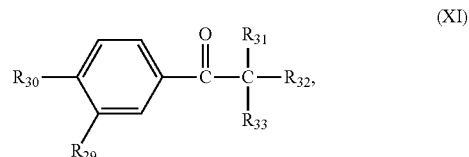
[0293] n is; and

[0294] m is an integer 2-10.

[0295] Specific examples are benzophenone, Esacure TZT® available from IGM, (a mixture of 2,4,6-trimethylbenzophenone and 4-methylbenzophenone), 4-phenylbenzophenone, 4-methoxybenzophenone, 4,4'-dimethoxybenzophenone, 4,4'-dimethylbenzophenone, 4,4'-dichlorobenzophenone, 4,4'-dimethylaminobenzophenone, 4,4'-diethylaminobenzophenone, 4-methylbenzophenone, 2,4,6-trimethylbenzophenone, 4-(4-methylthiophenyl)benzophenone, 3,3'-dimethyl-4-methoxybenzophenone, methyl-2-benzoylbenzoate, 4-(2-hydroxyethylthio)benzophenone, 4-(4-tolylthio)benzophenone, 4-benzoyl- $N,N,N$ -trimethylbenzenemethanaminium chloride, 2-hydroxy-3-(4-

(4-bromo-phenyl)-(4-octylsulfanyl-phenyl)-methanone; (4-dodecylsulfanyl-phenyl)-(4-methoxy-phenyl)-methanone; (4-benzoyl-phenoxy)-acetic acid methyl ester; biphenyl-[4-(2-hydroxy-ethylsulfanyl)-phenyl]-methanone; 1-[4-(4-benzoylphenylsulfanyl)phenyl]-2-methyl-2-(4-methylphenylsulfonyl)propan-1-one (Esacure®1001 available from IGM).

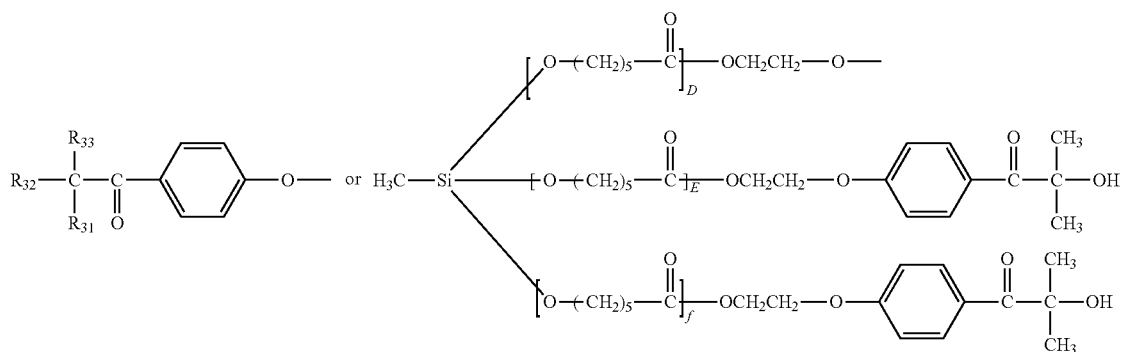
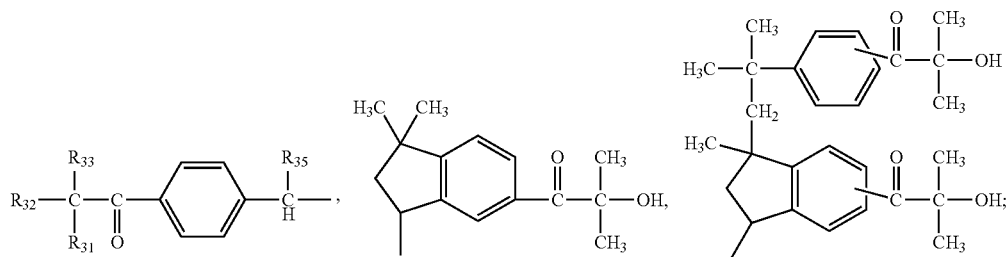
[0296] Examples of suitable alpha-hydroxy ketone, alpha-alkoxyketone or alpha-aminoketone compounds are of the formula



wherein

[0297]  $R_{29}$  is hydrogen or  $C_1$ - $C_{18}$ alkoxy;

[0298]  $R_{30}$  is hydrogen,  $C_1$ - $C_{18}$ alkyl,  $C_1$ - $C_{12}$ hydroxyalkyl,  $C_1$ - $C_{18}$ alkoxy,  $OCH_2CH_2-OR_{34}$ , morpholino,  $S-C_1$ - $C_{18}$ alkyl, a group  $-HC=CH_2$ ,  $-C(CH_3)=CH_2$ ,

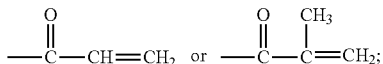


[0299] D, E and f are 1-3;

[0300] c is 2-10;

[0301]  $G_1$  and  $G_2$  independently of one another are end groups of the polymeric structure, preferably hydrogen or methyl;

[0302]  $R_{3,4}$  is hydrogen,



[0303]  $R_{3,1}$  is hydroxy,  $C_1$ - $C_{16}$ alkoxy, morpholino, dimethylamino or  $\text{---O(CH}_2\text{CH}_2\text{O)}_g\text{---C}_1$ - $C_{16}$ alkyl;

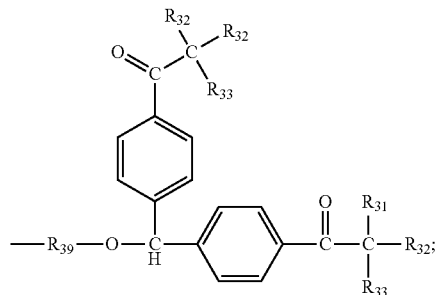
[0304] g is 1-20;

[0305]  $R_{3,2}$  and  $R_{3,3}$  independently of one another are hydrogen,  $C_1$ - $C_6$ alkyl,  $C_1$ - $C_{16}$ alkoxy or  $\text{---O(CH}_2\text{CH}_2\text{O)}_g\text{---C}_1$ - $C_{16}$ alkyl; or are unsubstituted phenyl or benzyl; or phenyl or benzyl substituted by  $C_1$ - $C_{12}$ -alkyl; or  $R_{3,2}$  and  $R_{3,3}$  together with the carbon atom to which they are attached form a cyclohexyl ring;

[0306]  $R_{3,5}$  is hydrogen,  $\text{OR}_{3,6}$  or  $\text{NR}_{3,7}\text{R}_{3,8}$ ;

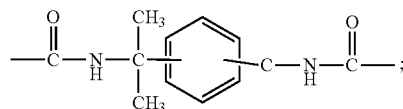
[0307]  $R_{3,6}$  is hydrogen,  $C_1$ - $C_{12}$ alkyl which optionally is interrupted by one or more non-consecutive O-atoms and which uninterrupted or interrupted  $C_1$ - $C_{12}$ alkyl optionally is substituted by one or more OH,

[0308] or  $R_{3,6}$  is



[0309]  $R_{3,7}$  and  $R_{3,8}$  independently of each other are hydrogen or  $C_1$ - $C_{12}$ alkyl which is unsubstituted or is substituted by one or more OH;

[0310]  $R_{3,9}$  is  $C_1$ - $C_{12}$ alkylene which optionally is interrupted by one or more non-consecutive O,  $\text{---(CO)---NH---C}_1$ - $C_{12}$ alkylene- $\text{NH---(CO)---}$  or

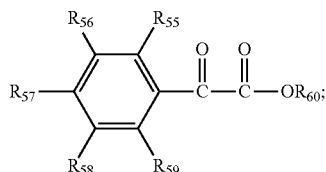


[0311] with the proviso that  $R_{3,1}$ ,  $R_{3,2}$  and  $R_{3,3}$  not all together are  $C_1$ - $C_{16}$ alkoxy or  $\text{---O(CH}_2\text{CH}_2\text{O)}_g\text{---C}_1$ - $C_{16}$ alkyl.

[0312] Specific examples are 1-hydroxy-cyclohexyl-phenyl-ketone or a mixture of 1-hydroxy-cyclohexyl-phenyl-ketone with benzophenone), 2-methyl-1[4-(methylthio)phe-

nyl]-2-morpholinopropan-1-one, 2-benzyl-2-dimethylamino-1-(4-morpholinophenyl)-butan-1-one, 2-dimethylamino-2-(4-methyl-benzyl)-1-(4-morpholin-4-yl-phenyl)-butan-1-one, (3,4-dimethoxy-benzoyl)-1-benzyl-1-dimethylamino propane, 1-[4-(2-hydroxyethoxy)-phenyl]-2-hydroxy-2-methyl-1-propan-1-one, 2,2-dimethoxy-1,2-diphenylethan-1-one, 2-hydroxy-2-methyl-1-phenylpropan-1-one, 2-hydroxy-1-{4-[4-(2-hydroxy-2-methylpropionyl)-benzyl]-phenyl}-2-methyl-propan-1-one, 2-hydroxy-1-{4-[4-(2-hydroxy-2-methylpropionyl)-phenoxy]-phenyl}-2-methyl-propan-1-one, Esacure KIP provided by IGM, 2-hydroxy-1-{1-[4-(2-hydroxy-2-methylpropionyl)-phenyl]-1,3,3-trimethyl-indan-5-yl}-2-methylpropan-1-one.

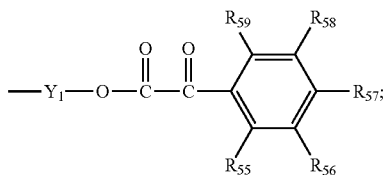
**[0313]** Examples of suitable phenylglyoxylate compounds are of the formula



(XIII)

wherein

**[0314]** R<sub>60</sub> is hydrogen, C<sub>1</sub>-C<sub>12</sub>alkyl or



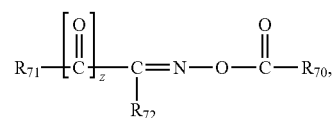
**[0315]** R<sub>55</sub>, R<sub>56</sub>, R<sub>57</sub>, R<sub>58</sub> and R<sub>59</sub> independently of one another are hydrogen, unsubstituted C<sub>1</sub>-C<sub>12</sub>alkyl or C<sub>1</sub>-C<sub>12</sub>alkyl substituted by one or more OH, C<sub>1</sub>-C<sub>4</sub>alkoxy, phenyl, naphthyl, halogen or by CN; wherein the alkyl chain optionally is interrupted by one or more oxygen atoms; or R<sub>55</sub>, R<sub>56</sub>, R<sub>57</sub>, R<sub>58</sub> and R<sub>59</sub> independently of one another are C<sub>1</sub>-C<sub>4</sub>alkoxy, C<sub>1</sub>-C<sub>4</sub>alkylthio or NR<sub>52</sub>R<sub>53</sub>,

**[0316]** R<sub>52</sub> and R<sub>53</sub> independently of one another are hydrogen, unsubstituted C<sub>1</sub>-C<sub>12</sub>alkyl or C<sub>1</sub>-C<sub>12</sub>alkyl substituted by one or more OH or SH wherein the alkyl chain optionally is interrupted by one to four oxygen atoms; or R<sub>52</sub> and R<sub>53</sub> independently of one another are C<sub>2</sub>-C<sub>12</sub>-alkenyl, cyclopentyl, cyclohexyl, benzyl or phenyl; and

**[0317]** Y<sub>1</sub> is C<sub>1</sub>-C<sub>12</sub>alkylene optionally interrupted by one or more oxygen atoms.

**[0318]** Specific examples of the compounds of the formula XIII are oxo-phenyl-acetic acid 2-[2-(2-oxo-2-phenyl-acetoxy)-ethoxy]-ethyl ester (Irgacure®754), methyl α-oxo benzeneacetate.

**[0319]** Examples of suitable oxime ester compounds are of the formula



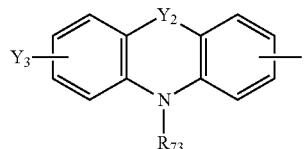
(XIV)

wherein z is 0 or 1;

**[0320]** R<sub>70</sub> is hydrogen, C<sub>3</sub>-C<sub>8</sub>cycloalkyl; C<sub>1</sub>-C<sub>12</sub>alkyl which is unsubstituted or substituted by one or more halogen, phenyl or by CN; or R<sub>70</sub> is C<sub>2</sub>-C<sub>5</sub>alkenyl; phenyl which is unsubstituted or substituted by one or more C<sub>1</sub>-C<sub>6</sub>alkyl, halogen, CN, OR<sub>73</sub>, SR<sub>74</sub> or by NR<sub>75</sub>R<sub>76</sub>; or R<sub>70</sub> is C<sub>1</sub>-C<sub>8</sub>alkoxy, benzyloxy; or phenoxy which is unsubstituted or substituted by one or more C<sub>1</sub>-C<sub>6</sub>alkyl or by halogen;

**[0321]** R<sub>71</sub> is phenyl, naphthyl, benzoyl or naphthoyl, each of which is substituted by one or more halogen, C<sub>1</sub>-C<sub>12</sub>alkyl, C<sub>3</sub>-C<sub>8</sub>cycloalkyl, benzyl, phenoxycarbonyl, C<sub>2</sub>-C<sub>12</sub>alkoxycarbonyl, OR<sub>73</sub>, SR<sub>74</sub>, SOR<sub>74</sub>, SO<sub>2</sub>R<sub>74</sub> or by NR<sub>75</sub>R<sub>76</sub>, wherein the substituents OR<sub>73</sub>, SR<sub>74</sub> and NR<sub>75</sub>R<sub>76</sub> optionally form 5- or 6-membered rings via the radicals R<sub>73</sub>, R<sub>74</sub>, R<sub>75</sub> and/or R<sub>76</sub> with further substituents on the phenyl or naphthyl ring; or each of which is substituted by phenyl or by phenyl which is substituted by one or more OR<sub>73</sub>, SR<sub>74</sub> or by NR<sub>75</sub>R<sub>66</sub>;

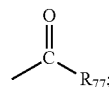
**[0322]** or R<sub>71</sub> is thioxanthyl, or



**[0323]** R<sub>72</sub> is hydrogen; unsubstituted C<sub>1</sub>-C<sub>20</sub>alkyl or C<sub>1</sub>-C<sub>20</sub>alkyl which is substituted by one or more halogen, OR<sub>73</sub>, SR<sub>74</sub>, C<sub>3</sub>-C<sub>8</sub>cycloalkyl or by phenyl; or is C<sub>3</sub>-C<sub>8</sub>cycloalkyl; or is phenyl which is unsubstituted or substituted by one or more C<sub>1</sub>-C<sub>6</sub>alkyl, phenyl, halogen, OR<sub>73</sub>, SR<sub>74</sub> or by NR<sub>75</sub>R<sub>76</sub>; or is C<sub>2</sub>-C<sub>20</sub>alkanoyl or benzoyl which is unsubstituted or substituted by one or more C<sub>1</sub>-C<sub>6</sub>alkyl, phenyl, OR<sub>73</sub>, SR<sub>74</sub> or by NR<sub>75</sub>R<sub>76</sub>; or is C<sub>2</sub>-C<sub>12</sub>alkoxycarbonyl, phenoxycarbonyl, CN, CONR<sub>75</sub>R<sub>76</sub>, NO<sub>2</sub>, C<sub>1</sub>-C<sub>4</sub>haloalkyl, S(O)<sub>y</sub>-C<sub>1</sub>-C<sub>6</sub>alkyl, or S(O)<sub>y</sub>-phenyl, y is 1 or 2;

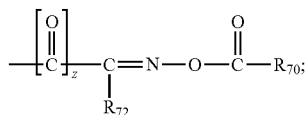
**[0324]** Y<sub>2</sub> is a direct bond or no bond:

**[0325]** Y<sub>3</sub> is NO<sub>2</sub> or



**[0326]** R<sub>73</sub> and R<sub>74</sub> independently of one another are hydrogen, C<sub>1</sub>-C<sub>20</sub>alkyl, C<sub>2</sub>-C<sub>12</sub>alkenyl, C<sub>3</sub>-C<sub>8</sub>cycloalkyl, C<sub>3</sub>-C<sub>8</sub>cycloalkyl which is interrupted by one or more, preferably 2, O, phenyl-C<sub>1</sub>-C<sub>3</sub>alkyl; or are C<sub>1</sub>-C<sub>8</sub>alkyl which is substituted by OH, SH, CN, C<sub>1</sub>-C<sub>8</sub>alkoxy, C<sub>1</sub>-C<sub>8</sub>alkanoyl, C<sub>3</sub>-C<sub>8</sub>cycloalkyl, by C<sub>3</sub>-C<sub>8</sub>cycloalkyl which is interrupted by one or more O, or which C<sub>1</sub>-C<sub>8</sub>alkyl is substituted by benzoyl which is unsubstituted or substituted by one or more C<sub>1</sub>-C<sub>6</sub>alkyl, halogen, OH, C<sub>1</sub>-C<sub>4</sub>alkoxy or by

C<sub>1</sub>-C<sub>4</sub>alkylsulfanyl; or are phenyl or naphthyl, each of which is unsubstituted or substituted by halogen, C<sub>1</sub>-C<sub>12</sub>alkyl, C<sub>1</sub>-C<sub>12</sub>alkoxy, phenyl-C<sub>1</sub>-C<sub>3</sub>alkyloxy, phenoxy, C<sub>1</sub>-C<sub>12</sub>alkylsulfanyl, phenylsulfanyl, N(C<sub>1</sub>-C<sub>12</sub>alkyl)<sub>2</sub>, diphenylamino or by



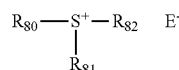
[0327] R<sub>75</sub> and R<sub>76</sub> independently of each other are hydrogen, C<sub>1</sub>-C<sub>20</sub>alkyl, C<sub>2</sub>-C<sub>4</sub>hydroxyalkyl, C<sub>2</sub>-C<sub>10</sub>alkoxyalkyl, C<sub>2</sub>-C<sub>5</sub>alkenyl, C<sub>3</sub>-C<sub>8</sub>cycloalkyl, phenyl-C<sub>1</sub>-C<sub>3</sub>alkyl, C<sub>1</sub>-C<sub>8</sub>alkanoyl, C<sub>3</sub>-C<sub>12</sub>alkenoyl, benzoyl; or are phenyl or naphthyl, each of which is unsubstituted or substituted by C<sub>1</sub>-C<sub>12</sub>alkyl, benzoyl or by C<sub>1</sub>-C<sub>12</sub>alkoxy; or R<sub>75</sub> and R<sub>76</sub> together are C<sub>2</sub>-C<sub>6</sub>alkylene optionally interrupted by O or NR<sub>73</sub> and optionally are substituted by hydroxyl, C<sub>1</sub>-C<sub>4</sub>alkoxy, C<sub>2</sub>-C<sub>4</sub>alkanoyloxy or by benzoyloxy;

[0328] R<sub>77</sub> is C<sub>1</sub>-C<sub>12</sub>alkyl, thienyl or phenyl which is unsubstituted or substituted by C<sub>1</sub>-C<sub>12</sub>alkyl, OR<sub>73</sub>, morpholino or by N-carbazolyl.

