

Method for Producing Silazane-Siloxane Copolymers and the Use of such Copolymers

5 **Technical Field**

The present invention relates to a method for producing silazane-siloxane copolymers and the use of such copolymers, particularly in LEDs.

10 **Background and description of the prior art**

15 In recent years the electronic industry has seen the rapid replacement of conventional technologies that have been in use for several decades without major improvements.

20 One such example is the conventional incandescent light bulb being replaced by light emitting diodes (LEDs). The lifetime of incandescent light bulbs is generally on the order of a few thousand hours, while LEDs claim lifetimes of several tens of thousands of hours. These long lifetimes are only made possible if the light emitting materials in an LED can effectively be protected from degradation by environmental factors, such as oxygen and moisture. Frequently this is done by encapsulating the LED in a polymer. However, such encapsulating polymers need to fulfill a number of further requirements:

- 25 - The polymer has to withstand high temperatures without degradation of mechanical and/or optical properties;
- 30 - in addition to optical clarity and high service temperature the polymer needs to have a high refractive index;
- the polymer is required to have a high resistance to radiation of high intensity; and
- there is a need for polymers that can be varied in elastic modulus from being very soft to hard.

35 Recently polysilazane/polysiloxane copolymers have been proposed in US 2015/0188006 A1 as encapsulation polymers.

Such copolymers are for example disclosed in WO 02/068535 A1.

5 However, the known methods of producing such polysilazane/polysiloxane copolymers have proven difficult to perform and do not offer a high degree of flexibility in producing copolymers with different constitution and/or composition, which would thus permit tailor-making such copolymer for a specific application with a specific set of requirements.

10 It is therefore an object of the present application to provide for an improved manufacturing process, particularly a manufacturing process suitable for tailor-making of such polymers.

15 It is a further object of the present application to provide a method of producing silazane-siloxane copolymers that can be up-scaled to industrial scale.

Summary of the invention

20 The present inventors have now surprisingly found that the above objects may be attained either individually or in any combination by the process of the present application.

25 The present application therefore provides for a method comprising the step of obtaining a silazane-siloxane copolymer by reacting an organosilane, an amine and an organosiloxane, the organosilane comprising two halogen end groups, and the organosiloxane comprising two halogen end groups or two hydroxy end groups.

30 Detailed description of the invention

For the purposes of the present application the term "organosilane" is used to denote an organyl derivative of a silane, i.e. a silane wherein one or more hydrogen
35 is replaced by the corresponding number of organyl groups.

For the purposes of the present application the term "organosiloxane" is used to denote an organyl derivative of a siloxane, i.e. a siloxane wherein one or more hydrogen is replaced by the corresponding number of organyl groups.

5 For the purposes of the present application the term "organyl" is used to denote any organic substituent group, regardless of functional type, having one free valence at a carbon atom.

10 For the purposes of the present application the term "organoheteryl" is used to denote any univalent group containing carbon, which is thus organic, but which has the free valence at an atom other than carbon.

15 For the purposes of the present application the term "carbyl group" includes both, organyl groups and organoheteryl groups. As used herein, the term "carbyl group" will be understood to mean any monovalent or multivalent organic radical moiety which comprises at least one carbon atom either without any non-carbon atoms (like for example $\text{-C}\equiv\text{C-}$), or optionally comprising one or more heteroatoms (for example carbonyl etc.).

20 The term "hydrocarbyl group" will be understood to mean a carbyl group that does additionally contain one or more H atoms and optionally contains one or more hetero atoms.

25 As used herein, the term "hetero atom" will be understood to mean an atom in an organic compound that is not a H- or C-atom, and preferably will be understood to mean N, O, S, P, Si, Se, As, Te or Ge.

30 A carbyl or hydrocarbyl group comprising a chain of 3 or more C atoms may be straight-chain, branched and/or cyclic, including spiro and/or fused rings.

35 Preferred carbyl and hydrocarbyl groups include alkyl, alkoxy, alkylcarbonyl, alkoxy carbonyl, alkylcarbonyloxy and alkoxy carbonyloxy, each of which is optionally substituted and has 1 to 40, preferably 1 to 25, very preferably 1 to 18 C atoms, furthermore optionally substituted aryl or aryloxy having 6 to 40, preferably 6 to 25 C atoms, furthermore alkylaryloxy, arylcarbonyl, aryloxy carbonyl, arylcarbonyloxy and aryloxy carbonyloxy, each of which is optionally substituted

and has 6 to 40, preferably 7 to 40 C atoms, wherein all these groups do optionally contain one or more hetero atoms, preferably selected from N, O, S, P, Si, Se, As, Te and Ge.

5 The carbyl or hydrocarbyl group may be a saturated or unsaturated acyclic group, or a saturated or unsaturated cyclic group. Unsaturated acyclic or cyclic groups are preferred, especially aryl, alkenyl and alkynyl groups (especially ethynyl). Where the C₁-C₄₀ carbyl or hydrocarbyl group is acyclic, the group may be straight-chain or
10 branched. The C₁-C₄₀ carbyl or hydrocarbyl group includes for example: a C₁-C₄₀ alkyl group, a C₁-C₄₀ fluoroalkyl group, a C₁-C₄₀ alkoxy or oxaalkyl group, a C₂-C₄₀ alkenyl group, a C₂-C₄₀ alkynyl group, a C₃-C₄₀ allyl group, a C₄-C₄₀ alkylidenyl group, a C₄-C₄₀ polyenyl group, a C₂-C₄₀ ketone group, a C₂-C₄₀ ester group, a C₆-C₁₈ aryl group, a C₆-C₄₀ alkylaryl group, a C₆-C₄₀ arylalkyl group, a C₄-C₄₀ cycloalkyl group, a C₄-C₄₀ cycloalkenyl group, and the like. Preferred among the foregoing groups are
15 a C₁-C₂₀ alkyl group, a C₁-C₂₀ fluoroalkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, a C₃-C₂₀ allyl group, a C₄-C₂₀ alkylidenyl group, a C₂-C₂₀ ketone group, a C₂-C₂₀ ester group, a C₆-C₁₂ aryl group, and a C₄-C₂₀ polyenyl group, respectively. Also included are combinations of groups having carbon atoms and groups having hetero atoms, like e.g. an alkynyl group, preferably ethynyl, that is substituted with
20 a silyl group, preferably a trialkylsilyl group.

The terms "aryl" and "heteroaryl" as used herein preferably mean a mono-, bi- or tricyclic aromatic or heteroaromatic group with 4 to 30 ring C atoms that may also
25 comprise condensed rings and is optionally substituted with one or more groups L, wherein L is selected from halogen, -CN, -NC, -NCO, -NCS, -OCN, -SCN, -C(=O)NR⁰R⁰⁰, -C(=O)X⁰, -C(=O)R⁰, -NH₂, -NR⁰R⁰⁰, -SH, -SR⁰, -SO₃H, -SO₂R⁰, -OH, -NO₂, -CF₃, -SF₅, P-Sp-, optionally substituted silyl, or carbyl or hydrocarbyl with 1 to 40 C atoms that is optionally substituted and optionally comprises one or more hetero atoms, and is preferably alkyl, alkoxy, thiaalkyl, alkylcarbonyl, alkoxycarbonyl or
30 alkoxycarbonyloxy with 1 to 20 C atoms that is optionally fluorinated, and R⁰, R⁰⁰, X⁰, P and Sp have the meanings given above and below.

Very preferred substituents L are selected from halogen, most preferably F, or alkyl, alkoxy, oxaalkyl, thioalkyl, fluoroalkyl and fluoroalkoxy with 1 to 12 C atoms or
35 alkenyl, and alkynyl with 2 to 12 C atoms.

Especially preferred aryl and heteroaryl groups are phenyl, phenyl wherein one or more CH groups are replaced by N, naphthalene, thiophene, selenophene, thienothiophene, dithienothiophene, fluorene and oxazole, all of which can be unsubstituted, mono- or polysubstituted with L as defined above. Very preferred rings are selected from pyrrole, preferably N-pyrrole, furan, pyridine, preferably 2- or 3-pyridine, pyrimidine, pyridazine, pyrazine, triazole, tetrazole, pyrazole, imidazole, isothiazole, thiazole, thiadiazole, isoxazole, oxazole, oxadiazole, thiophene, preferably 2-thiophene, selenophene, preferably 2-selenophene, thieno[3,2-b]thiophene, thieno[2,3-b]thiophene, furo[3,2-b]furan, furo[2,3-b]furan, seleno[3,2-b]selenophene, seleno[2,3-b]selenophene, thieno[3,2-b]selenophene, thieno[3,2-b]furan, indole, isoindole, benzo[b]furan, benzo[b]thiophene, benzo[1,2-b;4,5-b']dithiophene, benzo[2,1-b;3,4-b']dithiophene, quinole, 2-methylquinole, isoquinole, quinoxaline, quinazoline, benzotriazole, benzimidazole, benzothiazole, benzisothiazole, benzisoxazole, benzoxadiazole, benzoxazole, benzothiadiazole, all of which can be unsubstituted, mono- or polysubstituted with L as defined above. Further examples of aryl and heteroaryl groups are those selected from the groups shown hereinafter.

An alkyl or alkoxy radical, i.e. where the terminal CH₂ group is replaced by -O-, can be straight-chain or branched. It is preferably straight-chain (or linear). Suitable examples of such alkyl and alkoxy radical are methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, methoxy, ethoxy, propoxy, butoxy, pentoxy, hexoxy, heptoxy, octoxy, nonoxy, decoxy, undecoxy, dodecoxy, tridecoxy or tetradecoxy. Preferred alkyl and alkoxy radicals have 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 carbon atoms. Suitable examples of such preferred alkyl and alkoxy radicals may be selected from the group consisting of methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, methoxy, ethoxy, propoxy, butoxy, pentoxy, hexoxy, heptoxy, octoxy, nonoxy and decoxy.

An alkenyl group, wherein one or more CH₂ groups are replaced by -CH=CH- can be straight-chain or branched. It is preferably straight-chain, has 2 to 10 C atoms and accordingly is preferably vinyl, prop-1-enyl, or prop-2-enyl, but-1-enyl, but-2-enyl or but-3-enyl, pent-1-enyl, pent-2-enyl, pent-3-enyl or pent-4-enyl, hex-1-enyl, hex-2-enyl, hex-3-enyl, hex-4-enyl or hex-5-enyl, hept-1-enyl, hept-2-enyl, hept-3-enyl, hept-4-enyl, hept-5-enyl or hept-6-enyl, oct-1-enyl, oct-2-enyl, oct-3-enyl, oct-4-enyl, oct-5-enyl, oct-6-enyl or oct-7-enyl, non-1-enyl, non-2-enyl, non-3-enyl,

non-4-enyl, non-5-enyl, non-6-enyl, non-7-enyl or non-8-enyl, dec-1-enyl, dec-2-enyl, dec-3-enyl, dec-4-enyl, dec-5-enyl, dec-6-enyl, dec-7-enyl, dec-8-enyl or dec-9-enyl.

5 Especially preferred alkenyl groups are C₂-C₇-1E-alkenyl, C₄-C₇-3E-alkenyl, C₅-C₇-4-alkenyl, C₆-C₇-5-alkenyl and C₇-6-alkenyl, in particular C₂-C₇-1E-alkenyl, C₄-C₇-3E-alkenyl and C₅-C₇-4-alkenyl. Examples for particularly preferred alkenyl groups are vinyl, 1E-propenyl, 1E-butenyl, 1E-pentenyl, 1E-hexenyl, 1E-heptenyl, 3-butenyl, 3E-pentenyl, 3E-hexenyl, 3E-heptenyl, 4-pentenyl, 4Z-hexenyl, 4E-hexenyl, 4Z-heptenyl, 5-hexenyl, 6-heptenyl and the like. Alkenyl groups having up to 5 C
10 atoms are generally preferred.

An oxaalkyl group, i.e. where one CH₂ group is replaced by -O-, is preferably straight-chain 2-oxapropyl (= methoxymethyl), 2-(ethoxymethyl) or 3-oxabutyl (= 2-methoxyethyl), 2-, 3-, or 4-oxapentyl, 2-, 3-, 4-, or 5-oxahexyl, 2-, 3-, 4-, 5-, or 6-oxaheptyl, 2-, 3-, 4-, 5-, 6- or 7-oxaoctyl, 2-, 3-, 4-, 5-, 6-, 7- or 8-oxanonyl or 2-, 3-, 4-, 5-, 6-, 7-, 8- or 9-oxadecyl, for example. Oxaalkyl, i.e. where one CH₂ group is replaced by -O-, is preferably straight-chain 2-oxapropyl (= methoxymethyl), 2- (= ethoxymethyl) or 3-oxabutyl (= 2-methoxyethyl), 2-, 3-, or 4-oxapentyl, 2-, 3-, 4-, or 5-oxahexyl, 2-, 3-, 4-, 5-, or 6-oxaheptyl, 2-, 3-, 4-, 5-, 6- or 7-oxaoctyl, 2-, 3-, 4-, 5-, 6-, 7- or 8-oxanonyl or 2-, 3-, 4-, 5-, 6-, 7-, 8- or 9-oxadecyl, for example.
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In an alkyl group wherein one CH₂ group is replaced by -O- and one by -C(O)-, these radicals are preferably neighboured. Accordingly these radicals together form a carbonyloxy group -C(O)-O- or an oxycarbonyl group -O-C(O)-. Preferably this group is straight-chain and has 2 to 6 C atoms. It is accordingly preferably selected from the group consisting of acetyloxy, propionyloxy, butyryloxy, pentanoyloxy, hexanoyloxy, acetyloxymethyl, propionyloxymethyl, butyryloxymethyl, pentanoyloxymethyl, 2-acetyloxyethyl, 2-propionyloxyethyl, 2-butyryloxyethyl, 3-acetyloxypropyl, 3-propionyloxypropyl, 4-acetyloxybutyl, methoxycarbonyl, ethoxycarbonyl, propoxycarbonyl, butoxycarbonyl, pentoxycarbonyl, methoxycarbonylmethyl, ethoxycarbonylmethyl, propoxycarbonylmethyl, butoxycarbonylmethyl, 2-(methoxycarbonyl)ethyl, 2-(ethoxycarbonyl)ethyl, 2-(propoxycarbonyl)ethyl, 3-(methoxycarbonyl)propyl, 3-(ethoxycarbonyl)propyl, and 4-(methoxycarbonyl)-butyl.
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An alkyl group wherein two or more CH₂ groups are replaced by -O- and/or -C(O)O- can be straight-chain or branched. It is preferably straight-chain and has 3 to 12 C atoms. Accordingly it is preferably selected from the group consisting of bis-
 5 carboxy-methyl, 2,2-bis-carboxy-ethyl, 3,3-bis-carboxy-propyl, 4,4-bis-carboxy-butyl, 5,5-bis-carboxy-pentyl, 6,6-bis-carboxy-hexyl, 7,7-bis-carboxy-heptyl, 8,8-bis-carboxy-octyl, 9,9-bis-carboxy-nonyl, 10,10-bis-carboxy-decyl, bis-
 (methoxycarbonyl)-methyl, 2,2-bis-(methoxycarbonyl)-ethyl, 3,3-bis-
 (methoxycarbonyl)-propyl, 4,4-bis-(methoxycarbonyl)-butyl, 5,5-bis-
 10 (methoxycarbonyl)-pentyl, 6,6-bis-(methoxycarbonyl)-hexyl, 7,7-bis-
 (methoxycarbonyl)-heptyl, 8,8-bis-(methoxycarbonyl)-octyl, bis-(ethoxycarbonyl)-
 methyl, 2,2-bis-(ethoxycarbonyl)-ethyl, 3,3-bis-(ethoxycarbonyl)-propyl, 4,4-bis-
 (ethoxycarbonyl)-butyl, and 5,5-bis-(ethoxycarbonyl)-hexyl.