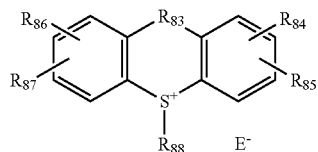
[0329] Specific examples are 1,2-octanedione 1-[4-(phenylthio)phenyl]-2-(O-benzoyloxime), ethanone 1-[9-ethyl-6-(2-methylbenzoyl)-9H-carbazol-3-yl]-1-(O-acetyloxime), 9H-thioxanthene-2-carboxaldehyde 9-oxo-2-(O-acetyloxime), ethanone 1-[9-ethyl-6-(4morpholinobenzoyl)-9H-carbazol-3-yl]-1-(O-acetyloxime), ethanone 1-[9-ethyl-6-(2-methyl-4-(2-(1,3-dioxo-2-dimethyl-cyclopent-5-yl)ethoxy)-benzoyl)-9H-carbazol-3-yl]-1-(O-acetyloxime) (Adeka N-1919), ethanone 1-[9-ethyl-6-nitro-9H-carbazol-3-yl]-1-[2-methyl-4-(1-methyl-2-methoxy)ethoxy]phenyl]-1-(O-acetyloxime) (Adeka NCI831), etc.

[0330] It is also possible to add cationic photoinitiators, such as benzoyl peroxide (other suitable peroxides are described in U.S. Pat. No. 4,950,581, column 19, lines 17-25), or aromatic sulfonium, phosphonium or iodonium salts, such as are described, for example, in U.S. Pat. No. 4,950,581, column 18, line 60 to column 19, line 10.

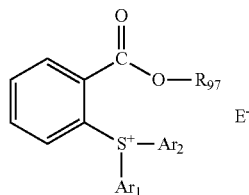
[0331] Suitable sulfonium salt compounds are of formula



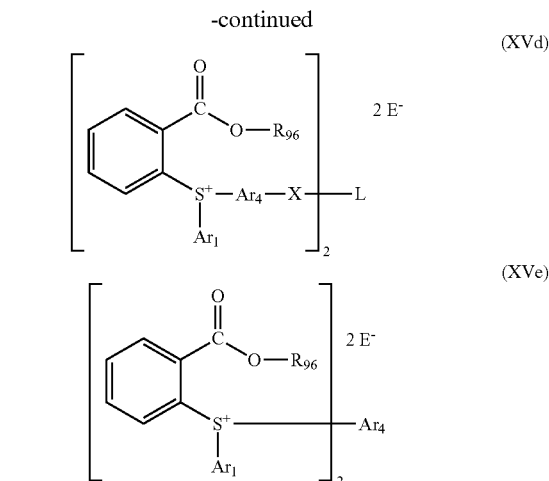
(XVa)



(XVb)

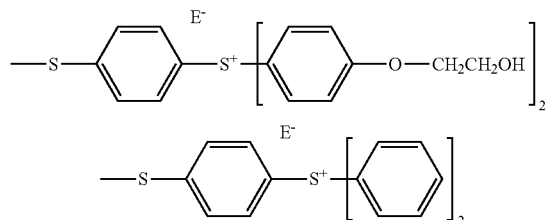


(XVc)

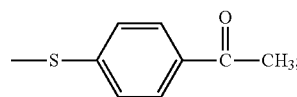


[0332] wherein

[0333] R<sub>80</sub>, R<sub>81</sub> and R<sub>82</sub> are each independently of the others unsubstituted phenyl, or phenyl substituted by —S-phenyl,



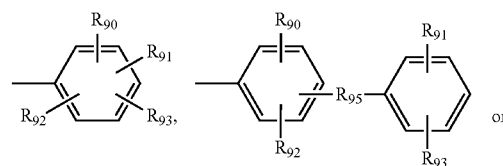
or by

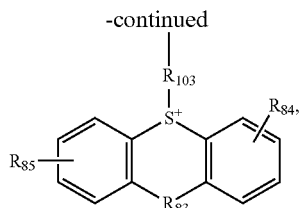


[0334] R<sub>83</sub> is a direct bond, S, O, CH<sub>2</sub>, (CH<sub>2</sub>)<sub>2</sub>, CO or NR<sub>89</sub>;

[0335] R<sub>84</sub>, R<sub>85</sub>, R<sub>86</sub> and R<sub>87</sub> independently of one another are hydrogen, C<sub>1</sub>-C<sub>20</sub>alkyl, C<sub>3</sub>-C<sub>8</sub>cycloalkyl, C<sub>1</sub>-C<sub>20</sub>alkoxy, C<sub>2</sub>-C<sub>20</sub>alkenyl, CN, OH, halogen, C<sub>1</sub>-C<sub>6</sub>alkylthio, phenyl, naphthyl, phenyl-C<sub>1</sub>-C<sub>7</sub>alkyl, naphthyl-C<sub>1</sub>-C<sub>3</sub>alkyl, phenoxy, naphthyl, phenyl-C<sub>1</sub>-C<sub>7</sub>alkyloxy, naphthyl-C<sub>1</sub>-C<sub>3</sub>alkyloxy, phenyl-C<sub>2</sub>-C<sub>6</sub>alkenyl, naphthyl-C<sub>2</sub>-C<sub>4</sub>alkenyl, S-phenyl, (CO)R<sub>89</sub>, O(CO)R<sub>89</sub>, (CO)OR<sub>89</sub>, SO<sub>2</sub>R<sub>89</sub> or OSO<sub>2</sub>R<sub>89</sub>;

[0336] R<sub>88</sub> is C<sub>1</sub>-C<sub>20</sub>alkyl C<sub>1</sub>-C<sub>20</sub>hydroxyalkyl,





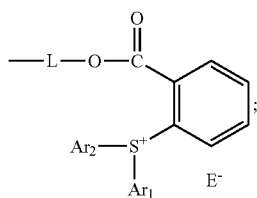
[0337]  $R_{89}$  is hydrogen,  $C_1$ - $C_{12}$ alkyl,  $C_1$ - $C_{12}$ hydroxyalkyl, phenyl, naphthyl or biphenyl;

[0338]  $R_{90}$ ,  $R_{91}$ ,  $R_{92}$  and  $R_{93}$  independently of one another have one of the meanings as given for  $R_{84}$ , or  $R_{90}$  and  $R_{91}$  are joined to form a fused ring system with the benzene rings to which they are attached;

[0339]  $R_{95}$  is a direct bond, S, O or  $CH_2$ ;

[0340]  $R_{96}$  is hydrogen,  $C_1$ - $C_{20}$ alkyl;  $C_2$ - $C_{20}$ alkyl interrupted by one or more O; or is  $-L-M-R_{98}$  or  $-L-R_{98}$ ;

[0341]  $R_{97}$  has one of the meanings as given for  $R_{96}$  or is



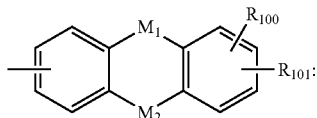
[0342]  $R_{98}$  is a monovalent sensitizer or photoinitiator moiety;

[0343]  $Ar_1$  and  $Ar_2$  independently of one another are phenyl unsubstituted or substituted by  $C_1$ - $C_{20}$ alkyl, halogen or  $OR_{99}$ ;

[0344] or are unsubstituted naphthyl, anthryl, phenanthryl or biphenyl;

[0345] or are naphthyl, anthryl, phenanthryl or biphenyl substituted by  $C_1$ - $C_{20}$ alkyl, OH or  $OR_{99}$ ;

[0346] or are  $-Ar_4-A_1-Ar_3$  or



[0347]  $Ar_3$  is unsubstituted phenyl, naphthyl, anthryl, phenanthryl or biphenyl;

[0348] or is phenyl, naphthyl, anthryl, phenanthryl or biphenyl substituted by  $C_1$ - $C_{20}$ alkyl,  $OR_{99}$  or benzoyl;

[0349]  $Ar_4$  is phenylene, naphthylene, anthrylene or phenanthrylene;

[0350]  $A_1$  is a direct bond, S, O or  $C_1$ - $C_{20}$ alkylene;

[0351] X is CO, C(O)O, OC(O), O, S or  $NR_{99}$ ;

[0352] L is a direct bond, S, O,  $C_1$ - $C_{20}$ alkylene or  $C_2$ - $C_{20}$ alkylene interrupted by one or more non-consecutive O;

[0353]  $R_{99}$  is  $C_1$ - $C_{20}$ alkyl or  $C_1$ - $C_{20}$ hydroxyalkyl; or is  $C_1$ - $C_{20}$ alkyl substituted by  $O(CO)R_{102}$ ;

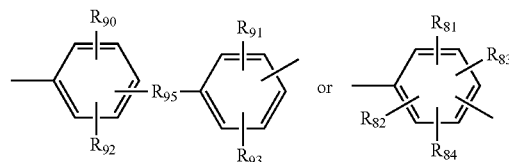
[0354]  $M_1$  is S, CO or  $NR_{100}$ ;

[0355]  $M_2$  is a direct bond,  $CH_2$ , O or S;

[0356]  $R_{100}$  and  $R_{101}$  independently of one another are hydrogen, halogen,  $C_1$ - $C_8$ alkyl,  $C_1$ - $C_8$ alkoxy or phenyl;

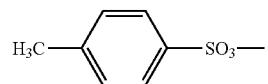
[0357]  $R_{102}$  is  $C_1$ - $C_{20}$ alkyl;

[0358]  $R_{103}$  is

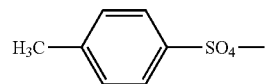


and

[0359] E is an anion, especially  $PF_6^-$ ,  $SbF_6^-$ ,  $AsF_6^-$ ,  $BF_4^-$ ,  $(C_6F_5)_4B^-$ , Cl, Br,  $HSO_4^-$ ,  $CF_3-SO_3^-$ ,  $F-SO_3^-$ ,

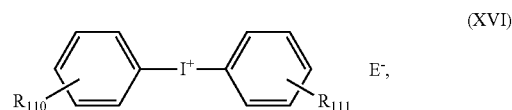


$CH_3-SO_3^-$ ,  $ClO_4^-$ ,  $PO_4^-$ ,  $NO_3^-$ ,  $SO_4^-$ ,  $CH_3-SO_4^-$ , or



[0360] Specific examples of sulfonium salt compounds are for example Irgacure®270 (BASF SE); Cyracure® UVI-6990, Cyracure®UVI-6974 (Union Carbide), Degacure®KI 85 (Degussa), SP-55, SP-150, SP-170 (Asahi Denka), GE UVE 1014 (General Electric), SarCat®KI-85 (=triarylsulfonium hexafluorophosphate; Sartomer), SarCat® CD 1010 (=mixed triarylsulfonium hexafluoroantimonate; Sartomer); SarCat® CD 1011(=mixed triarylsulfonium hexafluorophosphate; Sartomer),

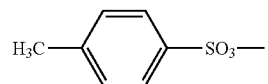
[0361] Suitable iodonium salt compounds are of formula



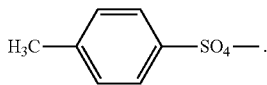
wherein

[0362]  $R_{110}$  and  $R_{111}$  are each independently of the other hydrogen,  $C_1$ - $C_{20}$ alkyl,  $C_1$ - $C_{20}$ alkoxy, OH— substituted  $C_1$ - $C_{20}$ alkoxy, halogen,  $C_2$ - $C_{12}$ alkenyl,  $C_3$ - $C_8$ cycloalkyl, especially methyl, isopropyl or isobutyl; and

[0363] E is an anion, especially  $PF_6^-$ ,  $SbF_6^-$ ,  $AsF_6^-$ ,  $BF_4^-$ ,  $(C_6F_5)_4B^-$ , Cl, Br,  $HSO_4^-$ ,  $CF_3-SO_3^-$ ,  $F-SO_3^-$ ,



CH<sub>3</sub>—SO<sub>3</sub>, ClO<sub>4</sub>, PO<sub>4</sub>, NO<sub>3</sub>, SO<sub>4</sub>, CH<sub>3</sub>—SO<sub>4</sub> or



**[0364]** Specific examples of iodonium salt compounds are e.g. tolylcumyliodonium tetrakis(pentafluorophenyl)borate, 4-[(2-hydroxy-tetradecyloxy)phenyl]phenyliodonium hexafluoroantimonate or hexafluorophosphate, tolylcumyliodonium hexafluorophosphate, 4-isopropylphenyl-4'-methylphenyliodonium hexafluorophosphate, 4-isobutylphenyl-4'-methylphenyliodonium hexafluorophosphate (Irgacure®250, BASF SE), 4-octyloxyphenylphenyliodonium hexafluorophosphate or hexafluoroantimonate, bis(dodecylphenyl)iodonium hexafluoroantimonate or hexafluorophosphate, bis(4-methylphenyl)iodonium hexafluorophosphate, bis(4-methoxyphenyl)iodonium hexafluorophosphate, 4-methylphenyl-4'-ethoxyphenyliodonium hexafluorophosphate, 4-methylphenyl-4'-dodecylphenyliodonium hexafluorophosphate, 4-methylphenyl-4'-phenoxyphenyliodonium hexafluorophosphate.

**[0365]** Of all the iodonium salts mentioned, compounds with other anions are, of course, also suitable. The preparation of iodonium salts is known to the person skilled in the art and described in the literature, for example U.S. Pat. Nos. 4,151,175, 3,862,333, 4,694,029, EP 562897, U.S. Pat. Nos. 4,399,071, 6,306,555, WO 98/46647 J. V. Crivello, "Photoinitiated Cationic Polymerization" in: UV Curing: Science and Technology, Editor S. P. Pappas, pages 24-77, Technology Marketing Corporation, Norwalk, Conn. 1980, ISBN No. 0-686-23773-0; J. V. Crivello, J. H. W. Lam, *Macromolecules*, 10, 1307 (1977) and J. V. Crivello, *Ann. Rev. Mater. Sci.* 1983, 13, pages 173-190 and J. V. Crivello, *Journal of Polymer Science, Part A: Polymer Chemistry*, Vol. 37, 4241-4254 (1999).

**[0366]** Acylphosphinioxides, such as, for example, bis(2,4,6-trimethylbenzoyl)-phenylphosphine oxide, 2,4,6-trimethylbenzoyl-diphenyl-phosphine oxide and ethyl phenyl(2,4,6-trimethylbenzoyl)phosphinate, are preferred for curing with light sources having emission peak(s) in the UV-A range and (near) VIS range (Laser, LEDs, LCD). alpha-Hydroxy ketone type compounds, such as, for example, 1-hydroxy-cyclohexyl-phenyl-ketone, 2-hydroxy-2-methyl-1-phenyl-propan-1-one, 2-hydroxy-1-[4-[4-(2-hydroxy-2-methyl-propionyl)-benzyl]-phenyl]-2-methyl-propan-1-one, 1-[4-(2-hydroxyethoxy)-phenyl]-2-hydroxy-2-methyl-1-propan-1-one, Esacure KIP provided by Lamberti, 2-hydroxy-1-[1-[4-(2-hydroxy-2-methyl-propionyl)-phenyl]-1,3,3-trimethyl-indan-5-yl]-2-methyl-propan-1-one and mixtures thereof, are preferred for curing with UV laser having emission peak at 355 nm (SLA).

**[0367]** If the light source emits radiation over a broad range, UV and visible range (e.g. mercury bilbs), or light sources of different wavelengths are combined (e.g. LEDs, laser), the absorption range of one photoinitiator might not cover the entire range. This can be achieved by combining two different photoinitiator types, e.g. alpha-hydroxy ketones (1-hydroxy-cyclohexyl-phenyl-ketone, 2-hydroxy-2-methyl-1-phenyl-propan-1-one, or 2-hydroxy-1-[4-[4-(2-hydroxy-2-methyl-propionyl)-benzyl]-phenyl]-2-methyl-propan-1-one) with acyl phosphinioxides (bis(2,4,6-trimethylbenzoyl)-phenylphosphine oxide, 2,4,6-

trimethylbenzoyl-diphenyl-phosphine oxide and ethyl phenyl(2,4,6-trimethylbenzoyl)phosphinate. If visible radiation is used for curing specific photoinitiators like titanocenes, such as, for example, bis(cyclopentadienyl) bis[2,6-difluoro-3-(1-pyrryl)phenyl titanium (Omnirad 784) are required.

**[0368]** In a preferred embodiment trialkyl benzoyl and dialkyl dibenzoyl germanium compounds, such as, for example, dibenzoyldiethyl germanium, benzoyltriethyl germanium and bis-4-(methoxybenzoyl)diethyl germanium can be used as photoinitiators.

**[0369]** In another preferred embodiment, camphorquinone in combination with a tertiary amine as conitiator is used as photoinitiator. The tertiary amine is preferably selected from ethyl 4-(dimethylamino)benzoate, triethanolamine, 2-(dimethylamino)ethylmethacrylate, 2-[4-(dimethylamino)phenyl]ethanol and N,N-dimethyl-p-toluidine.

**[0370]** The photoinitiators are used typically in a proportion of from about 0.5 to 10% by weight, especially 0.1 to 5.0% by weight based on the total weight of composition.

**[0371]** Halogen is fluorine, chlorine, bromine and iodine.

**[0372]** C<sub>1</sub>-C<sub>24</sub>alkyl (C<sub>1</sub>-C<sub>20</sub>alkyl, especially C<sub>1</sub>-C<sub>12</sub>alkyl) is typically linear or branched, where possible. Examples are methyl, ethyl, n-propyl, isopropyl, n-butyl, sec.-butyl, isobutyl, tert.-butyl, n-pentyl, 2-pentyl, 3-pentyl, 2,2-dimethylpropyl, 1,1,3,3-tetramethylpentyl, n-hexyl, 1-methylhexyl, 1,1,3,3,5,5-hexamethylhexyl, n-heptyl, isoheptyl, 1,1,3,3-tetramethylbutyl, 1-methylheptyl, 3-methylheptyl, n-octyl, 1,1,3,3-tetramethylbutyl and 2-ethylhexyl, n-nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, or octadecyl. C<sub>1</sub>-C<sub>8</sub>alkyl is typically methyl, ethyl, n-propyl, isopropyl, n-butyl, sec.-butyl, isobutyl, tert.-butyl, n-pentyl, 2-pentyl, 3-pentyl, 2,2-dimethyl-propyl, n-hexyl, n-heptyl, n-octyl, 1,1,3,3-tetramethylbutyl and 2-ethylhexyl. C<sub>1</sub>-C<sub>4</sub>alkyl is typically methyl, ethyl, n-propyl, isopropyl, n-butyl, sec.-butyl, isobutyl, tert.-butyl.