15 A thioalkyl group, i.e. where one CH₂ group is replaced by -S-, is preferably straight-chain thiomethyl (-SCH₃), 1-thioethyl (-SCH₂CH₃), 1-thiopropyl (= -SCH₂CH₂CH₃), 1-(thiobutyl), 1-(thiopentyl), 1-(thiohexyl), 1-(thioheptyl), 1-(thiooctyl), 1-(thiononyl), 1-(thiodecyl), 1-(thioundecyl) or 1-(thiododecyl), wherein preferably the CH₂ group adjacent to the sp² hybridised vinyl carbon atom is replaced.

20 A fluoroalkyl group is preferably perfluoroalkyl, C_iF_{2i+1}, wherein i is an integer from 1 to 15, in particular CF₃, C₂F₅, C₃F₇, C₄F₉, C₅F₁₁, C₆F₁₃, C₇F₁₅ or C₈F₁₇, very preferably C₆F₁₃, or partially fluorinated alkyl, in particular 1,1-difluoroalkyl, all of which are straight-chain or branched.

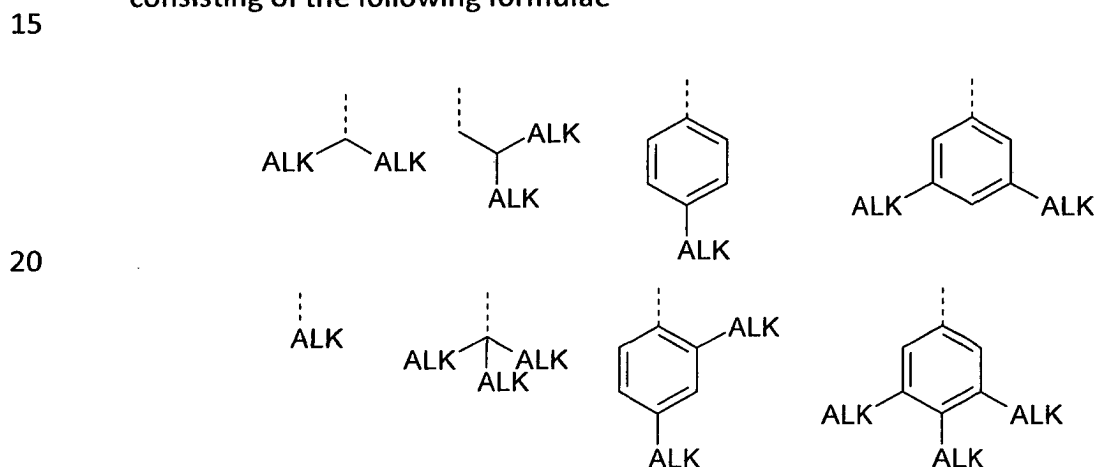
25 Alkyl, alkoxy, alkenyl, oxaalkyl, thioalkyl, carbonyl and carbonyloxy groups can be achiral or chiral groups. Particularly preferred chiral groups are 2-butyl (=1-methylpropyl), 2-methylbutyl, 2-methylpentyl, 3-methylpentyl, 2-ethylhexyl, 2-propylpentyl, in particular 2-methylbutyl, 2-methylbutoxy, 2-methylpentoxy, 3-methylpentoxy, 2-ethyl-hexoxy, 1-methylhexoxy, 2-octyloxy, 2-oxa-3-methylbutyl,
 30 3-oxa-4-methyl-pentyl, 4-methylhexyl, 2-hexyl, 2-octyl, 2-nonyl, 2-decyl, 2-dodecyl, 6-meth-oxyoctoxy, 6-methyloctoxy, 6-methyloctanoyloxy, 5-methylheptyloxy-carbonyl, 2-methylbutyryloxy, 3-methylvaleroyloxy, 4-methylhexanoyloxy, 2-chloropropionyloxy, 2-chloro-3-methylbutyryloxy, 2-chloro-4-methyl-valeryl-oxy, 2-chloro-3-methylvaleryloxy, 2-methyl-3-oxapentyl, 2-methyl-3-oxa-hexyl, 1-methoxypropyl-2-oxy, 1-ethoxypropyl-2-oxy, 1-propoxypropyl-2-oxy, 1-butoxypropyl-2-oxy, 2-fluorooctyloxy, 2-fluorodecyloxy, 1,1,1-trifluoro-2-octyloxy,

- 8 -

1,1,1-trifluoro-2-octyl, 2-fluoromethyloctyloxy for example. Very preferred are 2-hexyl, 2-octyl, 2-octyloxy, 1,1,1-trifluoro-2-hexyl, 1,1,1-trifluoro-2-octyl and 1,1,1-trifluoro-2-octyloxy.

5 Preferred achiral branched groups are isopropyl, isobutyl (= methylpropyl), isopentyl (= 3-methylbutyl), tert. butyl, isopropoxy, 2-methyl-propoxy and 3-methylbutoxy.

10 In a preferred embodiment, the hydrocarbonyl groups are independently of each other selected from primary, secondary or tertiary alkyl or alkoxy with 1 to 30 C atoms, wherein one or more H atoms are optionally replaced by F, or aryl, aryloxy, heteroaryl or heteroaryloxy that is optionally alkylated or alkoxyated and has 4 to 30 ring atoms. Very preferred groups of this type are selected from the group consisting of the following formulae



25 wherein "ALK" denotes optionally fluorinated, preferably linear, alkyl or alkoxy with 1 to 20, preferably 1 to 12 C-atoms, in case of tertiary groups very preferably 1 to 9 C atoms, and the dashed line denotes the link to the ring to which these groups are attached. Especially preferred among these groups are those wherein all ALK subgroups are identical.

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-CY¹=CY²- is preferably -CH=CH-, -CF=CF- or -CH=C(CN)-.

35 As used herein, "halogen" includes F, Cl, Br or I, preferably F, Cl or Br.

For the purposes of the present application the term "substituted" is used to denote that one or more hydrogen present is replaced by a group R^S as defined herein.

5 R^S is at each occurrence independently selected from the group consisting of any group R^T as defined herein, hydrocarbyl having from 1 to 40 carbon atoms wherein the hydrocarbyl may be further substituted with one or more groups R^T and hydrocarbyl having from 1 to 40 carbon atoms comprising one or more
10 heteroatoms selected from the group consisting of N, O, S, P, Si, Se, As, Te or Ge, with N, O and S being preferred heteroatoms, wherein the hydrocarbyl may be further substituted with one or more groups R^T .

Preferred examples of hydrocarbyl suitable as R^S may at each occurrence be independently selected from phenyl, phenyl substituted with one or more groups
15 R^T , alkyl and alkyl substituted with one or more groups R^T , wherein the alkyl has at least 1, preferably at least 5, more preferably at least 10 and most preferably at least 15 carbon atoms and/or has at most 40, more preferably at most 30, even more preferably at most 25 and most preferably at most 20 carbon atoms. It is
20 noted that for example alkyl suitable as R^S also includes fluorinated alkyl, i.e. alkyl wherein one or more hydrogen is replaced by fluorine, and perfluorinated alkyl, i.e. alkyl wherein all of the hydrogen are replaced by fluorine.

R^T is at each occurrence independently selected from the group consisting of F, Br, Cl, -CN, -NC, -NCO, -NCS, -OCN, -SCN, -C(O)NR⁰R⁰⁰, -C(O)X⁰, -C(O)R⁰, -NH₂, -NR⁰R⁰⁰, -
25 SH, -SR⁰, -SO₃H, -SO₂R⁰, -OH, -OR⁰, -NO₂, -SF₅ and -SiR⁰R⁰⁰R⁰⁰⁰. Preferred R^T are selected from the group consisting of F, Br, Cl, -CN, -NC, -NCO, -NCS, -OCN, -SCN, -C(O)NR⁰R⁰⁰, -C(O)X⁰, -C(O)R⁰, -NH₂, -NR⁰R⁰⁰, -SH, -SR⁰, -OH, -OR⁰ and -SiR⁰R⁰⁰R⁰⁰⁰.

R^0 , R^{00} and R^{000} are at each occurrence independently of each other selected from the group consisting of H, F, hydrocarbyl having from 1 to 40 carbon atoms. Said hydrocarbyl preferably have at least 5, more preferably at least 10 and most preferably at least 15 carbon atoms. Said hydrocarbyl preferably have at most 30,
30 even more preferably at most 25 and most preferably at most 20 carbon atoms. Preferably, R^0 , R^{00} and R^{000} are at each occurrence independently of each other
35 selected from the group consisting of H, F, alkyl, fluorinated alkyl, alkenyl, alkynyl, phenyl and fluorinated phenyl. More preferably, R^0 , R^{00} and R^{000} are at each

occurrence independently of each other selected from the group consisting of H, F, alkyl, fluorinated, preferably perfluorinated, alkyl, phenyl and fluorinated, preferably perfluorinated, phenyl.

5 It is noted that for example alkyl suitable as R^0 , R^{00} and R^{000} also includes perfluorinated alkyl, i.e. alkyl wherein all of the hydrogen are replaced by fluorine. Examples of alkyls may be selected from the group consisting of methyl, ethyl, n-propyl, iso-propyl, n-butyl, iso-butyl, tert-butyl (or "t-butyl"), pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, 10 heptadecyl, octadecyl, nonadecyl and eicosyl ($-C_{20}H_{41}$).

X^0 is halogen. Preferably X^0 is selected from the group consisting of F, Cl and Br.

15 The present application is directed to a method of obtaining a silazane-siloxane copolymer by reacting an organosilane, an amine and an organosiloxane.

The organosilane comprises two halogen end groups. The end groups may be the same or different; preferably they are the same. Preferably the two halogen end 20 groups are both Cl.

Preferably said organosilane is of formula (I)



25 wherein X^1 , X^2 , R^1 and R^2 are as defined herein.

X^1 and X^2 are at each occurrence independently of each other selected from the group consisting of Cl, Br, I. Preferably X^1 and X^2 are Cl. 30

R^1 and R^2 are at each occurrence independently H or a carbyl group, preferably H or a carbyl group as defined above.

35 With respect to R^1 and R^2 preferred carbyl groups may at each occurrence independently be selected from the group consisting of alkyl, substituted alkyl,

cycloalkyl, substituted cycloalkyl, alkenyl, substituted alkenyl, alkadienyl, substituted alkadienyl, aryl, and substituted aryl.

5 With respect to R^1 and R^2 more preferred carbyl groups may at each occurrence independently be selected from the group consisting of alkyl, substituted alkyl, cycloalkyl, substituted cycloalkyl, alkenyl, substituted alkenyl, alkadienyl and substituted alkadienyl.

10 With respect to R^1 and R^2 even more preferred carbyl groups may at each occurrence independently be selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkadienyl and substituted alkadienyl.

15 With respect to R^1 and R^2 still even more preferred carbyl groups may at each occurrence independently be selected from the group consisting of alkyl and substituted alkyl.

With respect to R^1 and R^2 most preferred carbyl groups may at each occurrence independently be selected from the group consisting of alkyl.

20 With respect to R^1 and R^2 preferred alkyl may be selected from alkyls having at least 1 carbon atom and at most 40 carbon atoms, preferably at most 30 or 20 carbon atoms, more preferably at most 15 carbon atoms, still even more preferably at most 10 carbon atoms and most preferably at most 5 carbon atoms.

25 With respect to R^1 and R^2 alkyl having at least 1 carbon atom and at most 5 carbon atoms may be selected from the group consisting of methyl, ethyl, n-propyl, iso-propyl, n-butyl, iso-butyl, tert-butyl, n-pentyl, iso-pentyl (2,2-methyl-butyl) and neo-pentyl (2,2-dimethyl-propyl); preferably from the group consisting of methyl, ethyl, n-propyl and iso-propyl; more preferably is methyl or ethyl; and most
30 preferably is methyl.

With respect to R^1 and R^2 preferred cycloalkyl may be selected from cycloalkyl having at least 3, preferably at least 4 and most preferably at least 5 carbon atoms.
35 With respect to R^1 and R^2 preferred cycloalkyl may be selected from cycloalkyl having at most 30, preferably at most 25, more preferably at most 20, even more preferably at most 15, and most preferably at most 10 carbon atoms.

With respect to R^1 and R^2 preferred examples of cycloalkyl may be selected from the group consisting of cyclopentyl, cyclohexyl, cycloheptyl and cyclooctyl.

5 With respect to R^1 and R^2 preferred alkenyl may be selected from alkenyl having at least 2 carbon atoms and at most 20, more preferably at most 15, even more preferably at most 10, and most preferably at most 6 carbon atoms. Said alkenyl may comprise the C=C double bond at any position within the molecule; for
10 example, the C=C double bond may be terminal or non-terminal.