**[0373]** C<sub>2</sub>-C<sub>12</sub>alkenyl (C<sub>2</sub>-C<sub>8</sub>alkenyl) groups are straight-chain or branched alkenyl groups, such as e.g. vinyl, allyl, methallyl, isopropenyl, 2-butenyl, 3-butenyl, isobutenyl, n-penta-2,4-dienyl, 3-methyl-but-2-enyl, n-oct-2-enyl, or n-dodec-2-enyl.

**[0374]** C<sub>1</sub>-C<sub>12</sub>alkoxy groups (C<sub>1</sub>-C<sub>8</sub>alkoxy groups) are straight-chain or branched alkoxy groups, e.g. methoxy, ethoxy, n-propoxy, isopropoxy, n-butoxy, sec-butoxy, tert-butoxy, amyloxy, isoamyloxy or tert-amyloxy, heptyloxy, octyloxy, isoctyloxy, nonyloxy, decyloxy, undecyloxy and dodecyloxy.

**[0375]** C<sub>1</sub>-C<sub>12</sub>alkylthio groups (C<sub>1</sub>-C<sub>8</sub>alkylthio groups) are straight-chain or branched alkylthio groups and have the same preferences as the alkoxy groups, except that oxygen is exchanged against sulfur.

**[0376]** C<sub>1</sub>-C<sub>12</sub>alkylene is bivalent C<sub>1</sub>-C<sub>12</sub>alkyl, i.e. alkyl having two (instead of one) free valencies, e.g. trimethylene or tetramethylene.

**[0377]** A cycloalkyl group is typically C<sub>3</sub>-C<sub>8</sub>cycloalkyl, such as, for example, cyclopentyl, cyclohexyl, cycloheptyl, or cyclooctyl, which may be unsubstituted or substituted.

**[0378]** In several cases it is advantageous to in addition to the photoinitiator employ a sensitizer compound. Examples of suitable sensitizer compounds are disclosed in WO 06/008251, page 36, line 30 to page 38, line 8, the disclosure of which is hereby incorporated by reference. As sensitizer inter alia benzophenone compounds as described above can be employed.



[0379] If desired, the photocurable compositions may comprise further mixture constituents which are preferably selected from

[0380] at least one component D which is in turn selected from

[0381] (H.4) defoamers and deaerating agents;

[0382] (H.5) lubricants and leveling agents;

[0383] (H.6) thermally curing and/or radiation-curing auxiliaries;

[0384] (H.7) substrate wetting auxiliaries;

[0385] (H.8) wetting and dispersing auxiliaries;

[0386] (H.9) hydrophobizing agents;

[0387] (H.10) in-can stabilizers; and

[0388] (H.11) auxiliaries for improving scratch resistance;

[0389] at least one component E which is in turn selected from

[0390] (E.1) dyes; and

[0391] (E.2) pigments;

[0392] at least one component F which is in turn selected from light, heat and oxidation stabilizers; and

[0393] at least one component G which is in turn selected from IR-absorbing compounds.

[0394] The effect of the defoamers and deaerating agents (H.4), lubricants and leveling agents (H.5), thermally curing or radiation-curing auxiliaries (H.6), substrate wetting auxiliaries (H.7), wetting and dispersing auxiliaries (H.8), hydrophobizing agents (H.9), in-can stabilizers (H.10) and auxiliaries for improving scratch resistance (H.11) listed under component D usually cannot be strictly distinguished from one another. For instance, lubricants and leveling agents often additionally act as defoamers and/or deaerating agents and/or as auxiliaries for improving scratch resistance. Radiation-curing auxiliaries can in turn act as lubricants and leveling agents and/or deaerating agents and/or also as substrate wetting auxiliaries. In accordance with the above statements, a certain additive may therefore be attributed to more than one of the groups (H.4) to (H.11) described below.

[0395] The defoamers of group (H.4) include silicon-free and silicon-containing polymers. The silicon-containing polymers are, for example, unmodified or modified polydialkylsiloxanes or branched copolymers, comb copolymers or block copolymers composed of polydialkylsiloxane and polyether units, the latter being obtainable from ethylene oxide or propylene oxide.

[0396] The deaerating agents of group (H.4) include, for example, organic polymers, for instance polyethers and polyacrylates, dialkylpolysiloxanes, especially dimethylpolysiloxanes, organically modified polysiloxanes, for instance arylalkyl-modified polysiloxanes, or else fluorosilicones. The action of defoamers is based essentially on preventing foam formation or destroying foam which has already formed. Deaerating agents act essentially in such a way that they promote the coalescence of finely distributed gas or air bubbles to larger bubbles in the medium to be deaerated, for example the inventive mixtures, and hence accelerate the escape of the gas (or of the air). Since defoamers can often also be used as deaerating agents and vice versa, these additives have been combined together under group (H.4). Such auxiliaries are, for example, obtainable commercially from Tego as TECO® Foamex 800, TECO® Foamex 805, TECO® Foamex 810, TECO® Foamex 815, TECO® Foamex 825, TECO® Foamex 835, TECO® Foamex 840, TECO® Foamex 842, TECO® Foamex 1435, TECO® Foamex 1488, TECO® Foamex 1495, TECO® Foamex

3062, TECO® Foamex 7447, TECO® Foamex 8020, Tego® Foamex N, TECO® Foamex K 3, TECO® Antifoam 2-18, TECO® Antifoam 2-57, TECO® Antifoam 2-80, TECO® Antifoam 2-82, TECO® Antifoam 2-89, TECO® Antifoam 2-92, TECO® Antifoam 14, TECO® Antifoam 28, TECO® Antifoam 81, TECO® Antifoam D 90, TECO® Antifoam 93, TECO® Antifoam 200, TECO® Antifoam 201, TECO® Antifoam 202, TECO® Antifoam 793, TECO® Antifoam 1488, TECO® Antifoam 3062, TEGOPREN® 5803, TEGOPREN® 5852, TEGOPREN® 5863, TEGOPREN® 7008, TECO® Antifoam 1-60, TECO® Antifoam 1-62, TECO® Antifoam 1-85, TECO® Antifoam 2-67, TECO® Antifoam WM 20, TECO® Antifoam 50, TECO® Antifoam 105, TECO® Antifoam 730, TECO® Antifoam MR 1015, TECO® Antifoam MR 1016, TECO® Antifoam 1435, TECO® Antifoam N, TECO® Antifoam KS 6, TECO® Antifoam KS 10, TECO® Antifoam KS 53, TECO® Antifoam KS 95, TECO® Antifoam KS 100, TECO® Antifoam KE 600, TECO® Antifoam KS 911, TECO® Antifoam MR 1000, TECO® Antifoam KS 1100, Tego® Airex 900, Tego® Airex 910, Tego® Airex 931, Tego® Airex 935, Tego® Airex 960, Tego® Airex 970, Tego® Airex 980 and Tego® Airex 985, and from BYK as BYK®-011, BYK®-019, BYK®-020, BYK®-021, BYK®-022, BYK®-023, BYK®-024, BYK®-025, BYK®-027, BYK®-031, BYK®-032, BYK®-033, BYK®-034, BYK®-035, BYK®-036, BYK®-037, BYK®-045, BYK®-051, BYK®-052, BYK®-053, BYK®-055, BYK®-057, BYK®-065, BYK®-067, BYK®-070, BYK®-080, BYK®-088, BYK®-141 and BYK®-A 530.

[0397] The auxiliaries of group (H.4) are typically used in a proportion of from about 0.05 to 3.0% by weight, preferably from about 0.5 to 2.0% by weight, based on the total weight of the composition.

[0398] The group (H.5) of the lubricants and leveling agents includes, for example, silicon-free but also silicon-containing polymers, for example polyacrylates or modified low molecular weight polydialkylsiloxanes. The modification consists in replacing some of the alkyl groups with a wide variety of organic radicals. These organic radicals are, for example, polyethers, polyesters or else long-chain alkyl radicals, the former finding most frequent use. The polyether radicals of the correspondingly modified polysiloxanes are typically formed by means of ethylene oxide and/or propylene oxide units. The higher the proportion of these alkylene oxide units is in the modified polysiloxane, the more hydrophilic is generally the resulting product.

[0399] Such auxiliaries are obtainable commercially, for example, from Tego as TECO® Glide 100, TECO® Glide ZG 400, TECO® Glide 406, TECO® Glide 410, TECO® Glide 411, TECO® Glide 415, TECO® Glide 420, TECO® Glide 435, TECO® Glide 440, TECO® Glide 450, TECO® Glide A 115, TECO® Glide B 1484 (also usable as a defoamer and deaerating agent), TECO® Flow ATF, TECO® Flow ATF2, TECO® Flow 300, TECO® Flow 460, TECO® Flow 425 and TECO® Flow ZFS 460. The radiation-curable lubricants and leveling agents used, which additionally also serve to improve scratch resistance, can be the products TECO® Rad 2100, TECO® Rad 2200, TECO® Rad 2300, TECO® Rad 2500, TECO® Rad 2600, TECO® Rad 2700 and TECO® Twin 4000, likewise obtainable from Tego. Such auxiliaries are obtainable from BYK, for example as BYK®-300, BYK®-306, BYK®-307,

BYK®-310, BYK®-320, BYK®-322, BYK®-331, BYK®-333, BYK®-337, BYK®-341, Byk® 354, Byk® 361 N, BYK®-378 and BYK®-388.

**[0400]** The auxiliaries of group (H.5) are typically used in a proportion of from about 0.005 to 1.0% by weight, preferably from about 0.01 to 0.2% by weight, based on the total weight of the composition.

**[0401]** Group (H.6) includes, as radiation-curing auxiliaries, in particular polysiloxanes with terminal double bonds which are, for example, part of an acrylate group. Such auxiliaries can be made to crosslink by actinic or, for example, electron beam radiation. These auxiliaries generally combine several properties in one. In the uncrosslinked state, they can act as defoamers, deaerating agents, lubricants and leveling agents and/or substrate wetting aids; in the crosslinked state, they increase in particular the scratch resistance, for example of coatings or films which can be produced with the inventive mixtures. The improvement in the shine performance, for example, coatings or films can essentially be regarded as the effect of the action of these auxiliaries as defoamers, devolatilizers and/or lubricants and leveling agents (in the uncrosslinked state). The radiation-curing auxiliaries which can be used are, for example, the products TECO® Rad 2100, TECO® Rad 2200, TECO® Rad 2500, TECO® Rad 2600 and TECO® Rad 2700 obtainable from Tego, and the product BYK®-371 obtainable from BYK. Thermally curing auxiliaries of group (H.6) comprise, for example, primary OH groups which can react with isocyanate groups.

**[0402]** The thermally curing auxiliaries used can, for example, be the products BYK®-370, BYK®-373 and BYK®-375 obtainable from BYK. The auxiliaries of group (H.6) are typically used in a proportion of from about 0.1 to 5.0% by weight, preferably from about 0.1 to 3.0% by weight, based on the total weight of the composition.

**[0403]** The auxiliaries of group (H.7) of the substrate wetting aids serve in particular to increase the wettability of the substrate, which is to be imprinted or coated, for instance, by printing inks or coating compositions, for example compositions (a.1) to (a.5). The generally associated improvement in the lubricating and leveling performance of such printing inks or coating compositions has an effect on the appearance of the finished (for example cross-linked) print or of the finished (for example cross-linked) layer. A wide variety of such auxiliaries are commercially available, for example, from Tego as TECO® Wet KL 245, TECO® Wet 250, TECO® Wet 260 and TECO® Wet ZFS 453, and from BYK as BYK®-306, BYK®-307, BYK®-310, BYK®-333, BYK®-344, BYK®-345, BYK®-346 and Byk®-348.

**[0404]** Also very suitable are the products of the Zonyl® brand from Dupont, such as Zonyl® FSA and Zonyl® FSG. These are fluorinated surfactants/wetting agents.

**[0405]** The auxiliaries of group (H.7) are typically used in a proportion of from about 0.01 to 3.0% by weight, preferably from about 0.01 to 1.5% by weight and especially from 0.03 to 1.5% by weight, based on the total weight of the composition.

**[0406]** The auxiliaries of group (H.8) of the wetting and dispersing aids serve in particular to prevent the leaching and floating and also the settling of pigments, and are therefore useful, if necessary, in pigmented compositions in particular.

**[0407]** These auxiliaries stabilize pigment dispersions essentially by electrostatic repulsion and/or steric hindrance of the additized pigment particles, the interaction of the auxiliary with the surrounding medium (for example binder) playing a major role in the latter case. Since the use of such wetting and dispersing aids is common practice, for example, in the technical field of printing inks and paints, the selection of such a suitable auxiliary in the given case generally presents no difficulties to the person skilled in the art.

**[0408]** Such wetting and dispersing aids are supplied commercially, for example, by Tego as TEGO® Dispers 610, TEGO® Dispers 610 S, TEGO® Dispers 630, TEGO® Dispers 700, TEGO® Dispers 705, TEGO® Dispers 710, TEGO® Dispers 720 W, TEGO® Dispers 725 W, TEGO® Dispers 730 W, TEGO® Dispers 735 W and TEGO® Dispers 740 W, and by BYK as Disperbyk®, Disperbyk®-107, Disperbyk®-108, Disperbyk®-110, Disperbyk®-111, Disperbyk®-115, Disperbyk®-130, Disperbyk®-160, Disperbyk®-161, Disperbyk®-162, Disperbyk®-163, Disperbyk®-164, Disperbyk®-165, Disperbyk®-166, Disperbyk®-167, Disperbyk®-170, Disperbyk®-174, Disperbyk®-180, Disperbyk®-181, Disperbyk®-182, Disperbyk®-183, Disperbyk®-184, Disperbyk®-185, Disperbyk®-190, Anti-Terra®-U, Anti-Terra®-U 80, Anti-Terra®-P, Anti-Terra®-203, Anti-Terra®-204, Anti-Terra® 5 206, BYK®-151, BYK®-154, BYK®-155, BYK®-P 104 S, BYK®-P 105, Lactimon®, Lactimon®-WS and Bykumen®. The abovementioned Zonyl® brands, such as Zonyl® FSA and Zonyl® FSG, from DuPont are also useful here.

**[0409]** The dosage of the auxiliaries of group (H.8) depends mainly upon the surface area of the pigments to be covered and upon the mean molar mass of the auxiliary.

**[0410]** For inorganic pigments and low molecular weight auxiliaries, a content of the latter of from about 0.5 to 2.0% by weight based on the total weight of pigment and auxiliary is typically assumed. In the case of high molecular weight auxiliaries, the content is increased to from about 1.0 to 30% by weight.

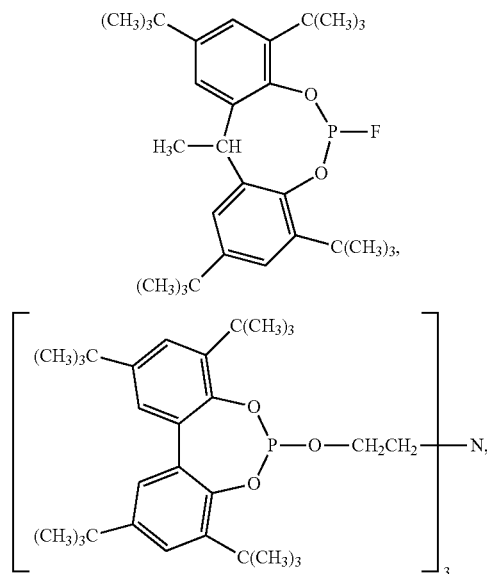
**[0411]** In the case of organic pigments and low molecular weight auxiliaries, the content of the latter is from about 1.0 to 5.0% by weight based on the total weight of pigment and auxiliary. In the case of high molecular weight auxiliaries, this content may be in the range from about 10.0 to 90% by weight. In every case, therefore, preliminary experiments are recommended, which can, though, be accomplished by the person skilled in the art in a simple manner.

**[0412]** The hydrophobizing agents of group (H.9) can be used with a view, for example, to providing prints or coatings obtained with inventive mixtures with water-repellent properties. This means that swelling resulting from water absorption and hence a change, for example, in the optical properties of such prints or coatings is no longer possible or at least greatly suppressed. In addition, when the mixtures are used, for example, as a printing ink in offset printing, their absorption of water can be prevented or at least greatly inhibited. Such hydrophobizing agents are commercially available, for example, from Tego as Tego® Phobe WF, Tego® Phobe 1000, Tego® Phobe 1000 S, Tego® Phobe 1010, Tego® Phobe 1030, Tego® Phobe 1040, Tego® Phobe 1050, Tego® Phobe 1200, Tego® Phobe 1300, Tego® Phobe 1310 and Tego® Phobe 1400.

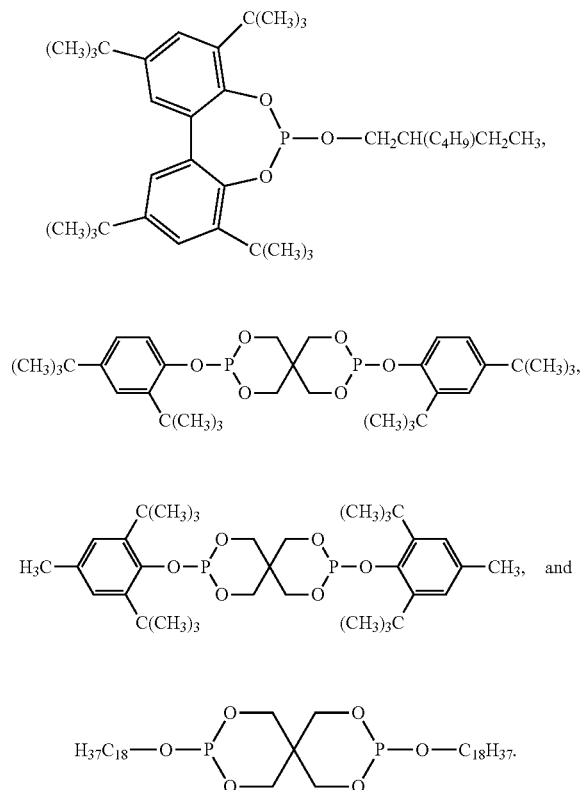
**[0413]** The auxiliaries of group (H.9) are used typically in a proportion of from about 0.05 to 5.0% by weight, preferably from about 0.1 to 3.0% by weight, based on the total weight of the composition.