With respect to R^1 and R^2 alkenyl having at least 2 and at most 10 carbon atoms may be vinyl or allyl, preferably vinyl.

15 With respect to R^1 and R^2 preferred alkadienyl may be selected from alkadienyl having at least 4 and at most 20, more preferably at most 15, even more preferably at most 10, and most preferably at most 6 carbon atoms. Said alkenyl may comprise the two C=C double bonds at any position within the molecule, provided that the two C=C double bonds are not adjacent to each other; for example, the C=C double
20 bonds may be terminal or non-terminal.

With respect to R^1 and R^2 alkadienyl having at least 4 and at most 6 carbon atoms may, for example, be butadiene or hexadiene.

25 With respect to R^1 and R^2 preferred aryl may be selected from aryl having at least 6 carbon atoms, and at most 30, preferably at most 24 carbon atoms.

30 With respect to R^1 and R^2 preferred examples of aryl may be selected from the group consisting of phenyl, naphthyl, phenanthrenyl, anthracenyl, tetracenyl, benz[a]anthracenyl, pentacenyl, chrysenyl, benzo[a]pyrenyl, azulenyl, perylenyl, indenyl, fluorenyl and any of these wherein one or more (for example 2, 3 or 4) CH groups are replaced by N. Of these phenyl, naphthyl and any of these wherein one or more (for example 2, 3 or 4) CH groups are replaced by N. Phenyl is most preferred.

35 The organosiloxane comprises two halogen end groups, preferably two Cl end groups, or two hydroxy (-OH) end groups.

Preferably said organosiloxane is of formula (II)



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wherein a, X^3 , X^4 , R^3 and R^4 are as defined herein.

a is an integer of at least 4 and of at most 10,000.

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X^3 and X^4 are identical and are at each occurrence independently preferably selected from the group consisting of Cl, Br, I and OH, more preferably are Cl or OH.

R^3 and R^4 are as defined above for R^1 and R^2 .

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Preferably said amine is of formula (III)



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with R^5 as defined herein. It is noted that said amine may also be a blend of amines with different groups R^5 .

R^5 is as defined above for R^1 and R^2 . Preferably R^5 is selected from H and alkyl. Most preferably R^5 is H, i.e. the amine is ammonia.

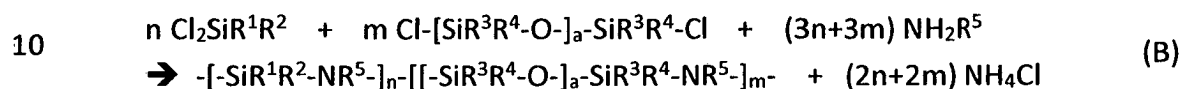
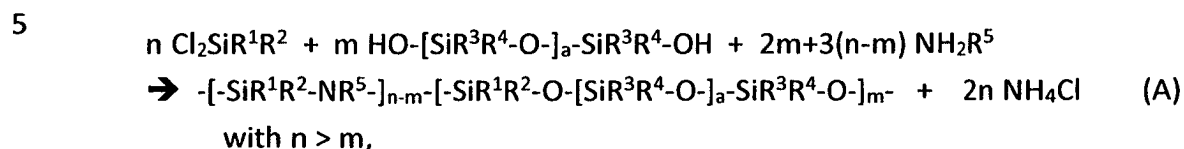
25

With respect to R^5 preferred alkyl may be selected from alkyls having at least 1 carbon atom and at most 40 carbon atoms, preferably at most 30 or 20 carbon atoms, more preferably at most 15 carbon atoms, still even more preferably at most 10 carbon atoms and most preferably at most 5 carbon atoms.

30

With respect to R^1 , R^2 , R^3 , R^4 and R^5 alkyl having at least 1 carbon atom and at most 5 carbon atoms may be selected from the group consisting of methyl, ethyl, n-propyl, iso-propyl, n-butyl, iso-butyl, tert-butyl, n-pentyl, iso-pentyl (2,2-methyl-butyl) and neo-pentyl (2,2-dimethyl-propyl); preferably from the group consisting of methyl, ethyl, n-propyl and iso-propyl; more preferably is methyl or ethyl; and
35 most preferably is methyl.

Preferred methods of obtaining a silazane-siloxane copolymer in accordance with the present application may, for example, be represented by the following Routes (A) and (B)



15

Preferably the present silazane-siloxane copolymers have a molecular weight M_w , as determined by GPC, of at least 1,000 g/mol, more preferably of at least 2,000 g/mol, even more preferably of at least 3,000 g/mol, still even more preferably of at least 4,000 g/mol and most preferably of at most 5,000 g/mol.

20

The conditions for reacting the organosilane, the amine and the organosiloxane are not particularly limited. It is, however, preferred to conduct the reaction within specific ranges of conditions, for example, in respect to temperature and solvent. Preferably said solvent is an aprotic organic solvent such as a hydrocarbon, an aromatic compound, an ester or an ether. Examples of such solvents are n-heptane, cyclohexane, xylene, pyridine, tetrahydrofuran, 1,4-dioxane, methyl-acetate or ethyl-acetate.

25

Preferably the present reaction is performed at a temperature of at least -30°C and of at most 120°C, more preferably of at least -20°C and of at most 110°C and most preferably of at least -10°C and of at most 100°C.

30

Another preferred synthetic method is to perform the reaction in liquid amine, for example in liquid ammonia. Then the amine, for example the ammonia, is the solvent and one of the reactants at the same time. If liquid ammonia is used, the preferred reaction conditions are a temperature of at least -20°C and of at most 40°C and a pressure of at most 20 bar.

35

5 The present application is also directed to a method for producing an electronic device, said process, in addition to the step of reacting the organosilane, the amine and the organosiloxane thus obtaining a silazane-siloxane copolymer, comprising the steps of providing a composition comprising the so-obtained silazane-siloxane copolymer and applying it to a substrate in an electronic device.

Preferably, the method for producing an electronic device thus comprises the steps of

- 10 (a) obtaining a silazane-siloxane copolymer by reacting an organosilane, the amine and an organosiloxane,
- (b) providing a composition comprising the silazane-siloxane copolymer obtained in step (a), and
- (c) subsequently depositing said composition on a substrate.

15 Preferably, in addition to the silazane-siloxane copolymer, said composition further comprises one or more selected from the group consisting of light emitting material, viscosity modifier, surfactant, additive influencing film formation, additive influencing evaporation behavior, crosslinker and solvent. Most preferably, said composition further comprises a light emitting material.

20

Preferably, said light emitting material is a phosphor, i.e. a substance that has luminescent properties. The term "luminescent" is intended to include both, phosphorescent as well as fluorescent.

25 For the purposes of the present application, the type of phosphor is not particularly limited. Suitable phosphors are well known to the skilled person and can easily be obtained from commercial sources. For the purposes of the present application the term "phosphor" is intended to include materials that absorb in one wavelength of the electromagnetic spectrum and emit at a different wavelength.

30

Examples of suitable phosphors are inorganic fluorescent materials in particle form comprising one or more emitting centers. Such emitting centers may, for example, be formed by the use of so-called activators, which are preferably atoms or ions selected from the group consisting of rare earth elements, transition metal elements, main group elements and any combination of any of these. Example of

35 suitable rare earth elements may be selected from the group consisting of La, Ce,

Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. Examples of suitable transition metal elements may be selected from the group consisting of Cr, Mn, Fe, Co, Ni, Cu, Ag, Au and Zn. Examples of suitable main group elements may be selected from the group consisting of Na, Tl, Sn, Pb, Sb and Bi. Examples of suitable phosphors include
 5 phosphors based on garnet, silicate, orthosilicate, thiogallate, sulfide, nitride, silicon-based oxynitride, nitridosilicate, nitridoaluminumsilicate, oxonitridosilicate, oxonitridoaluminumsilicate and rare earth doped sialon.

Suitable yellow phosphors may, for example, comprise or be based on $(\text{Gd,Y})_3(\text{Al,Ga})_5\text{O}_{12}$ doped with Ce, such as the commercially available cerium-doped yttrium aluminum garnet (frequently abbreviated as "Ce:YAG" or "YAG:Ce"); or $\text{Th}_{3-x}\text{M}_x\text{O}_{12}:\text{Ce}$ (TAG) with M being selected from the group consisting of Y, Gd, La and Lu; or $\text{Sr}_{2-x-y}\text{Ba}_x\text{Ca}_y\text{SiO}_4:\text{Eu}$.

15 Examples of green phosphors may be selected from the group of $\text{SrGa}_2\text{S}_4:\text{Eu}$; $\text{Sr}_{2-y}\text{Ba}_y\text{SiO}_4:\text{Eu}$ and/or $\text{SrSi}_2\text{O}_2\text{N}_2:\text{Eu}$.

Examples of suitable phosphors may be selected from the following: $\text{Ba}_2\text{SiO}_4:\text{Eu}^{2+}$, $\text{BaSi}_2\text{O}_5:\text{Pb}^{2+}$, $\text{Ba}_x\text{Sr}_{1-x}\text{F}_2:\text{Eu}^{2+}$, $\text{BaSrMgSi}_2\text{O}_7:\text{Eu}^{2+}$, BaTiP_2O_7 , $(\text{Ba,Ti})_2\text{P}_2\text{O}_7:\text{Ti}$,
 20 $\text{Ba}_3\text{WO}_6:\text{U}$, $\text{BaY}_2\text{F}_8:\text{Er}^{3+}, \text{Yb}^{3+}$, $\text{Be}_2\text{SiO}_4:\text{Mn}^{2+}$, $\text{Bi}_4\text{Ge}_3\text{O}_{12}$, $\text{CaAl}_2\text{O}_4:\text{Ce}^{3+}$, $\text{CaLa}_4\text{O}_7:\text{Ce}^{3+}$, $\text{CaAl}_2\text{O}_4:\text{Eu}^{2+}$, $\text{CaAl}_2\text{O}_4:\text{Mn}^{2+}$, $\text{CaAl}_4\text{O}_7:\text{Pb}^{2+}$, Mn^{2+} , $\text{CaAl}_2\text{O}_4:\text{Tb}^{3+}$, $\text{Ca}_3\text{Al}_2\text{Si}_3\text{O}_{12}:\text{Ce}^{3+}$, $\text{Ca}_3\text{Al}_2\text{Si}_3\text{O}_{12}:\text{Ce}^{3+}$, $\text{Ca}_3\text{Al}_2\text{Si}_3\text{O}_2:\text{Eu}^{2+}$, $\text{Ca}_2\text{B}_5\text{O}_9\text{Br}:\text{Eu}^{2+}$, $\text{Ca}_2\text{B}_5\text{O}_9\text{Cl}:\text{Eu}^{2+}$, $\text{Ca}_2\text{B}_5\text{O}_9\text{Cl}:\text{Pb}^{2+}$, $\text{CaB}_2\text{O}_4:\text{Mn}^{2+}$, $\text{Ca}_2\text{B}_2\text{O}_5:\text{Mn}^{2+}$, $\text{CaB}_2\text{O}_4:\text{Pb}^{2+}$, $\text{CaB}_2\text{P}_2\text{O}_9:\text{Eu}^{2+}$, $\text{Ca}_5\text{B}_2\text{SiO}_{10}:\text{Eu}^{3+}$, $\text{Ca}_{0.5}\text{Ba}_{0.5}\text{Al}_{12}\text{O}_{19}:\text{Ce}^{3+}, \text{Mn}^{2+}$, $\text{Ca}_2\text{Ba}_3(\text{PO}_4)_3\text{Cl}:\text{Eu}^{2+}$, $\text{CaBr}_2:\text{Eu}^{2+}$ in SiO_2 , $\text{CaCl}_2:\text{Eu}^{2+}$ in
 25 SiO_2 , $\text{CaCl}_2:\text{Eu}^{2+}, \text{Mn}^{2+}$ in SiO_2 , $\text{CaF}_2:\text{Ce}^{3+}$, $\text{CaF}_2:\text{Ce}^{3+}, \text{Mn}^{2+}$, $\text{CaF}_2:\text{Ce}^{3+}, \text{Tb}^{3+}$, $\text{CaF}_2:\text{Eu}^{2+}$, $\text{CaF}_2:\text{Mn}^{2+}$, $\text{CaF}_2:\text{U}$, $\text{CaGa}_2\text{O}_4:\text{Mn}^{2+}$, $\text{CaGa}_4\text{O}_7:\text{Mn}^{2+}$, $\text{CaGa}_2\text{S}_4:\text{Ce}^{3+}$, $\text{CaGa}_2\text{S}_4:\text{Eu}^{2+}$, $\text{CaGa}_2\text{S}_4:\text{Mn}^{2+}$, $\text{CaGa}_2\text{S}_4:\text{Pb}^{2+}$, $\text{CaGeO}_3:\text{Mn}^{2+}$, $\text{CaI}_2:\text{Eu}^{2+}$ in SiO_2 , $\text{CaI}_2:\text{Eu}^{2+}, \text{Mn}^{2+}$ in SiO_2 , $\text{CaLaBO}_4:\text{Eu}^{3+}$, $\text{CaLaB}_3\text{O}_7:\text{Ce}^{3+}, \text{Mn}^{2+}$, $\text{Ca}_2\text{La}_2\text{BO}_{6.5}:\text{Pb}^{2+}$, $\text{Ca}_2\text{MgSi}_2\text{O}_7$, $\text{Ca}_2\text{MgSi}_2\text{O}_7:\text{Ce}^{3+}$, $\text{CaMgSi}_2\text{O}_6:\text{Eu}^{2+}$, $\text{Ca}_3\text{MgSi}_2\text{O}_8:\text{Eu}^{2+}$, $\text{Ca}_2\text{MgSi}_2\text{O}_7:\text{Eu}^{2+}$, $\text{CaMgSi}_2\text{O}_6:\text{Eu}^{2+}, \text{Mn}^{2+}$,
 30 $\text{Ca}_2\text{MgSi}_2\text{O}_7:\text{Eu}^{2+}, \text{Mn}^{2+}$, CaMoO_4 , $\text{CaMoO}_4:\text{Eu}^{3+}$, $\text{CaO}:\text{Bi}^{3+}$, $\text{CaO}:\text{Cd}^{2+}$, $\text{CaO}:\text{Cu}^{+}$, $\text{CaO}:\text{Eu}^{3+}$, $\text{CaO}:\text{Eu}^{3+}$, Na^{+} , $\text{CaO}:\text{Mn}^{2+}$, $\text{CaO}:\text{Pb}^{2+}$, $\text{CaO}:\text{Sb}^{3+}$, $\text{CaO}:\text{Sm}^{3+}$, $\text{CaO}:\text{Tb}^{3+}$, $\text{CaO}:\text{Tl}$, $\text{CaO}:\text{Zn}^{2+}$, $\text{Ca}_2\text{P}_2\text{O}_7:\text{Ce}^{3+}$, $\alpha\text{-Ca}_3(\text{PO}_4)_2:\text{Ce}^{3+}$, $\beta\text{-Ca}_3(\text{PO}_4)_2:\text{Ce}^{3+}$, $\text{Ca}_5(\text{PO}_4)_3\text{Cl}:\text{Eu}^{2+}$, $\text{Ca}_5(\text{PO}_4)_3\text{Cl}:\text{Mn}^{2+}$, $\text{Ca}_5(\text{PO}_4)_3\text{Cl}:\text{Sb}^{3+}$, $\text{Ca}_5(\text{PO}_4)_3\text{Cl}:\text{Sn}^{2+}$, $\beta\text{-Ca}_3(\text{PO}_4)_2:\text{Eu}^{2+}, \text{Mn}^{2+}$, $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Mn}^{2+}$, $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sb}^{3+}$, $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sn}^{2+}$,
 35 $\alpha\text{-Ca}_3(\text{PO}_4)_2:\text{Eu}^{2+}$, $\beta\text{-Ca}_3(\text{PO}_4)_2:\text{Eu}^{2+}$, $\text{Ca}_2\text{P}_2\text{O}_7:\text{Eu}^{2+}$, $\text{Ca}_2\text{P}_2\text{O}_7:\text{Eu}^{2+}, \text{Mn}^{2+}$, $\text{CaP}_2\text{O}_6:\text{Mn}^{2+}$, $\alpha\text{-Ca}_3(\text{PO}_4)_2:\text{Pb}^{2+}$, $\alpha\text{-Ca}_3(\text{PO}_4)_2:\text{Sn}^{2+}$, $\beta\text{-Ca}_3(\text{PO}_4)_2:\text{Sn}^{2+}$, $\beta\text{-Ca}_2\text{P}_2\text{O}_7:\text{Sn}, \text{Mn}$,