**[0414]** In-can stabilizers of group (H.10) provide increased storage stability from manufacturing to curing. Examples of in-can stabilizers of group (H.10) are:

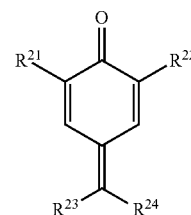
**[0415]** Phosphites and phosphonites (processing stabilizer), for example triphenyl phosphite, diphenylalkyl phosphites, phenyldialkyl phosphites, tris(nonylphenyl) phosphite, trilauryl phosphite, trioctadecyl phosphite, distearyl pentaerythritol diphosphite, tris(2,4-di-tert-butylphenyl) phosphite, diisodecyl pentaerythritol diphosphite, bis(2,4-di-tert-butylphenyl) pentaerythritol diphosphite, bis(2,4-di-cumylphenyl) pentaerythritol diphosphite, bis(2,6-di-tert-butyl-4-methylphenyl) pentaerythritol diphosphite, diisodecyl pentaerythritol diphosphite, bis(2,4-di-tert-butyl-6-methylphenyl) pentaerythritol diphosphite, bis(2,4,6-tris(tert-butylphenyl) pentaerythritol diphosphite, tristearyl sorbitol triphosphite, tetrakis(2,4-di-tert-butylphenyl) 4,4'-biphenylene diphosphonite, 6-isooctyl-2,4,8,10-tetra-tert-butyl-12H-dibenz[d,g]-1,3,2-dioxaphosphocin, bis(2,4-di-tert-butyl-6-methylphenyl)methyl phosphite, bis(2,4-di-tert-butyl-6-methylphenyl)ethyl phosphite, 6-fluoro-2,4,8,10-tetra-tert-butyl-12-methyl-dibenz[d,g]-1,3,2-dioxaphosphocin, 2,2',2''-nitrilo[triethyltris(3,3',5,5'-tetra-tert-butyl-1,1'-biphenyl-2,2'-diyl)phosphite], 2-ethylhexyl(3,3',5,5'-tetra-tert-butyl-1,1'-biphenyl-2,2'-diyl)phosphite, 5-butyl-5-ethyl-2-(2,4,6-tri-tert-butylphenoxy)-1,3,2-dioxaphosphirane, phosphorous acid, mixed 2,4-bis(1,1-dimethylpropyl)phenyl and 4-(1,1-dimethylpropyl)phenyl triesters (CAS No. 939402-02-5), Phosphorous acid, triphenyl ester, polymer with alpha-hydro-omega-hydroxypoly[oxy(methyl-1,2-ethanedyl)], C10-16 alkyl esters (CAS No. 1227937-46-3). The following phosphites are especially preferred: Tris(2,4-di-tert-butylphenyl) phosphite, tris(nonylphenyl) phosphite,



-continued



**[0416]** Quinone Methides of the Formula

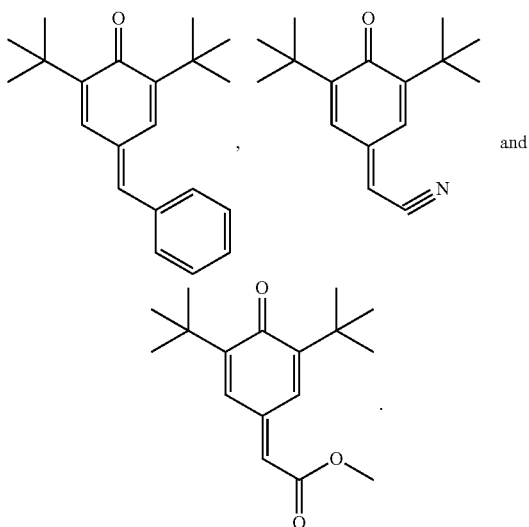


(providing long term shelf life stability), wherein

**[0417]**  $R^{21}$  and  $R^{22}$  independently of each other are  $C_1$ - $C_{18}$ alkyl,  $C_5$ - $C_{12}$ cycloalkyl,  $C_7$ - $C_{15}$ -phenylalkyl, optionally substituted  $C_6$ - $C_{10}$ aryl;

**[0418]**  $R^{23}$  and  $R^{24}$  independently of each other are H, optionally substituted  $C_6$ - $C_{10}$ -aryl, 2-,3-,4-pyridyl, 2-,3-furyl or thienyl, COOH, COOR<sup>25</sup>, CONH<sub>2</sub>, CONHR<sup>25</sup>, CONR<sup>25</sup>R<sup>26</sup>, -CN, -COR<sup>25</sup>, -OCOR<sup>25</sup>, -OPO(OR<sup>25</sup>)<sub>2</sub>, wherein  $R^{25}$  and  $R^{26}$  are independently of each other  $C_1$ - $C_8$ alkyl, or phenyl. Quinone methides are preferred, wherein  $R^{21}$  and  $R^{22}$  are tert-butyl;

**[0419]**  $R^{23}$  is H, and  $R^{24}$  is optionally substituted phenyl, COOH, COOR<sup>25</sup>, CONH<sub>2</sub>, CONHR<sup>25</sup>, CONR<sup>25</sup>R<sup>26</sup>, -CN, -COR<sup>25</sup>, -OCOR<sup>25</sup>, -OPO(OR<sup>25</sup>)<sub>2</sub>, wherein  $R^{25}$  and  $R^{26}$  are  $C_1$ - $C_8$ alkyl, or phenyl. Examples of quinone methides are



[0420] The quinone methides may be used in combination with highly sterically hindered nitroxyl radicals as described, for example, in US20110319535.

[0421] In-can stabilizers of group (H.10) are used typically in a proportion of from about 0.01 to 0.3% by weight, preferably from about 0.04 to 0.15% by weight, based on the total weight of the composition.

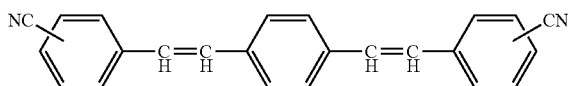
[0422] The group (H.11) of the auxiliaries for improving scratch resistance includes, for example, the products TECO® Rad 2100, TECO® Rad 2200, TECO® Rad 2500, TECO® Rad 2600 and TECO® Rad 2700 which are obtainable from Tego and have already been mentioned above.

[0423] For these auxiliaries, useful amounts are likewise those mentioned in group (H.6), i.e. these additives are typically used in a proportion of from about 0.1 to 5.0% by weight, preferably from about 0.1 to 3.0% by weight, based on the total weight of the composition.

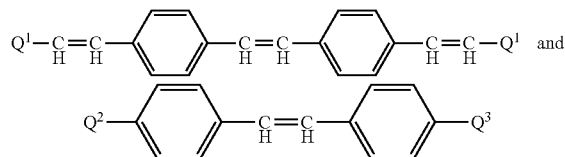
[0424] The group (E.1) of the dyes includes, for example, dyes from the class of the azo dyes, metal complex dyes, basic dyes such as di- and triarylmethane dyes and salts thereof, azomethine derivatives, polymethines, anthraquinone dyes and the like. An overview of suitable dyes which can be used in the inventive mixture is given by the book by H. Zollinger, "Color Chemistry", Wiley-VCH, Weinheim, 3<sup>rd</sup> edition 2003.

[0425] It is in particular also possible to add to the inventive mixtures photochromic, thermochromic or luminescent dyes, and dyes which have a combination of these properties. In addition to the typical fluorescent dyes, fluorescent dyes should also be understood to mean optical brighteners. Optical brighteners may be used for the optimization of the absorption characteristics (critical energy and depth of penetration) of the photocurable composition.

[0426] Examples of the latter include the class of the bisstyrylbenzenes, especially of the cyanostyryl compounds, and correspond to the formula

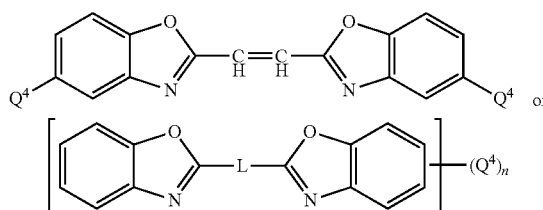


[0427] Further suitable optical brighteners from the class of the stilbenes are, for example, those of the formulae

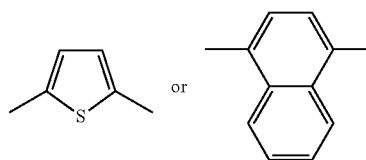


[0428] in which Q<sup>1</sup> is in each case C<sub>1</sub>-C<sub>4</sub>-alkoxycarbonyl or cyano, Q<sup>2</sup> is benzoxazol-2-yl, which may be mono- or disubstituted by C<sub>1</sub>-C<sub>4</sub>-alkyl, especially methyl, Q<sup>3</sup> is C<sub>1</sub>-C<sub>4</sub>-alkoxycarbonyl or 3-(C<sub>1</sub>-C<sub>4</sub>-alkyl)-1,2,4-oxadiazol-3-yl.

[0429] Further suitable optical brighteners from the class of the benzoxazoles obey, for example, the formulae

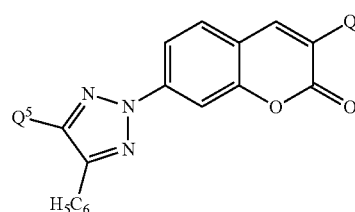


[0430] in which Q<sup>4</sup> is in each case C<sub>1</sub>-C<sub>4</sub>-alkyl, especially methyl, L is a radical of the formula



[0431] and n is an integer from 0 to 2.

[0432] Suitable optical brighteners from the class of the coumarins have, for example, the formula

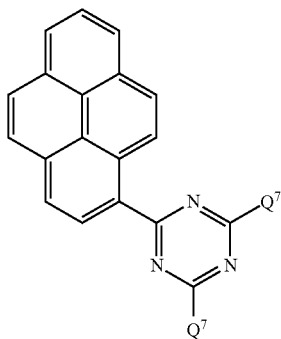


[0433] in which

[0434] Q<sup>5</sup> is C<sub>1</sub>-C<sub>4</sub>-alkyl and

[0435] Q<sup>6</sup> is phenyl or 3-halopyrazol-1-yl, especially 3-chloropyrazol-1-yl.

[0436] Further suitable optical brighteners from the class of the pyrenes correspond, for example, to the formula



[0437] in which

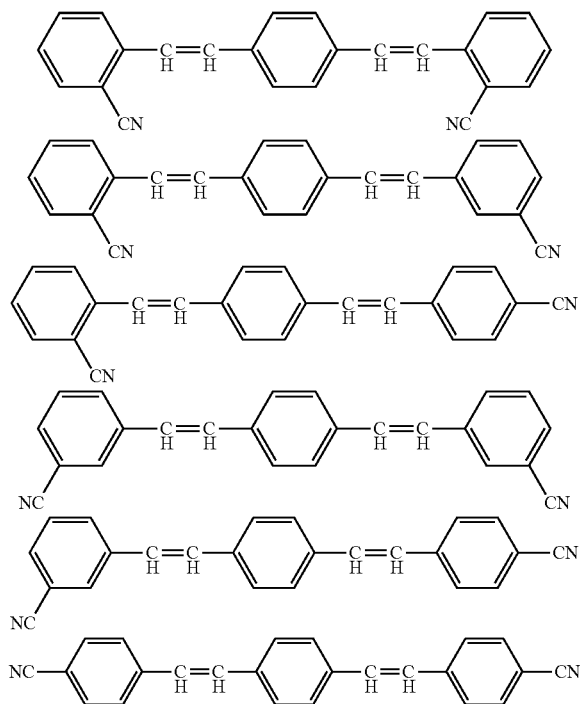
[0438]  $Q^7$  is in each case  $C_1$ - $C_4$ -alkoxy, especially methoxy.

[0439] The abovementioned brighteners can be used either alone or in a mixture with one another.

[0440] The abovementioned optical brighteners are generally commercially available products known per se. They are described, for example, in Ullmann's Encyclopedia of Industrial Chemistry, 5<sup>th</sup> edition, volume A18, pages 156 to 161, or can be obtained by the methods described there.

[0441] In particular, if desired, one or more optical brighteners from the class of the bistyrylbenzenes is used, especially of the cyanostyrylbenzenes. The latter may be used as individual compounds, but also as a mixture of the isomeric compounds.

[0442] In this case, the isomers correspond to the formulae



[0443] Optical brighteners are sold, for example, commercially as Ultraphor® SF 004, Ultraphor® SF MO, Ultraphor® SF MP and Ultraphor® SF PO from BASF SE.

[0444] The group (E.2) of the pigments includes both inorganic and organic pigments. An overview of inorganic colored pigments which can be used in the inventive mixtures is given by the book by H. Endriß "Aktuelle anorganische Bunt-Pigmente" ["Current inorganic colored pigments"] (publisher U. Zorll, Curt-R.-Vincentz-Verlag Hanover 1997), and the book by G. Buxbaum, "Industrial Inorganic Pigments", Wiley-VCH, Weinheim, 3<sup>rd</sup> edition 2005. In addition, useful further pigments which are not listed in the aforementioned book are also Pigment Black 6 and Pigment Black 7 (carbon black), Pigment Black 11 (iron oxide black,  $Fe_3O_4$ ), Pigment White 4 (zinc oxide, ZnO), Pigment White 5 (lithopone, ZnS/BaSO<sub>4</sub>), Pigment White 6 (titanium oxide, TiO<sub>2</sub>) and Pigment White 7 (zinc sulfide, ZnS).

[0445] An overview of organic pigments which can be added to the inventive mixtures is provided by the book by W. Herbst and K. Hunger "Industrielle organische Pigmente" ["Industrial Organic Pigments"], Wiley-VCH, Weinheim, 3rd edition 2004. It is also possible to add to the inventive mixtures magnetic, electrically conductive, photochromic, thermochromic or luminescent pigments, and also pigments which have a combination of these properties.

[0446] In addition to some organic pigments, for example Lumogen® Yellow 0795 (BASF SE), useful pigments having luminescent properties are also inorganic, doped or undoped compounds essentially based on alkaline earth metal oxides, alkaline earth metal/transition metal oxides, alkaline earth metal/aluminum oxides, alkaline earth metal/silicon oxides or alkaline earth metal/phosphorus oxides, alkaline earth metal halides, Zn/silicon oxides, Zn/alkaline earth metal halides, rare earth metal oxides, rare earth metal/aluminum oxides, rare earth metal/silicon oxides or rare earth metal/phosphorus oxides, rare earth metal oxide sulfides or oxide halides, zinc oxide, sulfide or selenide, cadmium oxide, sulfide or selenide or zinc/cadmium oxide, sulfide or selenide, the cadmium compounds being of lower importance owing to their toxicological and ecological relevance.

[0447] The dopants used in these compounds are usually aluminum, tin, antimony, rare earth metals, such as cerium, europium or terbium, transition metals, such as manganese, copper, silver or zinc, or combinations of these elements.

[0448] Luminescent pigments are specified below by way of example, the notation "compound:element(s)" being taken to mean to the relevant person skilled in the art that said compound has been doped with the corresponding element(s). In addition, for example, the notation "(P,V)", denotes that the corresponding lattice positions in the solid structure of the pigment are randomly occupied by phosphorus and vanadium.

[0449] Examples of such compounds which are capable of luminescence are  $MgWO_4$ ,  $CaWO_4$ ,  $Sr_4Al_{14}O_{25}:Eu$ ,  $BaMg_2Al_{12}O_{27}:Eu$ ,  $MgAl_{11}O_{19}:Ce,Tb$ ,  $MgSiO_3:Mn$ ,  $Ca_{10}(PO_4)_6(F,Cl):Sb,Mn$ ,  $(SrMg)_2P_2O_7:Eu$ ,  $SrMg_3P_2O_7:Sn$ ,  $BaFCl:Eu$ ,  $Zn_2SiO_4:Mn$ ,  $(Zn,Mg)F_2:Mn$ ,  $Y_2O_3:Eu$ ,  $YVO_4:Eu$ ,  $Y(P,V)O_4:Eu$ ,  $Y_2SiO_5:Ce,Tb$ ,  $Y_2O_2S:Eu$ ,  $Y_2O_2S:Tb$ ,  $La_2O_2S:Tb$ ,  $Gd_2O_2S:Tb$ ,  $LaOBr:Tb$ ,  $ZnO:Zn$ ,  $ZnS:Mn$ ,  $ZnS:Ag$ ,  $ZnS/CdS:Ag$ ,  $ZnS:Cu,Al$ ,  $ZnSe:Mn$ ,  $ZnSe:Ag$  and  $ZnSe:Cu$ .

[0450] Examples of light, heat and/or oxidation stabilizers as component F include: alkylated monophenols, such as 2,6-di-tert-butyl-4-methylphenol, 2-tert-butyl-4,6-dimethylphenol, 2,6-di-tert-butyl-4-ethylphenol, 2,6-di-tert-butyl-

4-n-butylphenol, 2,6-di-tert-butyl-4-isobutylphenol, 2,6-dicyclopentyl-4-methylphenol, 2-( $\alpha$ -methylcyclohexyl)-4,6-dimethylphenol, 2,6-dioctadecyl-4-methylphenol, 2,4,6-tricyclohexylphenol, 2,6-di-tert-butyl-4-methoxymethylphenol, nonylphenols which have a linear or branched side chain, for example 2,6-dinonyl-4-methylphenol, 2,4-dimethyl-6-(1'-methylundec-1'-yl)phenol, 2,4-dimethyl-6-(1'-methylheptadec-1'-yl)phenol, 2,4-dimethyl-6-(1'-methyltridec-1'-yl)phenol and mixtures of these compounds, alkylthiomethylphenols, such as 2,4-dioctylthiomethyl-6-tert-butylphenol, 2,4-dioctylthiomethyl-6-methylphenol, 2,4-dioctylthiomethyl-6-ethylphenol and 2,6-didodecylthiomethyl-4-nonylphenol, hydroquinones and alkylated hydroquinones, such as 2,6-di-tert-butyl-4-methoxyphenol, 2,5-di-tert-butylhydroquinone, 2,5-di-tert-amylhydroquinone, 2,6-diphenyl-4-octadecyloxyphenol, 2,6-di-tert-butylhydroquinone, 2,5-di-tert-butyl-4-hydroxyanisole, 3,5-di-tert-butyl-4-hydroxyanisole, 3,5-di-tert-butyl-4-hydroxyphenyl stearate and bis(3,5-di-tert-butyl-4-hydroxyphenyl)adipate, tocopherols, such as  $\alpha$ -tocopherol,  $\beta$ -tocopherol,  $\gamma$ -tocopherol,  $\delta$ -tocopherol and mixtures of these compounds, and tocopherol derivatives, such as tocopheryl acetate, succinate, nicotinate and polyoxyethyl-enesuccinate ("tocofersolate"), hydroxylated diphenyl thioethers, such as 2,2'-thiobis(6-tert-butyl-4-methylphenol), 2,2'-thiobis(4-octylphenol), 4,4'-thiobis(6-tert-butyl-3-methylphenol), 4,4'-thiobis(6-tert-butyl-2-methylphenol), 4,4'-thiobis(3,6-di-sec-amylphenol) and 4,4'-bis(2,6-dimethyl-4-hydroxyphenyl) disulfide, alkylidenebisphenols, such as 2,2'-methylenebis(6-tert-butyl-4-methylphenol), 2,2'-methylenebis(6-tert-butyl-4-ethylphenol), 2,2'-methylenebis[4-methyl-6-( $\alpha$ -methylcyclohexyl)phenol], 2,2'-methylenebis(4-methyl-6-cyclohexylphenol), 2,2'-methylenebis(6-nonyl-4-methylphenol), 2,2'-methylenebis(4,6-di-tert-butylphenol), 2,2-ethylidenebis(4,6-di-tert-butylphenol), 2,2'-ethylidenebis(6-tert-butyl-4-isobutylphenol), 2,2'-methylenebis[6-( $\alpha$ -methylbenzyl)-4-nonylphenol], 2,2'-methylenebis[6-( $\alpha$ , $\alpha$ -dimethylbenzyl)-4-nonylphenol], 4,4'-methylenebis(2,6-di-tert-butylphenol), 4,4'-methylenebis(6-tert-butyl-2-methylphenol), 1,1-bis(5-tert-butyl-4-hydroxy-2-methylphenyl)butane, 2,6-bis(3-tert-butyl-5-methyl-2-hydroxybenzyl)-4-methyl phenol, 1,1,3-tris(5-tert-butyl-4-hydroxy-2-methylphenyl)butane, 1,1-bis(5-tert-butyl-4-hydroxy-2-methylphenyl)-3-n-dodecylmercaptobutane, ethylene glycol bis[3,3-bis(3'-tert-butyl-4'-hydroxyphenyl)butyrate], bis(3-tert-butyl-4-hydroxy-5-methylphenyl)dicyclopentadiene, bis[2-(3'-tert-butyl-2'-hydroxy-5'-methylbenzyl)-6-tert-butyl-4-methylphenyl] terephthalate, 1,1-bis(3,5-dimethyl-2-hydroxyphenyl)butane, 2,2-bis(3,5-di-tert-butyl-4-hydroxyphenyl)propane, 2,2-bis(5-tert-butyl-4-hydroxy-2-methylphenyl)-4-n-dodecyl-mercaptobutane and 1,1,5,5-tetrakis(5-tert-butyl-4-hydroxy-2-methylphenyl)pentane, O-, N- and S-benzyl compounds, such as 3,5,3',5'-tetra-tert-butyl-4,4'-dihydroxydibenzyl ether, octadecyl 4-hydroxy-3,5-dimethylbenzylmercaptoacetate, tridecyl 4-hydroxy-3,5-di-tert-butylbenzylmercaptoacetate, tris(3,5-di-tert-butyl-4-hydroxybenzyl)amine, bis(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl) dithioterephthalate, bis(3,5-di-tert-butyl-4-hydroxybenzyl) sulfide and isoctyl-3,5-di-tert-butyl-4-hydroxybenzylmercaptoacetate, aromatic hydroxybenzyl compounds, such as 1,3,5-tris(3,5-di-tert-butyl-4-hydroxybenzyl)-2,4,6-trimethylbenzene, 1,4-bis(3,5-di-tert-butyl-4-hydroxybenzyl)-2,3,5,6-tetramethylbenzene and 2,4,6-tris

(3,5-di-tert-butyl-4-hydroxybenzyl)phenol, triazine compounds, such as 2,4-bis(octylmercapto)-6-(3,5-di-tert-butyl-4-hydroxyanilino)-1,3,5-triazine, 2-octylmercapto-4,6-bis(3,5-di-tert-butyl-4-hydroxyanilino)-1,3,5-triazine, 2-octylmercapto-4,6-bis(3,5-di-tert-butyl-4-hydroxyphenoxy)-1,3,5-triazine, 2,4,6-tris(3,5-di-tert-butyl-4-hydroxyphenoxy)-1,2,3-triazine, 1,3,5-tris(3,5-di-tert-butyl-4-hydroxybenzyl) isocyanurate, 1,3,5-tris(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl) isocyanurate, 2,4,6-tris(3,5-di-tert-butyl-4-hydroxyphenylethyl)-1,3,5-triazine, 1,3,5-tris-(3,5-di-tert-butyl-4-hydroxyphenylpropionyl) hexahydro-1,3,5-triazine, 1,3,5-tris(3,5-dicyclohexyl-4-hydroxybenzyl) isocyanurate and 1,3,5-tris(2-hydroxyethyl) isocyanurate, benzylphosphonates, such as dimethyl 2,5-di-tert-butyl-4-hydroxybenzylphosphonate, diethyl 3,5-di-tert-butyl-4-hydroxybenzylphosphonate, dioctadecyl 3,5-di-tert-butyl-4-hydroxybenzylphosphonate and dioctadecyl 5-tert-butyl-4-hydroxy-3-methylbenzylphosphonate, acylaminophenols, such as 4-hydroxy-lauroylanilide, 4-hydroxystearoylanilide and octyl N-(3,5-di-tert-butyl-4-hydroxyphenyl)carbamate, propionic and acetic esters, for example of monohydric or polyhydric alcohols, such as methanol, ethanol, n-octanol, isooctanol, octadecanol, 1,6-hexanediol, 1,9-nonanediol, ethylene glycol, 1,2-propanediol, neopentyl glycol, thiodiethylene glycol, diethylene glycol, triethylene glycol, pentaerythritol, tris(hydroxyethyl) isocyanurate, N,N'-bis(hydroxyethyl)oxamide, 3-thiaundecanol, 3-thiapentadecanol, trimethylhexanediol, trimethylolpropane and 4-hydroxymethyl-1-phospha-2,6,7-trioxabicyclo[2.2.2]octane, propionamides based on amine derivatives, such as N,N'-bis(3,5-di-tert-butyl-4-hydroxyphenylpropionyl)hexamethylenediamine, N,N'-bis(3,5-di-tert-butyl-4-hydroxyphenylpropionyl)trimethylenediamine and N,N'-bis(3,5-di-tert-butyl-4-hydroxyphenylpropionyl)hydrazine, ascorbic acid (Vitamin C) and ascorbic acid derivatives, such as ascorbyl palmitate, laurate and stearate, and ascorbyl sulfate and phosphate, antioxidants based on amine compounds, such as N,N'-diisopropyl-p-phenylenediamine, N,N'-di-sec-butyl-p-phenylenediamine, N,N'-bis(1,4-dimethylpentyl)-p-phenylenediamine, N,N'-bis(1-ethyl-3-methylpentyl)-p-phenylenediamine, N,N'-bis(1-methylheptyl)-p-phenylenediamine, N,N'-dicyclohexyl-p-phenylenediamine, N,N'-diphenyl-p-phenylenediamine, N,N'-bis(2-naphthyl)-p-phenylenediamine, N-isopropyl-N'-phenyl-p-phenylenediamine, N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine, N-(1-methylheptyl)-N'-phenyl-p-phenylenediamine, N-cyclohexyl-N'-phenyl-p-phenylenediamine, 4-(p-toluenesulfamoyl)diphenylamine, N,N'-dimethyl-N,N'-di-sec-butyl-p-phenylenediamine, diphenylamine, N-allyldiphenylamine, 4-isopropoxydiphenylamine, N-phenyl-1-naphthylamine, N-(4-tert-octylphenyl)-1-naphthylamine, N-phenyl-2-naphthylamine, octyl-substituted diphenylamine, such as p,p'-di-tert-octyldiphenylamine, 4-n-butylaminophenol, 4-butyrylaminophenol, 4-nonanoylaminophenol, 4-dodecanoylaminophenol, 4-octadecanoylaminophenol, bis[4-methoxyphenyl]amine, 2,6-di-tert-butyl-4-dimethylaminomethylphenol, 2,4-diaminodiphenylmethane, 4,4'-diaminodiphenylmethane, N,N,N',N'-tetramethyl-4,4'-diaminodiphenylmethane, 1,2-bis[(2-methylphenyl)amino]ethane, 1,2-bis(phenylamino)propane, (o-tolyl)biguanide, bis[4-(1',3'-dimethylbutyl)phenyl]amine, tert-octyl-substituted N-phenyl-1-naphthylamine, a mixture of mono- and dialkylated tert-butyl/tert-octyldiphenylamine, a mixture of

mono- and dialkylated nonyldiphenylamine, a mixture of mono- and dialkylated dodecyldiphenylamine, a mixture of mono- and dialkylated isopropyl/isohexyldiphenylamine, a mixture of mono- and dialkylated tert-butyl diphenylamine, 2,3-dihydro-3,3-dimethyl-4H-1,4-benzothiazine, phenothiazine, a mixture of mono- and dialkylated tert-butyl/tert-octylphenothiazine, a mixture of mono- and dialkylated tert-octylphenothiazine, N-allylphenothiazine, N,N,N',N'-tetraphenyl-1,4-diaminobut-2-ene, N,N-bis(2,2,6,6-tetramethylpiperidin-4-yl)hexamethylenediamine, bis(2,2,6,6-tetramethylpiperidin-4-yl) sebacate, 2,2,6,6-tetramethylpiperidin-4-one and 2,2,6,6-tetramethylpiperidin-4-ol, phosphites and phosphonites, such as triphenylphosphite, diphenyl alkyl phosphite, phenyl dialkyl phosphite, tris(nonylphenyl) phosphite, trilauryl phosphite, trioctadecyl phosphite, distearyl pentaerythritol diphosphite, tris(2,4-di-tert-butylphenyl) phosphite, diisodecyl pentaerythritol diphosphite, bis(2,4-di-tert-butylphenyl) pentaerythritol diphosphite, bis(2,6-di-tert-butyl-4-methylphenyl) pentaerythritol diphosphite, diisodecyl pentaerythritol diphosphite, bis(2,4-di-tert-butyl-6-methylphenyl) pentaerythritol diphosphite, bis(2,4,6-tris(tert-butylphenyl)) pentaerythritol diphosphite, tristearyl sorbitol triphosphite, tetrakis(2,4-di-tert-butylphenyl) 4,4'-biphenylenediphosphonite, 6-isooctyl-2,4,8,10-tetra-tert-butyl-12H-dibenzo[d,g]-1,3,2-dioxaphosphocine, 6-fluoro-2,4,8,10-tetra-tert-butyl-12-methyl-dibenzo[d,g]-1,3,2-dioxaphosphocine, bis(2,4-di-tert-butyl-6-methylphenyl) methyl phosphite and bis(2,4-di-tert-butyl-6-methylphenyl) ethyl phosphite, 2-(2'-hydroxyphenyl)benzotriazoles, such as 2-(2'-hydroxy-5'-methylphenyl)benzotriazole, 2-(3',5'-di-tert-butyl-2'-hydroxyphenyl)benzotriazole, 2-(5'-tert-butyl-2'-hydroxyphenyl)benzotriazole, 2-(2'-hydroxy-5'-(1,1,3,3-tetramethylbutyl)phenyl)benzotriazole, 2-(3',5'-di-tert-butyl-2'-hydroxyphenyl)-5-chlorobenzotriazole, 2-(3'-tert-butyl-2'-hydroxy-5'-methylphenyl)-5-chlorobenzotriazole, 2-(3'-sec-butyl-5'-tert-butyl-2'-hydroxyphenyl)benzotriazole, 2-(2'-hydroxy-4'-octyloxyphenyl)benzotriazole, 2-(3',5'-di-tert-amyl-2'-hydroxyphenyl)benzotriazole, 2-(3',5'-bis(α,α-dimethylbenzyl)-2'-hydroxyphenyl)benzotriazole, a mixture of 2-(3'-tert-butyl-2'-hydroxy-5'-(2-octyloxy-carbonyl)phenyl)-5-chlorobenzotriazole, 2-(3'-tert-butyl-5'-[2-(2-ethylhexyloxy)carbonyl]phenyl)-2'-hydroxyphenyl)-5-chlorobenzotriazole, 2-(3'-tert-butyl-2'-hydroxy-5'-(2-methoxycarbonyl)phenyl)-5-chlorobenzotriazole, 2-(3'-tert-butyl-2'-hydroxy-5'-(2-methoxycarbonyl)phenyl)benzotriazole, 2-(3'-tert-butyl-2'-hydroxy-5'-(2-octyloxy-carbonyl)phenyl)benzotriazole, 2-(3'-tert-butyl-5'-[2-(2-ethylhexyloxy)carbonyl]phenyl)-2'-hydroxyphenyl)benzotriazole, 2-(3'-dodecyl-2'-hydroxy-5'-methylphenyl)benzotriazole and 2-(3'-tert-butyl-2'-hydroxy-5'-(2-isooctyloxy-carbonyl)phenyl)benzotriazole, 2,2'-methylenebis[4-(1,1,3,3-tetramethylbutyl)-6-benzotriazol-2-ylphenol]; the product of complete esterification of 2-[3'-tert-butyl-5'-(2-methoxycarbonyl)phenyl]-2'-hydroxyphenyl]-2H-benzotriazole with polyethylene glycol 300; [R—CH<sub>2</sub>CH<sub>2</sub>—COO(CH<sub>2</sub>)<sub>3</sub>]<sub>2</sub>, where R=3'-tert-butyl-4'-hydroxy-5'-2H-benzotriazol-2-ylphenyl], sulfur-containing peroxide scavengers and sulfur-containing antioxidants, such as esters of 3,3'-thiodipropionic acid, for example the lauryl, stearyl, myristyl and tridecyl esters, mercaptobenzimidazole and the zinc salt of 2-mercaptobenzimidazole, dibutylzinc dithiocarbamate, dioctadecyl disulfide and pentaerythritol tetrakis(β-dodecylmercapto)propionate, 2-hy-

droxybenzophenones, such as the 4-hydroxy, 4-methoxy, 4-octyloxy, 4-decyloxy, 4-dodecyloxy, 4-benzyloxy, 4,2', 4'-trihydroxy and 2'-hydroxy-4,4'-dimethoxy derivatives, esters of unsubstituted and substituted benzoic acids, such as 4-tert-butylphenyl salicylate, phenyl salicylate, octylphenyl salicylate, dibenzoylresorcinol, bis(4-tert-butylbenzoyl)resorcinol, benzoylresorcinol, 2,4-di-tert-butylphenyl 3,5-di-tert-butyl-4-hydroxybenzoate, hexadecyl-3,5-di-tert-butyl-4-hydroxybenzoate, octadecyl-3,5-di-tert-butyl-4-hydroxybenzoate and 2-methyl-4,6-di-tert-butylphenyl-3,5-di-tert-butyl-4-hydroxybenzoate, acrylates, such as ethyl α-cyano-β,β-diphenylacrylate, isooctyl α-cyano-β,β-diphenylacrylate, methyl α-methoxycarbonylcinnamate, methyl α-cyano-β-methyl-p-methoxycinnamate, butyl-α-cyano-β-methyl-p-methoxycinnamate and methyl-α-methoxycarbonyl-p-methoxycinnamate, sterically hindered amines, such as bis(2,2,6,6-tetramethylpiperidin-4-yl) sebacate, bis(2,2,6,6-tetramethylpiperidin-4-yl) succinate, bis(1,2,2,6,6-pentamethylpiperidin-4-yl) sebacate, bis(1-octyloxy-2,2,6,6-tetramethylpiperidin-4-yl) sebacate, bis(1,2,2,6,6-pentamethylpiperidin-4-yl)-n-butyl-3,5-di-tert-butyl-4-hydroxybenzylmalonate, the condensation product of 1-(2-hydroxyethyl)-2,2,6,6-tetramethyl-4-hydroxypiperidine and succinic acid, the condensation product of N,N'-bis(2,2,6,5-tetramethylpiperidin-4-yl)hexamethylenediamine and 4-tert-octylamino-2,6-dichloro-1,3,5-triazine, tris(2,2,6,6-tetramethylpiperidin-4-yl) nitrilotriacetate, tetrakis(2,2,6,6-tetramethylpiperidin-4-yl) 1,2,3,4-butanetetracarboxylate, 1,1'-(1,2-ethylene)bis(3,3,5,5-tetramethylpiperazinone), 4-benzoyl-2,2,6,6-tetramethylpiperidine, 4-stearoyloxy-2,2,6,6-tetramethylpiperidine, bis(1,2,2,6,6-pentamethylpiperidin-4-yl) 2-n-butyl-2-(2-hydroxy-3,5-di-tert-butylbenzyl) malonate, 3-n-octyl-7,7,9,9-tetramethyl-1,3,8-triazaspiro[4.5]decane-2,4-dione, bis(1-octyloxy-2,2,6,6-tetramethylpiperidin-4-yl) sebacate, bis(1-octyloxy-2,2,6,5-tetramethylpiperidin-4-yl) succinate, the condensation product of N,N'-bis(2,2,6,6-tetramethylpiperidin-4-yl)hexamethylenediamine and 4-morpholino-2,6-dichloro-1,3,5-triazine, the condensation product of 2-chloro-4,6-bis(4-n-butylamino-2,2,6,6-tetramethylpiperidin-4-yl)-1,3,5-triazine and 1,2-bis(3-aminopropylamino)ethane, the condensation product of 2-chloro-4,6-di(4-n-butylamino-1,2,2,6,6-pentamethylpiperidin-4-yl)-1,3,5-triazine and 1,2-bis(3-aminopropylamino)ethane, 8-acetyl-3-dodecyl-7,7,9,9-tetramethyl-1,3,8-triazaspiro[4.5]decane-2,4-dione, 3-dodecyl-1-(2,2,6,6-tetramethylpiperidin-4-yl)pyrrolidine-2,5-dione, 3-dodecyl-1-(1,2,2,6,6-pentamethylpiperidin-4-yl)pyrrolidine-2,5-dione, a mixture of 4-hexadecyloxy- and 4-stearoyloxy-2,2,6,6-tetramethylpiperidine, the condensation product of N,N'-bis(2,2,6,6-tetramethylpiperidin-4-yl) hexamethylenediamine and 4-cyclohexylamino-2,6-dichloro-1,3,5-triazine, the condensation product of 1,2-bis(3-aminopropylamino)ethane and 2,4,6-trichloro-1,3,5-triazine, 4-butylamino-2,2,6,6-tetramethylpiperidine, N-(2,2,6,6-tetramethylpiperidin-4-yl)-n-dodecylsuccinimide, N-(1,2,2,6,6-pentamethylpiperidin-4-yl)-n-dodecylsuccinimide, 2-undecyl-7,7,9,9-tetramethyl-1-oxa-3,8-diaza-4-oxo-spiro[4.5]decane, the condensation product of 7,7,9,9-tetramethyl-2-cycloundecyl-1-oxa-3,8-diaza-4-oxo-spiro[4.5]decane and epichlorohydrin, the condensation products of 4-amino-2,2,6,6-tetramethylpiperidine with tetramethylolacetylenediureas and poly(methoxypropyl-3-oxy)-[4(2,2,6,6-tetramethylpiperidinyl)siloxane, oxamides, such as 4,4'-diethoxyoxanilide, 2,2'-diethoxyoxanilide, 2,2'-