α -Ca₃(PO₄)₂:Tr, CaS:Bi³⁺, CaS:Bi³⁺,Na, CaS:Ce³⁺, CaS:Eu²⁺, CaS:Cu⁺,Na⁺, CaS:La³⁺,
 CaS:Mn²⁺, CaSO₄:Bi, CaSO₄:Ce³⁺, CaSO₄:Ce³⁺,Mn²⁺, CaSO₄:Eu²⁺, CaSO₄:Eu²⁺,Mn²⁺,
 CaSO₄:Pb²⁺, CaS:Pb²⁺, CaS:Pb²⁺,Cl, CaS:Pb²⁺,Mn²⁺, CaS:Pr³⁺,Pb²⁺,Cl, CaS:Sb³⁺,
 CaS:Sb³⁺,Na, CaS:Sm³⁺, CaS:Sn²⁺, CaS:Sn²⁺,F, CaS:Tb³⁺, CaS:Tb³⁺,Cl, CaS:Y³⁺, CaS:Yb²⁺,
 CaS:Yb²⁺,Cl, CaSiO₃:Ce³⁺, Ca₃SiO₄Cl₂:Eu²⁺, Ca₃SiO₄Cl₂:Pb²⁺, CaSiO₃:Eu²⁺,
 CaSiO₃:Mn²⁺,Pb, CaSiO₃:Pb²⁺, CaSiO₃:Pb²⁺,Mn²⁺, CaSiO₃:Ti⁴⁺, CaSr₂(PO₄)₂:Bi³⁺,
 β -(Ca,Sr)₃(PO₄)₂:Sn²⁺Mn²⁺, CaTi_{0.9}Al_{0.1}O₃:Bi³⁺, CaTiO₃:Eu³⁺, CaTiO₃:Pr³⁺, Ca₅(VO₄)₃Cl,
 CaWO₄, CaWO₄:Pb²⁺, CaWO₄:W, Ca₃WO₆:U, CaYAlO₄:Eu³⁺, CaYBO₄:Bi³⁺,
 CaYBO₄:Eu³⁺, CaYB_{0.8}O_{3.7}:Eu³⁺, CaY₂ZrO₆:Eu³⁺, (Ca,Zn,Mg)₃(PO₄)₂:Sn, CeF₃,
 (Ce,Mg)BaAl₁₁O₁₈:Ce, (Ce,Mg)SrAl₁₁O₁₈:Ce, CeMgAl₁₁O₁₉:Ce:Tb, Cd₂B₆O₁₁:Mn²⁺,
 CdS:Ag⁺,Cr, CdS:In, CdS:In, CdS:In,Te, CdS:Te, CdWO₄, CsF, CsI, CsI:Na⁺, CsI:TI,
 (ErCl₃)_{0.25}(BaCl₂)_{0.75}, GaN:Zn, Gd₃Ga₅O₁₂:Cr³⁺, Gd₃Ga₅O₁₂:Cr,Ce, GdNbO₄:Bi³⁺,
 Gd₂O₂S:Eu³⁺, Gd₂O₂Pr³⁺, Gd₂O₂S:Pr,Ce,F, Gd₂O₂S:Tb³⁺, Gd₂SiO₅:Ce³⁺, KAl₁₁O₁₇:Ti⁴⁺,
 KGa₁₁O₁₇:Mn²⁺, K₂La₂Ti₃O₁₀:Eu, KMgF₃:Eu²⁺, KMgF₃:Mn²⁺, K₂SiF₆:Mn⁴⁺,
 LaAl₃B₄O₁₂:Eu³⁺, LaAlB₂O₆:Eu³⁺, LaAlO₃:Eu³⁺, LaAlO₃:Sm³⁺, LaAsO₄:Eu³⁺, LaBr₃:Ce³⁺,
 LaBO₃:Eu³⁺, (La,Ce,Tb)PO₄:Ce:Tb, LaCl₃:Ce³⁺, La₂O₃:Bi³⁺, LaOBr:Tb³⁺, LaOBr:Tm³⁺,
 LaOCl:Bi³⁺, LaOCl:Eu³⁺, LaOF:Eu³⁺, La₂O₃:Eu³⁺, La₂O₃:Pr³⁺, La₂O₂S:Tb³⁺, LaPO₄:Ce³⁺,
 LaPO₄:Eu³⁺, LaSiO₃Cl:Ce³⁺, LaSiO₃Cl:Ce³⁺,Tb³⁺, LaVO₄:Eu³⁺, La₂W₃O₁₂:Eu³⁺,
 LiAlF₄:Mn²⁺, LiAl₅O₈:Fe³⁺, LiAlO₂:Fe³⁺, LiAlO₂:Mn²⁺, LiAl₅O₈:Mn²⁺,
 Li₂CaP₂O₇:Ce³⁺,Mn²⁺, LiCeBa₄Si₄O₁₄:Mn²⁺, LiCeSrBa₃Si₄O₁₄:Mn²⁺, LiInO₂:Eu³⁺,
 LiInO₂:Sm³⁺, LiLaO₂:Eu³⁺, LuAlO₃:Ce³⁺, (Lu,Gd)₂SiO₅:Ce³⁺, Lu₂SiO₅:Ce³⁺, Lu₂Si₂O₇:Ce³⁺,
 LuTaO₄:Nb⁵⁺, Lu_{1-x}Y_xAlO₃:Ce³⁺, MgAl₂O₄:Mn²⁺, MgSrAl₁₀O₁₇:Ce, MgB₂O₄:Mn²⁺,
 MgBa₂(PO₄)₂:Sn²⁺, MgBa₂(PO₄)₂:U, MgBaP₂O₇:Eu²⁺, MgBaP₂O₇:Eu²⁺,Mn²⁺,
 MgBa₃Si₂O₈:Eu²⁺, MgBa(SO₄)₂:Eu²⁺, Mg₃Ca₃(PO₄)₄:Eu²⁺, MgCaP₂O₇:Mn²⁺,
 Mg₂Ca(SO₄)₃:Eu²⁺, Mg₂Ca(SO₄)₃:Eu²⁺,Mn²⁺, MgCeAl_nO₁₉:Tb³⁺, Mg₄(F)GeO₆:Mn²⁺,
 Mg₄(F)(Ge,Sn)O₆:Mn²⁺, MgF₂:Mn²⁺, MgGa₂O₄:Mn²⁺, Mg₈Ge₂O₁₁F₂:Mn⁴⁺, MgS:Eu²⁺,
 MgSiO₃:Mn²⁺, Mg₂SiO₄:Mn²⁺, Mg₃SiO₃F₄:Ti⁴⁺, MgSO₄:Eu²⁺, MgSO₄:Pb²⁺,
 MgSrBa₂Si₂O₇:Eu²⁺, MgSrP₂O₇:Eu²⁺, MgSr₅(PO₄)₄:Sn²⁺, MgSr₃Si₂O₈:Eu²⁺,Mn²⁺,
 Mg₂Sr(SO₄)₃:Eu²⁺, Mg₂TiO₄:Mn⁴⁺, MgWO₄, MgYBO₄:Eu³⁺, Na₃Ce(PO₄)₂:Tb³⁺, NaI:TI,
 Na_{1.23}K_{0.42}Eu_{0.12}TiSi₄O₁₁:Eu³⁺, Na_{1.23}K_{0.42}Eu_{0.12}TiSi₅O₁₃·xH₂O:Eu³⁺,
 Na_{1.29}K_{0.46}Er_{0.08}TiSi₄O₁₁:Eu³⁺, Na₂Mg₃Al₂Si₂O₁₀:Tb, Na(Mg_{2-x}Mn_x)LiSi₄O₁₀F₂:Mn,
 NaYF₄:Er³⁺, Yb³⁺, NaYO₂:Eu³⁺, P46(70%) + P47 (30%), SrAl₁₂O₁₉:Ce³⁺, Mn²⁺,
 SrAl₂O₄:Eu²⁺, SrAl₄O₇:Eu³⁺, SrAl₁₂O₁₉:Eu²⁺, SrAl₂S₄:Eu²⁺, Sr₂B₅O₉Cl:Eu²⁺,
 SrB₄O₇:Eu²⁺(F,Cl,Br), SrB₄O₇:Pb²⁺, SrB₄O₇:Pb²⁺, Mn²⁺, SrB₈O₁₃:Sm²⁺, Sr_xBayCl₂Al₂O_{4-z/2}:
 Mn²⁺, Ce³⁺, SrBaSiO₄:Eu²⁺, Sr(Cl,Br,I)₂:Eu²⁺ in SiO₂, SrCl₂:Eu²⁺ in SiO₂, Sr₅Cl(PO₄)₃:Eu,
 Sr_wF_xB₄O_{6.5}:Eu²⁺, Sr_wF_xB_yO_z:Eu²⁺,Sm²⁺, SrF₂:Eu²⁺, SrGa₁₂O₁₉:Mn²⁺, SrGa₂S₄:Ce³⁺,