dioctyloxy-5,5'-di-tert-butoxanilide, 2,2'-didodecyloxy-5,5'-di-tert-butoxanilide, 2-ethoxy-2'-ethyloxanilide, N,N'-bis(3-dimethylaminopropyl)oxamide, 2-ethoxy-5-tert-butyl-2'-ethoxanilide and its mixture with 2-ethoxy-2'-ethyl-5,4'-di-tert-butoxanilide, and mixtures of ortho-, para-methoxy-disubstituted oxanilides and mixtures of ortho- and para-ethoxy-disubstituted oxanilides, and 2-(2-hydroxyphenyl)-1,3,5-triazines, such as 2,4,6-tris-(2-hydroxy-4-octyloxyphenyl)-1,3,5-triazine, 2-(2-hydroxy-4-octyloxyphenyl)-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine, 2-(2,4-dihydroxyphenyl)-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine, 2,4-bis(2-hydroxy-4-propyloxyphenyl)-6-(2,4-dimethylphenyl)-1,3,5-triazine, 2-(2-hydroxy-4-octyloxyphenyl)-4,6-bis(4-methyl-5-phenyl)-1,3,5-triazine, 2-(2-hydroxy-4-dodecyloxyphenyl)-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine, 2-(2-hydroxy-4-tridecyloxyphenyl)-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine, 2-[2-hydroxy-4-(2-hydroxy-3-butyloxypropoxy)phenyl]-4,6-bis(2,4-dimethyl)-1,3,5-triazine, 2-[2-hydroxy-4-(2-hydroxy-3-octyloxypropoxy)phenyl]-4,6-bis(2,4-dimethyl)-1,3,5-triazine, 2-[4-(dodecyloxy/tridecyloxy-2-hydroxypropoxy)-2-hydroxyphenyl]-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine, 2-[2-hydroxy-4-(2-hydroxy-3-dodecyloxypropoxy)phenyl]-4,6-bis(2,4-dimethylphenyl)-1,3,5-triazine, 2-(2-hydroxy-4-hexyloxyphenyl)-4,6-diphenyl-1,3,5-triazine, 2-(2-hydroxy-4-methoxyphenyl)-4,6-diphenyl-1,3,5-triazine, 2,4,6-tris[2-hydroxy-4-(3-butoxy-2-hydroxypropoxy)phenyl]-1,3,5-triazine and 2-(2-hydroxyphenyl)-4-(4-methoxyphenyl)-6-phenyl-1,3,5-triazine.

**[0451]** The components G of the IR absorber used are compounds which exhibit one or more absorption bands in the infrared spectral region, i.e. from >750 nm, e.g. from 751 nm, to 1 mm. Preference is given to compounds which exhibit one absorption band in the near infrared (NIR) spectral region, i.e. from >750 (e.g. 751) to 2000 nm, and optionally additionally also in the visible spectral region, especially from 550 to 750 nm. When the compounds absorb both in the IR and in the visible spectral region, they preferably exhibit the greatest absorption maximum in the IR region and a smaller maximum (frequently in the form of a so-called absorption shoulder) in the visible region. In a particular embodiment, the compounds of component G additionally also exhibit fluorescence. Fluorescence is the transition of a system excited by absorption of electromagnetic radiation (usually visible light, UV radiation, X-rays or electron beams) to a state of lower energy by spontaneous emission of radiation of the same wavelength (resonance fluorescence) or longer wavelength. Preferred compounds of component G exhibit, when they fluoresce, a fluorescence in the IR spectral region, preferably in the NIR.

**[0452]** Such compounds are, for example, selected from naphthalenes, anthracenes, phenanthrenes, tetracenes, perylenes, terrylenes, quaterrylenes, pentarylenes, hexarylenes, anthraquinones, indanthrones, acridines, carbazoles, dibenzofuranes, dinaphthofuranes, benzimidazoles, benzthiazoles, phenazines, di-oxazines, quinacridones, metal phthalocyanines, metal naphthalocyanines, metal porphyrines, coumarines, dibenzofuranones, dinaphthofuranones, benzimidazolones, indigo compounds, thioindigo compounds, quinophthalones, naphthoquinophthalones and diketopyrrolopyrroles. Particularly preferred compounds of component G which absorb IR radiation and optionally fluoresce are selected from naphthalenes, anthracenes,

phenanthrenes, tetracenes, perylenes, terrylenes, quaterrylenes, pentarylenes and hexarylenes, more preferably from perylenes, terrylenes and quaterrylenes and especially from terrylenes and quaterrylenes. The compound is especially a quaterrylene. Suitable compounds are described in WO 2008/012292, which is hereby fully incorporated by reference.

**[0453]** The present disclosure(s) also provides methods suitable for making 3-dimensional structures comprising a plurality of polymer layers and 3-dimensional patterns.

**[0454]** Some embodiments provide methods of patterning a polymeric image on a substrate, each method comprising;

**[0455]** (a) depositing a layer of photocurable composition of any one of the compositions described herein on the substrate;

**[0456]** (b) irradiating a portion of the layer of photocurable composition with a light having appropriate wavelength (s), thereby providing a patterned layer of polymerized and unpolymerized regions. Certain other embodiments further comprise removing the unpolymerized region of the pattern.

**[0457]** The method may comprise depositing a plurality of layers of a photocurable composition on a substrate before irradiation, at least one of which is the photocurable composition of the present invention.

**[0458]** The irradiated portion is patterned through use of a photomask, by a direct writing application of light, by interference, nanoimprint, or diffraction gradient lithography, by inkjet 3D printing, stereolithography, holography, LCD or digital light projection (DLP).

**[0459]** The photocurable compositions may be irradiated by any variety of methods known in the art. Patterning may be achieved by photolithography, using a positive or negative image photomask, by interference lithography (i.e., using a diffraction grating), by proximity field nanopatterning by diffraction gradient lithography, or by a direct laser writing application of light, such as by multi-photon lithography, by nanoimprint lithography, by inkjet 3D printing, stereolithography and the digital micromirror array variation of stereolithography (commonly referred to as digital light projection (DLP)). The photocurable compositions are especially amenable to preparing structures using stereolithographic methods, for example including digital light projection (DLP). The photocurable compositions may be processed as bulk structures, for example using vat polymerization, wherein the photopolymer is cured directly onto a translated or rotated substrate, and the irradiation is patterned via stereolithography, holography, or digital light projection (DLP).

**[0460]** Stereolithography (SLA) is a form of three-dimensional (3D) printing technology used for creating models, prototypes, patterns and production parts in a layer by layer fashion (so-called "additive manufacturing") using photopolymerization, a process by which light causes chains of molecules to link, forming polymers. Those polymers then make up the body of a three-dimensional solid. Typically, an SLA additive manufacturing process uses a build platform having a build tray submerged in a liquid photosensitive material. A 3D model of the item to be manufactured is imported into an associated 3D printer software, which software slices the 3D model into 2D images that are then projected onto the build platform to expose the photopolymer.

**[0461]** FIG. 3 of U.S. Pat. No. 4,575,330 depicts a known prior art "top-down" approach to printing. A container 21 is



filled with a UV curable liquid 22 or the like, to provide a designated working surface 23. A programmable source of ultraviolet (UV) light 26 produces a spot of ultraviolet light 27 in the plane of surface 23. The spot 27 is movable across the surface 23 by the motion of mirrors or other optical or mechanical elements that are a part of light source 26. The position of the spot 27 on surface 23 is controlled by a computer 28. A movable elevator platform 29 inside container 21 is moved up and down selectively, the position of the platform being controlled by the computer 28. The elevator platform may be driven mechanically, pneumatically, hydraulically or electrically, and it typically uses optical or electronic feedback to precisely control its position. As the device operates, it produces a three-dimensional object 30 by step-wise buildup of integrated laminate such as 30a, 30b, 30c. During this operation, the surface of the UV curable liquid 22 is maintained at a constant level in the container 21, and the spot of UV light 27 is moved across the working surface 23 in a programmed manner. As the liquid 22 cures and solid material forms, the elevator platform 29 that was initially just below surface 23 is moved down from the surface in a programmed manner by any suitable actuator. In this way, the solid material that was initially formed is taken below surface 23 and new liquid 22 flows across the surface 23. A portion of this new liquid is, in turn, converted to solid material by the programmed UV light spot 27, and the new material adhesively connects to the material below it. This process is continued until the entire three-dimensional object 30 is formed.

**[0462]** A computer controlled pump (not shown) may be used to maintain a constant level of the liquid 22 at the working surface 23. Appropriate level detection system and feedback networks can be used to drive a fluid pump or a liquid displacement device to offset changes in fluid volume and maintain constant fluid level at the surface 23. Alternatively, the source 26 can be moved relative to the sensed level 23 and automatically maintain sharp focus at the working surface 23. All of these alternatives can be readily achieved by conventional software operating in conjunction with the computer control system 28.

**[0463]** An alternative approach is to build the item from the “bottom-up” as depicted in FIG. 4 of U.S. Pat. No. 4,575,330. In this approach, the UV curable liquid 22 floats on a heavier UV transparent liquid 32 that is non-miscible and non-wetting with the curable liquid 22. By way of example, ethylene glycol or heavy water are suitable for the intermediate liquid layer 32. In the system of FIG. 4, the three-dimensional object 30 is pulled up from the liquid 22, rather than down and further into the liquid medium, as shown in the system of FIG. 3. In particular, the UV light source 26 in FIG. 4 focuses the spot 27 at the interface between the liquid 22 and the non-miscible intermediate liquid layer 32, the UV radiation passing through a suitable UV transparent window 33, of quartz or the like, supported at the bottom of the container 21.

**[0464]** According WO2018106977, and in lieu of printing just from resin in its liquid phase, one or more layers of the item are printed from resin that is foamed (at the build surface 23).

**[0465]** FIG. 3 of WO2018106977 depicts a representative implementation of an additive manufacturing method and apparatus wherein resin foam is the source material for the printer. A top-down printing method is depicted. In this example embodiment, the SLA apparatus comprises a radia-

tion source 300 (e.g., DLP, laser, electron beam (EB), x-ray, etc. and scanner), a movement control mechanism 302 (e.g., a stepper motor) that moves a build platform 304 vertically up and down within a tank 305 that holds the photopolymer resin 306, and a sweeper 308 (also known as a “recoater” blade) that sweeps horizontally. These elements are used to print a part 310 in the manner previously described. The SLA apparatus is augmented with a foam producing and dispensing mechanism to facilitate production of resin foam at the printer interface, namely, the layer being printed. To this end, the mechanism comprises a foaming or pressure vessel 312, an electromechanical valve 314, and a hose or tube 316. A manifold 318 is attached to the sweeper 308 to evenly distribute the foamed resin across the top layer of the build surface. In particular, and as depicted, the foaming vessel receives liquid resin and a suitable gas (e.g., CO<sub>2</sub>, N<sub>2</sub>O, etc.). Gas is dissolved in the liquid resin within the foaming vessel (e.g., by shaking, mixing, agitation, etc.) and selectively delivered to the build plate/platform via the hose 316 when the valve 314 is actuated, e.g., by a solenoid or other electromechanical, pneumatic, optical or electronic control device. Typically, the mechanism is under program control using a computer, which may be the same computer used to control the printer. In this embodiment, the mechanism includes a frother 320 (e.g., a mechanical agitator, an ultrasonic device, etc.) to shake or otherwise dissolve the gas within the liquid vessel if needed to produce foam.

**[0466]** Upon delivery of the resin and gas mixture (directly onto the build plate via the manifold 318), the gas spontaneously evolves out of the liquid mixture (due to the lower pressure) to produce a foam that is radiation-curable. The sweeper 308 spreads the foam evenly onto the plate, and the light engine is then activated to display the appropriate image to cure (solidify) the foam into a layer. Once the layer is formed, the movement control mechanism moves the platform down so that the next layer of the item can be built; the process is then repeated, once again preferably using the foam layer at the print interface.

**[0467]** While the preferred technique uses layer-wise additive manufacturing, other manufacturing processes may be used to process the foam to produce the build item, such as, for example, laser holography, wherein two lasers intersect in a tank of foamed resin and cure the resin at that spot.

**[0468]** The photocurable composition of the present invention is preferably used in vat photopolymerization (stereolithography) and photopolymer jetting/printing.

**[0469]** In addition, the present invention is directed to a method for producing a three-dimensional article, comprising

**[0470]** a) providing the photocurable composition of the present invention,

**[0471]** b) exposing the photocurable composition to actinic radiation to form a cured crosssection,

**[0472]** c) repeating steps (a) and (b) to build up a three-dimensional article.

**[0473]** In a preferred embodiment the method comprises a vat photopolymerization, wherein the photocurable of the present invention in step b) is cured directly onto a translated or rotated substrate, and the irradiation is patterned via stereolithography, holography, or digital light projection (DLP).

**[0474]** In another preferred embodiment the method comprises

[0475] a) applying a layer of the photocurable composition of the present invention onto a surface;

[0476] b) exposing the layer imagewise to actinic radiation to form an imaged cured cross-section;

[0477] c) applying a second layer of the photocurable composition onto the previously exposed imaged cross-section;

[0478] d) exposing the layer from step (c) imagewise to actinic radiation to form an additional imaged cross-section, wherein the radiation causes curing of the second layer in the exposed areas and adhesion to the previously exposed cross-section; and

[0479] e) repeating steps (c) and (d) in order to build up a three-dimensional article.

[0480] Accordingly, the present invention is also directed to a three-dimensional article produced by the method of the present invention, or a three-dimensional article, which is a cured product of the photocurable composition of the present invention.

[0481] The photocurable compositions of the present invention may be used in dual cure stereolithography resins suitable for stereolithography techniques (particularly for CLIP). Reference is made to U.S. Pat. No. 9,453,142, US2016/0136889, US2016/0137838 and US2016/016077. These resins usually include a first polymerizable system typically polymerized by light (sometimes referred to as "Part A") from which an intermediate object is produced, and also include at least a second polymerizable system ("Part B") which is usually cured after the intermediate object is first formed, and which impart desirable structural and/or tensile properties to the final object. The photocurable compositions of the present invention may be comprised by Part A.

[0482] The following examples illustrate the invention without restricting it.

## EXAMPLES

### Experimental

[0483] Materials

[0484] 4-Methacryloylmorpholine (ACMO, 98%) was purchased from TCI. 1,5-Diaminopentane (DAP) and Laromer® UA 9089 were kindly provided by BASF. Glycidyl methacrylate (GMA, 97%, 100 ppm MEHQ), butylated hydroxytoluene (BHT, 99%), tetrabutylammonium bromide (TBAB, 99%), 4,7,10-Trioxa-1,13-tridecanediamine (TODA, 98%), 4,9-Dioxa-1,12-dodecanediamine (DO112DA, 99%), 1,8-Diamino-3,6-dioxaoctane (DO18DA, 98%), 1,3-Cyclohexandiyldimethanamin (CDMA, 98%), m Xylylenediamine (XDA, 99%) Iso-phorone diamine (99%, mixture of cis and trans) and Diphenyl(2,4,6-trimethylbenzoyl)phosphine oxide (TPO, 97%) were obtained from Sigma Aldrich. Samples of JEFFAMINE® THF-170 (PTHFA, 1700 g mol<sup>-1</sup>), JEFFAMINE® T3000 (JT3000, 3000 g mol<sup>-1</sup>) and JEFFAMINE® T403 (JT403, 400 g mol<sup>-1</sup>) were kindly provided by Huntsman. Carbon dioxide (N45) was obtained from Air Liquide. A Sample of Priamine™ 1075 (PA) was kindly provided by Croda.

[0485] Methods

[0486] NMR spectra were recorded in deuterated chloroform on an ARX 300 spectrometer from Bruker at room temperature. The chemical shifts were referenced to the solvent signals. DSC measurements were performed using a

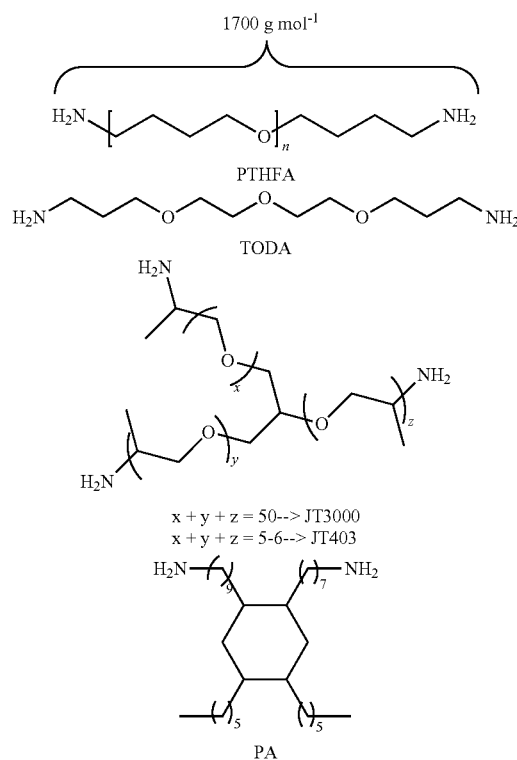
Perkin Elmer's Pyris 1 with a heating and cooling rate of 20 K min<sup>-1</sup> in the temperature range between 0 and 200° C. Tensile testing was performed on a Zwick 2005 (Ulm, Germany, ISO 527-1/2) with a drawing speed of 5 mm min<sup>-1</sup>. The mechanical properties such as elastic modulus, tensile strength and breaking elongation were extracted from measurements at 21° C. by taking the statistical average of four to six test specimens (5 A), which were conditioned before testing (24 h, 21° C., const. humidity). The viscosities were measured on a MARS from Thermo Scientific using a plate-plate set-up with a plate diameter of 35 mm and a gap of 0.6 mm at various shear rates from 0.1 to 100 s<sup>-1</sup> (100 steps, logarithmic, 5 s per step, 3 s integration time) and the final viscosity received as an average over all 100 values. Significant shear-thinning was usually not observed, as indicated by the standard deviations.

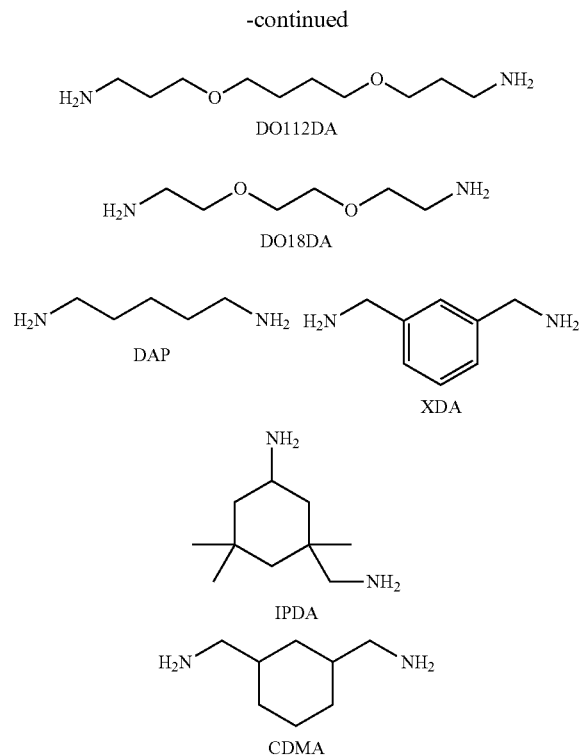
[0487] Synthesis of Glycerol Carbonate Dimethacrylate GCMA

[0488] Glycidyl methacrylate (GMA, 1045.0 g, 7.3514 mol), butylated hydroxytoluene (BHT, 5.2 g, 0.024 mol) and tetrabutylammonium bromide (TBAB, 10.5 g, 0.0326 mol) were placed in a stainless steel reactor and put under 30 bar of carbon dioxide. The mixture was heated to 100° C. and stirred with 500 RPM for 24 h. The Reaction product was used without further purification.

[0489] Synthesis of Hydroxyurethane Methacrylates (HUMA)

[0490] For the preparation of hydroxyurethane methacrylates, the respective amine compound and GCMA were placed in a three-necked flask with an attached mechanical stirrer. In total, eleven di- and triamines were selected, which are displayed in the following figure.





**[0491]** In case of short diamines like TODA, DO112DA, DO18DA, DAP, XDA and CDMA an ice bath was attached during the initial stirring for 5-10 minutes, since the exothermic heat of the reaction may cause acrylate polymerization to occur. Afterwards the flask was put into a preheated oil bath and the reaction performed under vigorous stirring in order to mix air bubbles into the reaction mixture and to increase surface contact with the air atmosphere as a mean to inhibit acrylate polymerization. Since GCMA contains 2 wt % of BHT, no additional inhibitor was added. The weight portions and reaction conditions are summarized in Table 1. All products were used without further purification. Amine equivalents (AE) of JEFFAMINES were determined via <sup>1</sup>H-NMR by applying naphthalene as external standard. AE (PTHFA)=1.22 mmol g<sup>-1</sup>, AE (JT3000)=1.1 mmol g<sup>-1</sup>, AE (JT403)=6.5 mmol g<sup>-1</sup>.

TABLE 1

HUMA	Weight portions and reaction conditions of hydroxyurethane methacrylate (HUMA) syntheses.					
	amine		GCMA		t [h]	η <sup>a</sup> [mPa · s]
	m [g]	n [mmol]	m [g]	n [mmol]		
PTHFA-G	251.61	153.5	48.55	255.8	9.5	43 ± 4
JT3000-G	258.62	94.83	41.45	218.8	37	7.3 ± 0.1
JT403-G	53.09	115.0	54.36	284.6	24	—
TODA-G	64.91	294.6	93.23	491.1	1.5	73 ± 3
DO112DA-G	60.67	297.0	93.56	494.9	1.5	88 ± 2
DO18DA-G	46.64	314.7	99.61	524.5	1.2	156 ± 5
DAP-G	18.94	157.6	49.65	262.7	1.3	—
PA-G	31.80	116.77	18.40	97.40	3.5	208 ± 5
XDA-G	14.85	109.0	34.51	182.21	1.5	—

TABLE 1-continued

HUMA	Weight portions and reaction conditions of hydroxyurethane methacrylate (HUMA) syntheses.					
	amine		GCMA		t [h]	η <sup>a</sup> [mPa · s]
	m [g]	n [mmol]	m [g]	n [mmol]		
CDMA-G	16.51	116.1	34.63	193.4	1.5	—
IPDA-G	35.38	207.8	65.45	346.3	11	—

<sup>a</sup> Determined with a plate-plate rheometer (from 0.1 to 100 s<sup>-1</sup>, 100 steps, logarithmic, 5 s per step, 3 s integration time)

**[0492]** The consumption of amine and cyclic carbonate groups were monitored with <sup>1</sup>H- and <sup>13</sup>C-NMR spectroscopy. For low-molecular weight amines, like TODA or DAP, full conversion was typically achieved within 90 minutes. Primary amine groups attached to a tertiary amine, as present in Jeffamine T3000 (JT3000) or isophorone diamine (IPDA), are less reactive and therefore need longer reaction times. In addition, higher molecular weight amines like the Jeffamines tend to increase the reaction time due to a lower density of reactive groups. The final hydroxyurethane methacrylates (HUMA) exhibit viscosity values between 43-208 Pa·s at 25° C., in case of HUMA containing flexible ether or long-chain methylene sequences. The absence of flexible groups yields high-viscosity products and in case of IPDA-G a solid, for which a viscosity value at 25° C. could not be determined.

#### [0493] Preparation and Curing of Acrylate Resins

**[0494]** The resin formulations consist of 4-methacryloylmorpholine (ACMO) and a HUMA in a 59:39-ratio. Additionally, 1 wt % Diphenyl(2,4,6-trimethylbenzoyl) phosphine oxide (TPO) as a photoinitiator was added. For the preparation of the acrylate resins, TPO was first dissolved in the respective amount of ACMO and subsequently the HUMA homogenized with this solution according to the weight portions in Table 2.

#### [0495] Functionalization of HUMA

**[0496]** The number of nucleophilic groups per gram of DO112DA-G was calculated from the respective weight portions and accounts for Nu-V=3.85 mmol g<sup>-1</sup>. DO112DA-G (17.145 g, 66.009 mmol Nu), methacrylic anhydride (11.192 g, 72.601 mmol, 1.1 eq) and magnesium oxide (nano, 0.3684 g, 1.3 wt %) were vigorously stirred for 4 h at 100° C. under air atmosphere using a mechanical stirrer. The turnover of methacrylic anhydride was monitored with <sup>1</sup>H-NMR spectroscopy. After full conversion the reaction product was dissolved in 50 ml dichloromethane and washed four times with 1 M K<sub>2</sub>CO<sub>3</sub> solution and once with distilled water. The organic phase was then dried over MgSO<sub>4</sub> and the solvent evaporated under reduced pressure to yield DO112DA-G5.

**[0497]** This procedure allows for the functionalization of all secondary amines and nearly all hydroxy groups. This is accompanied by a marked decrease in hydrogen bonding, as reflected by the measured viscosity (at 25° C.) of 42±3 Pa·s for DO112DA-G5 when compared to 88±2 Pa·s for DO112DA-G. The functionalization further accounts for a higher acrylate functionality. This consequently leads to materials with higher stiffness and glass transition temperatures T<sub>g</sub>, as shown in Table 4.

TABLE 2

Acrylate resins and the respective weight portions of their acrylate components.			
Resin <sup>a</sup>	Prepolymer	m (Prepolymer) [g]	m (ACMO + TPO) <sup>b</sup> [g]
ACMO_PTHFA-G	PTHFA-G	4.682	7.207
ACMO_JT3000-G	JT3000-G	5.248	8.060
ACMO_JT403-G	JT403-G	4.236	6.510
ACMO_TODA-G	TODA-G	4.983	7.664
ACMO_DO112DA-G	DO112DA-G	4.807	7.332
ACMO_DO18DA-G	DO18DA-G	5.185	7.976
ACMO_DAP-G	DAP-G	4.565	7.023
ACMO_PA-G	PA-G	5.368	8.253
ACMO_XDA-G	XDA-G	5.957	9.153
ACMO_CDMA-G	CDMA-G	5.008	7.713
ACMO_IPDA-G	IPDA-G	4.962	7.634
ACMO_DO112DA-G5	DO112DA-G5	3.774	5.811

<sup>a</sup>HUMA/ACMO/TPO mixture in a 39:59:1-ratio,

<sup>b</sup>ACMO/TPO mixture in a 59:1-ratio

**[0498]** In case of PTHFA-G, JT3000-G, TODA-G, DO112DA-G, DO18DA-G and PA-G the resins were homogenized using a SpeedMixer DAC 150.1 FV from Hausschild (2 min, 2500 RPM). For the other formulations the homogenization was performed through mechanical stirring at 70° C. The UV curing of the casted samples was performed under a Mercury-vapor lamp (400 W, 280-700 nm, 10 cm distance, 2x10 min from both sides) with a thermal post-cure (30 min, 150° C.) in an oven. The results from the rheological experiments, tensile testing and the calorimetric measurements are shown in Table 3.

second group summarizes small and flexible building blocks. Due to their lower molecular weight, they afford higher network densities as compared to the first group, which markedly increases stiffness, as represented by Young's moduli up to 3600 MPa, and tensile strength up to 85 MPa. Due to flexible ether groups in the molecule backbone, these compounds still maintain viscosity values low enough to achieve resin viscosity values between 250 and 565 Pa·s. In the absence of such flexible groups, as represented by the third category, low molecular weight HUMA exhibit high viscosity and increase the resin viscos-

TABLE 3

Viscosities, mechanical data and glass transition temperatures of acrylate resins comprising HUMA oligomers.					
Acrylate resin	$\eta$ (25° C.) <sup>a</sup> [mPa · s]	Y.'s Modulus <sup>b</sup> [MPa]	$\sigma_{max}$ <sup>b</sup> [MPa]	$\epsilon_{break}$ <sup>b</sup> [%]	T <sub>g</sub> <sup>c</sup> (DSC) [° C.]
Flexible/large HUMA building block					
ACMO_PTHFA-G	750 ± 20	869 ± 17	20.5 ± 1.7	74 ± 11	n.a.
ACMO_JT3000-G	190 ± 30	1000 ± 100	21.9 ± 0.9	90 ± 40	n.a.
ACMO_PA-G	267 ± 12	2140 ± 40	59.1 ± 1.0	14 ± 6	90
Flexible/small HUMA building block					
ACMO_TODA-G	254 ± 18	2540 ± 180	67 ± 3	12 ± 5	78
ACMO_DO112DA-G	310 ± 30	3160 ± 40	81 ± 7	4.2 ± 1.4	86
ACMO_DO18DA-G	250 ± 20	3600 ± 500	85 ± 2	3.9 ± 0.4	95
ACMO_JT403-G	565 ± 8	3070 ± 40	57 ± 5	2.1 ± 0.3	84
Rigid/small HUMA building block					
ACMO_DAP-G	794 ± 14	3610 ± 70	61 ± 3	1.8 ± 0.1	90
ACMO_XDA-G	630 ± 11	5700 ± 600	61 ± 16	1.6 ± 0.5	115
ACMO_CDMA-G	710 ± 40	4400 ± 300	71 ± 14	2.0 ± 0.5	114
ACMO_IPDA-G	880 ± 20	3990 ± 60	46 ± 7	1.2 ± 0.2	120

<sup>a</sup>Determined with a plate-plate rheometer (from 0.1 to 100 s<sup>-1</sup>, 100 steps, logarithmic, 5 s per step, 3 s integration time),

<sup>b</sup>tensile testing (ISO 527 1/2, 5 A, 5 mm min<sup>-1</sup>),

<sup>c</sup>DSC (10K min, 2<sup>nd</sup> heating cycle).

**[0499]** The respective HUMA building blocks can be categorized into three groups as shown in Table 3. The first group comprises HUMA with long-chain polyether or methylene sequences. Due to their relatively high molecular weight they provide lower network density. Both factors contribute towards relatively flexible materials as represented by the Young's moduli between 869 and 2140 MPa and the elongation at break values between 14 and 90%. The

ity up to 880 Pa·s. Especially rigid cycloaliphatic or aromatic molecule structures afford high material stiffness with Young's moduli up to 5700 MPa and elongation at break values of 2% and lower.

**[0500]** Based on this new class of hydroxyurethane methacrylate oligomers, a broad spectrum of material properties can be covered, which allows for a defined design of properties for customized demands and applications.

TABLE 4

Viscosities, mechanical data and glass transition temperatures of acrylate resins comprising DO112DA-G and DO112DA-G5.					
Acrylate resin	$\eta$ (25° C.) <sup>a</sup> [mPa · s]	Y.'s Modulus <sup>b</sup> [MPa]	$\sigma_{max}$ <sup>b</sup> [MPa]	$\epsilon_{break}$ <sup>b</sup> [%]	T <sub>g</sub> <sup>c</sup> (DSC) [° C.]
ACMO_DO112DA-G	310 ± 30	3160 ± 40	81 ± 7	4.2 ± 1.4	86
ACMO_DO112DA-G5	159 ± 5	4200 ± 600	68 ± 10	3.1 ± 0.9	173

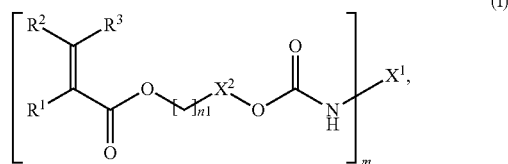
<sup>a</sup>Determined with a plate-plate rheometer (from 0.1 to 100 s<sup>-1</sup>, 100 steps, logarithmic, 5 s per step, 3 s integration time).

<sup>b</sup>tensile testing (ISO 527 1/2, 5 A, 5 mm min<sup>-1</sup>).

<sup>c</sup>DSC (10K min, 2<sup>nd</sup> heating cycle).

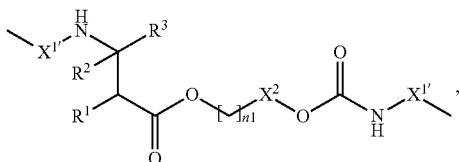
**[0501]** Applying DO112DA G5 over DO112DA G markedly increases the T<sub>g</sub> from 86° C. to 173° C. and the Young's Modulus from 3160 MPa to 4200 MPa.

1. A prepolymer of formula



wherein

X<sup>1</sup> is a linking group, or a group of formula



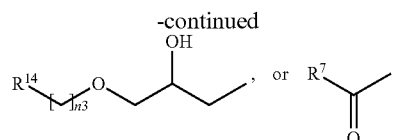
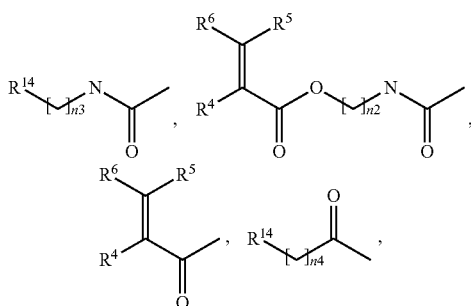
X<sup>1</sup>' is a linking group;

X<sup>2</sup> is independently in each occurrence a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—,

R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are independently of each other H, or a C<sub>1</sub>-C<sub>4</sub>-alkyl group;

n<sub>1</sub> is an integer of 1 to 12;

m is an integer of 1 to 4; wherein optionally the hydrogen atom of the hydroxy groups and/or the amino groups of the prepolymer may be replaced by a group of formula



wherein

R<sup>4</sup>, R<sup>5</sup> and R<sup>6</sup> are independently of each other H, or a C<sub>1</sub>-C<sub>4</sub>-alkyl group;

R<sup>7</sup> is a C<sub>1</sub>-C<sub>25</sub>alkyl group, a C<sub>2</sub>-C<sub>25</sub>alkenyl group, or a phenyl group, which can be substituted by one, or more C<sub>1</sub>-C<sub>8</sub>alkyl groups, C<sub>1</sub>-C<sub>8</sub>alkoxy groups,

R<sup>14</sup> is a group of formula —SiR<sup>15</sup>(R<sup>16</sup>)<sub>2</sub>,

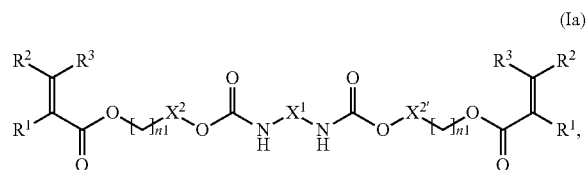
R<sup>15</sup> is a C<sub>1</sub>-C<sub>8</sub>alkoxy group,

R<sup>16</sup> is a C<sub>1</sub>-C<sub>8</sub>alkyl group, or a C<sub>1</sub>-C<sub>8</sub>alkoxy group,

n<sub>2</sub> is an integer of 1 to 12; and

n<sub>3</sub> and n<sub>4</sub> are an integer of 1 to 12.

2. The prepolymer according to claim 1, which is a prepolymer of formula



wherein

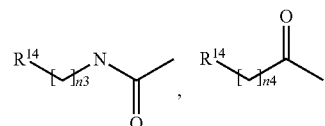
X<sup>1</sup> is a linking group,

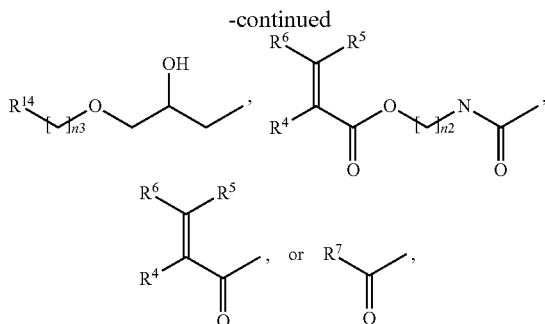
R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are independently of each other H, a C<sub>1</sub>-C<sub>4</sub>-alkyl group;

n<sub>1</sub> is an integer of 1 to 12;

X<sup>2</sup> is a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—, and

X<sup>2</sup>' is a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—, wherein optionally the hydrogen atom of the hydroxy groups and/or the amino groups of the prepolymer may be replaced by a group of formula





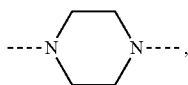
wherein  $R^4$ ,  $R^5$ ,  $R^6$ ,  $R^7$ ,  $R^{14}$ ,  $n_2$ ,  $n_3$  and  $n_4$  are defined in claim 1.

3. The prepolymer according to claim 1, wherein  $R^2$  and  $R^3$  are H.

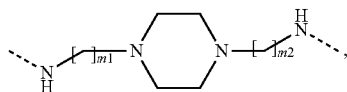
4. The prepolymer according to claim 1, wherein  $R^1$  is a methyl group.

5. The prepolymer according to claim 1, wherein  $n_1$  is 1.

6. The prepolymer according to claim 1, wherein . . .  $\text{HNX}^1\text{NH}$  . . . is

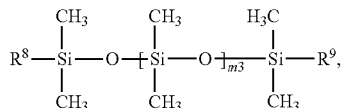


a group of formula



wherein  $m_1$  and  $m_2$  are an integer of 1 to 25 and optionally comprise a group derived from 1,4-bis(3-aminopropyl)piperazine;

a group of formula



wherein

$R^8$  and  $R^9$  are a group of formula  $-(\text{CH}_2)_{m_4}\text{NH}$  . . . ,  $m_3$  is 2 to 200 and  $m_4$  is an integer of 1 to 8;

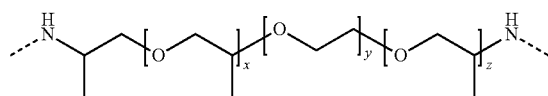
a group of formula . . .  $\text{HN}-(\text{CH}_2)_{n_4}\text{NH}$  . . . , wherein part of the hydrogen atoms may be replaced by a  $\text{C}_1$ - $\text{C}_4$ alkyl group and  $n_4$  is an integer of 1 to 25, such as, for example, groups derived from diaminoethane, diaminopropane, 1,2-diamino-2-methylpropane, 1,3-diamino-2,2-dimethylpropane, diaminobutane, diaminopentane, 1,5-diamino-2-methylpentane, 2,5-neopentylidiamine, diaminohexane, 1,6-diamino-2,2,4-trimethylhexane, 1,6-diamino-2,4,4-trimethylhexane, diaminoheptane, diamino-octane, diamino-nonane, diamino-decane, diamino-undecane, diamino-dodecane, or mixtures thereof;

a group of formula . . .  $\text{HN}-(\text{CH}_2)_{n_5}\text{Y}^1-(\text{CH}_2)_{n_6}\text{NH}$  . . . , wherein  $\text{Y}^1$  is a  $\text{C}_3$ - $\text{C}_8$ cycloalkylene group, or a phenylene group, which may be substituted by one, or more  $\text{C}_1$ - $\text{C}_8$ alkyl groups, and  $n_5$  and  $n_6$  independently of each other 0, or an integer 1 to 4, such as, for example, groups derived from 1,4-cyclohexanediamine, 4,4'-methylenebis(cyclohexylamine), 4,4'-isopropylenebis(cyclohexylamine), isophoronediamine, m-xylylenediamine, 1,2-(bisaminomethyl)cyclohexane, 1,3-(bisaminomethyl)cyclohexane, 1,4-(bisaminomethyl)cyclohexane, bis(4-aminocyclohexyl)methane;

a group of formula . . .  $\text{HN}-(\text{CH}_2)_{n_7}\text{O}(\text{CH}_2)_{n_8}\text{O}-(\text{CH}_2)_{n_9}\text{NH}$  . . . , wherein  $n_7$ ,  $n_8$  and  $n_9$  are independently of each other an integer 2 to 4;

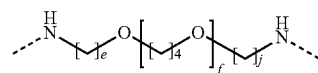
a group of formula . . .  $\text{HN}-(\text{CH}_2)_{n_{10}}\text{O}(\text{CH}_2)_2\text{O}(\text{CH}_2)_2\text{O}-(\text{CH}_2)_{n_{11}}\text{NH}$  . . . , wherein  $n_{10}$  and  $n_{11}$  are independently of each other an integer 2 to 4; or

a group of formula



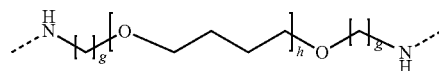
wherein  $y=0$ -39,  $x+z=1$ -68; or

a group of formula

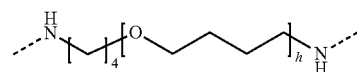


wherein  $e$  and  $j$  are independently of each other an integer of 2 to 6 and  $f$  is an integer of 2 to 30;

a group of formula or



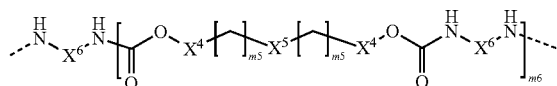
or



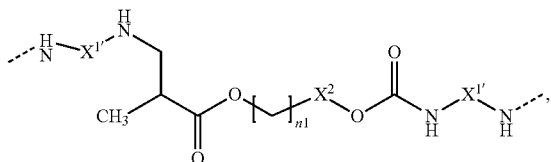
wherein  $g$  is an integer of 1 to 12;

$h$  is 3 to 50;

a group of formula or



a group of formula



wherein

X<sup>2</sup> is a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—,

X<sup>4</sup> is independently in each occurrence a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—,

n<sub>1</sub> is an integer of 1 to 12,

X<sup>5</sup> is a linking group,

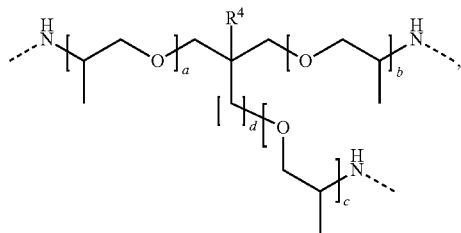
X<sup>6</sup> is a linking group,

m<sub>5</sub> is 0, or an integer of 1 to 12;

m<sub>6</sub> is 1 to 20, and

... HNX<sup>1</sup>NH ... has the meaning of ... HNX<sup>1</sup>NH .

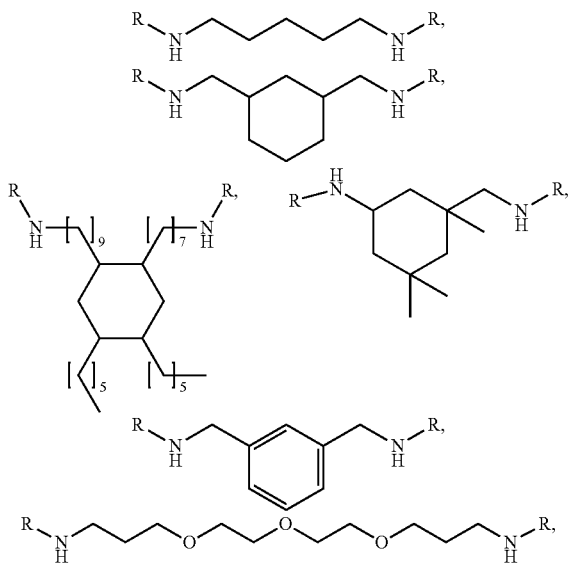
7. The prepolymer according to claim 1, wherein X<sup>1</sup>(NH ... )<sub>3</sub> is a group of formula



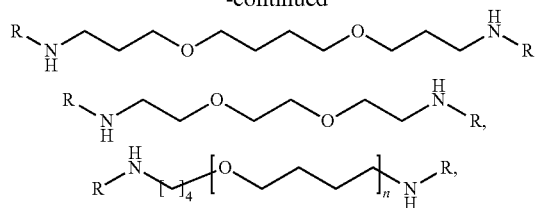
wherein R<sup>4</sup> is H,

or C<sub>2</sub>H<sub>5</sub>, d is 0, or 1, a+b+c=5-85.

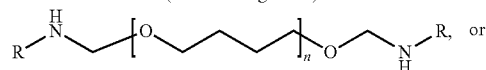
8. The prepolymer according to claim 1, which is a compound of formula



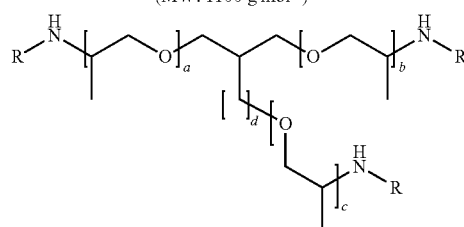
-continued



(MW: 1700 g mol<sup>-1</sup>)

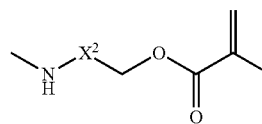


(MW: 1100 g mol<sup>-1</sup>)



wherein d is 0, a+b+c=50, or 5-6,

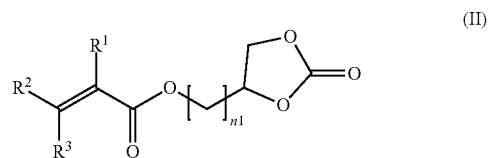
R is a group of formula



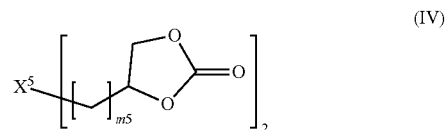
and X<sup>2</sup> is a group of formula —CH(CH<sub>2</sub>OH)—, or —CH(OH)—(CH<sub>2</sub>)—.

9. A process for the production of a prepolymer, comprising

a) reacting a cyclic carbonate of formula



with a polyamine of formula (H<sub>2</sub>N)<sub>m</sub>X<sup>1</sup> (III), or reacting a diglycidylethercarbonate of formula



with a polyamine of formula (III) and the obtained reaction product with a cyclic carbonate of formula (II), wherein

R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are independently of each other H, or a C<sub>1</sub>-C<sub>4</sub>-alkyl group;

$n_1$  is an integer of 1 to 12;

$m$  is an integer of 1 to 4;

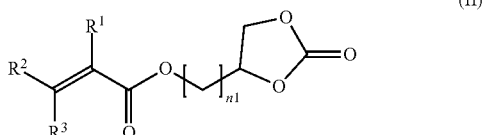
$X^1$  is a linking group,

$X^5$  is a linking group,

$m_5$  is an integer of 1 to 12.

10. The process according to claim 9, which comprises

a) reacting a cyclic carbonate of formula



with a diamine of formula  $(H_2N)_2X^1$  (IIIa),

wherein

$X^1$  is a linking group,

$R^1$ ,  $R^2$  and  $R^3$  are independently of each other H, or methyl,

$n_1$  is an integer of 1 to 12.

11. A photocurable composition, comprising

(A) the prepolymer according to claim 1,

(B) a diluent (B),

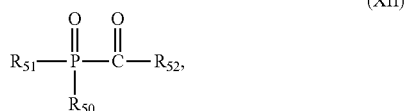
(C) optionally an oligomer (C), and

(D) a photoinitiator (D).

12. The photocurable composition according to claim 11,

wherein the diluent (B) is selected from acrylamides, methacrylamides, acrylates, methacrylates, vinylamides, difunctional acrylates and methacrylates and mixtures thereof.

13. The photocurable composition according to claim 11, wherein the photoinitiator (D) is a compound of the formula XII



wherein

$R_{50}$  is unsubstituted cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl; or is cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl substituted by one or more halogen,  $C_1$ - $C_{12}$ alkyl,  $C_1$ - $C_{12}$ alkoxy,  $C_1$ - $C_{12}$ alkylthio or by  $NR_{53}R_{54}$ ; or

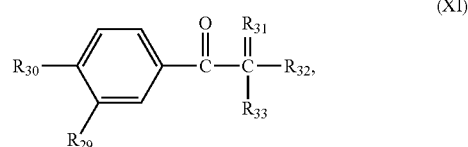
$R_{50}$  is unsubstituted  $C_1$ - $C_{20}$ alkyl or is  $C_1$ - $C_{20}$ alkyl which is substituted by one or more halogen,  $C_1$ - $C_{12}$ alkoxy,  $C_1$ - $C_{12}$ alkylthio,  $NR_{53}R_{54}$  or by  $-(CO)-O-C_1-C_2$ alkyl;

$R_{51}$  is unsubstituted cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl; or is cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl substituted by one or more halogen,  $C_1$ - $C_{12}$ alkyl,  $C_1$ - $C_{12}$ alkoxy,  $C_1$ - $C_{12}$ alkylthio or by  $NR_{53}R_{54}$ ; or  $R_{51}$  is  $-(CO)R'_{52}$ ; or  $R_{51}$  is  $C_1$ - $C_{12}$ alkyl which is unsubstituted or substituted by one or more halogen,  $C_1$ - $C_{12}$ alkoxy,  $C_1$ - $C_{12}$ alkylthio, or by  $NR_{53}R_{54}$ ;

$R_{52}$  and  $R'_{52}$  independently of each other are unsubstituted cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl, or are cyclohexyl, cyclopentyl, phenyl, naphthyl or biphenyl substituted by one or more halogen,

$C_1$ - $C_4$ alkyl or  $C_1$ - $C_4$ alkoxy; or  $R_{52}$  is a 5- or 6-membered heterocyclic ring comprising an S atom or N atom;

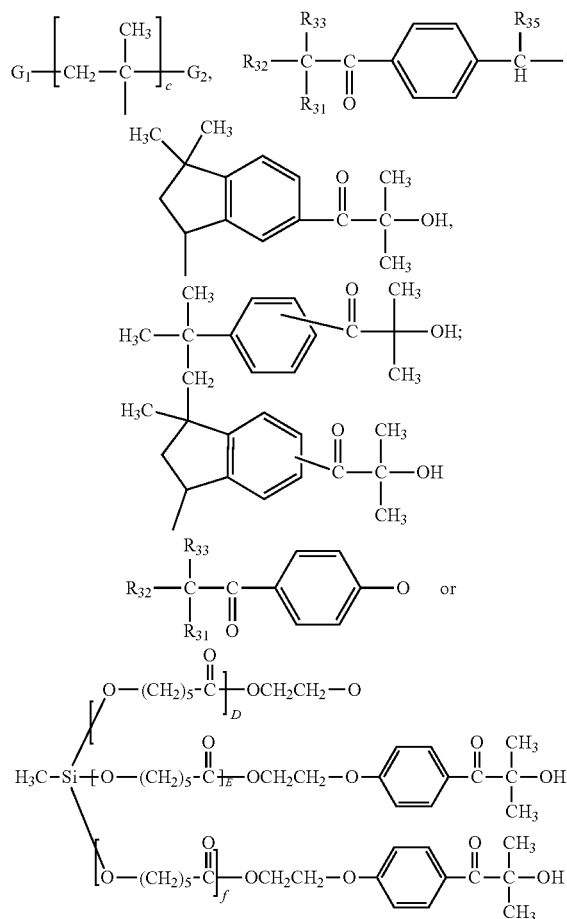
$R_{53}$  and  $R_{54}$  independently of one another are hydrogen, unsubstituted  $C_1$ - $C_{12}$ alkyl or  $C_1$ - $C_{12}$ alkyl substituted by one or more OH or SH wherein the alkyl chain optionally is interrupted by one to four oxygen atoms; or  $R_{53}$  and  $R_{54}$  independently of one another are  $C_2$ - $C_{12}$ alkenyl, cyclopentyl, cyclohexyl, benzyl or phenyl, or the photoinitiator (C) is a mixture of a compound of the formula (XII) and a compound of the formula



wherein

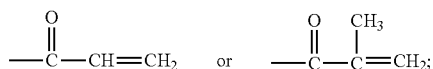
$R_{29}$  is hydrogen or  $C_1$ - $C_{18}$ alkoxy;

$R_{30}$  is hydrogen,  $C_1$ - $C_{18}$ alkyl,  $C_1$ - $C_{12}$ hydroxyalkyl,  $C_1$ - $C_{18}$ alkoxy,  $OCH_2CH_2-OR_{34}$ , morpholino,  $S-C_1-C_{18}$ alkyl, a group  $-HC=CH_2$ ,  $-C(CH_3)=CH_2$ ,





d, e and f are 1-3;  
 c is 2-10;  
 $G_1$  and  $G_2$  independently of one another are end groups of the polymeric structure;  
 $R_{34}$  is hydrogen,



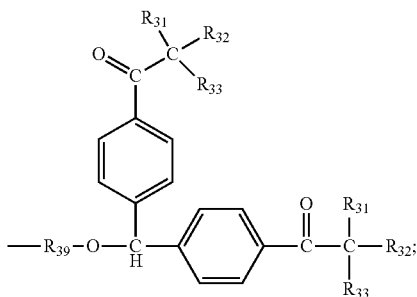
$R_{31}$  is hydroxy,  $C_1$ - $C_{16}$ alkoxy, morpholino, dimethyl-amino or  $\text{—O(CH}_2\text{CH}_2\text{O)}_g\text{—C}_1$ - $C_{16}$ alkyl;

g is 1-20;

$R_{32}$  and  $R_{33}$  independently of one another are hydrogen,  $C_1$ - $C_6$ alkyl,  $C_1$ - $C_{16}$ alkoxy or  $\text{—O(CH}_2\text{CH}_2\text{O)}_g\text{—C}_1$ - $C_{16}$ alkyl; or are unsubstituted phenyl or benzyl; or phenyl or benzyl substituted by  $C_1$ - $C_{12}$ -alkyl; or  $R_{32}$  and  $R_{33}$  together with the carbon atom to which they are attached form a cyclohexyl ring;

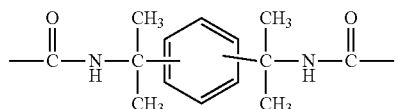
$R_{35}$  is hydrogen,  $\text{OR}_{36}$  or  $\text{NR}_{37}\text{R}_{38}$ ;

$R_{36}$  is hydrogen,  $C_1$ - $C_{12}$ alkyl which optionally is interrupted by one or more non-consecutive O-atoms and which uninterrupted or interrupted  $C_1$ - $C_{12}$ alkyl optionally is substituted by one or more OH, or  $R_{36}$  is



$R_{37}$  and  $R_{38}$  independently of each other are hydrogen or  $C_1$ - $C_{12}$ alkyl which is unsubstituted or is substituted by one or more OH;

$R_{39}$  is  $C_1$ - $C_{12}$ alkylene which optionally is interrupted by one or more non-consecutive O,  $\text{—(CO)—NH—C}_1$ - $C_{12}$ alkylene-NH—(CO)— or



with the proviso that  $R_{31}$ ,  $R_{32}$  and  $R_{33}$  not all together are  $C_1$ - $C_{16}$ alkoxy or  $\text{—O(CH}_2\text{CH}_2\text{O)}_g\text{—C}_1$ - $C_{16}$ alkyl, or the photoinitiator is a mixture of different compounds of the formula (XII), or the photoinitiator is a trialkyl benzoyl, or dialkyl dibenzoyl germanium compound, or the photoinitiator is camphorquinone in combination with a tertiary amine.

14. A method for producing a three-dimensional article, comprising

- providing the photocurable composition according to claim 1,
- exposing the photocurable composition to actinic radiation to form a cured crosssection,
- repeating steps (a) and (b) to build up a three-dimensional article.

15. A three-dimensional article, which is a cured product of the photocurable composition according to claim 11.

16. Use of the prepolymer according to claim 1, in a photopolymerization 3D printing process, coatings, inks, varnishes, adhesives, composite materials and solder resists.

17. The prepolymer according to claim 1 wherein  $R^1$ ,  $R^2$ , and  $R^3$  are methyl.

18. The prepolymer according to claim 1 wherein  $R^4$ ,  $R^5$ , and  $R^6$  are methyl.

\* \* \* \* \*