SrGa₂S₄:Eu²⁺, SrGa₂S₄:Pb²⁺, SrIn₂O₄:Pr³⁺, Al³⁺, (Sr,Mg)₃(PO₄)₂:Sn, SrMgSi₂O₆:Eu²⁺,
 Sr₂MgSi₂O₇:Eu²⁺, Sr₃MgSi₂O₈:Eu²⁺, SrMoO₄:U, SrO·3B₂O₃:Eu²⁺, Cl, β-SrO·3B₂O₃:Pb²⁺,
 β-SrO·3B₂O₃:Pb²⁺, Mn²⁺, α-SrO·3B₂O₃:Sm²⁺, Sr₆P₅BO₂₀:Eu, Sr₅(PO₄)₃Cl:Eu²⁺,
 Sr₅(PO₄)₃Cl:Eu²⁺, Pr³⁺, Sr₅(PO₄)₃Cl:Mn²⁺, Sr₅(PO₄)₃Cl:Sb³⁺, Sr₂P₂O₇:Eu²⁺,
 β-Sr₃(PO₄)₂:Eu²⁺, Sr₅(PO₄)₃F:Mn²⁺, Sr₅(PO₄)₃F:Sb³⁺, Sr₅(PO₄)₃F:Sb³⁺, Mn²⁺,
 Sr₅(PO₄)₃F:Sn²⁺, Sr₂P₂O₇:Sn²⁺, β-Sr₃(PO₄)₂:Sn²⁺, β-Sr₃(PO₄)₂:Sn²⁺, Mn²⁺(Al), SrS:Ce³⁺,
 SrS:Eu²⁺, SrS:Mn²⁺, SrS:Cu⁺, Na, SrSO₄:Bi, SrSO₄:Ce³⁺, SrSO₄:Eu²⁺, SrSO₄:Eu²⁺, Mn²⁺,
 Sr₅Si₄O₁₀Cl₆:Eu²⁺, Sr₂SiO₄:Eu²⁺, SrTiO₃:Pr³⁺, SrTiO₃:Pr³⁺, Al³⁺, Sr₃WO₆:U, SrY₂O₃:Eu³⁺,
 ThO₂:Eu³⁺, ThO₂:Pr³⁺, ThO₂:Tb³⁺, YAl₃B₄O₁₂:Bi³⁺, YAl₃B₄O₁₂:Ce³⁺, YAl₃B₄O₁₂:Ce³⁺, Mn,
 YAl₃B₄O₁₂:Ce³⁺, Tb³⁺, YAl₃B₄O₁₂:Eu³⁺, YAl₃B₄O₁₂:Eu³⁺, Cr³⁺, YAl₃B₄O₁₂:Th⁴⁺, Ce³⁺, Mn²⁺,
 YAlO₃:Ce³⁺, Y₃Al₅O₁₂:Ce³⁺, Y₃Al₅O₁₂:Cr³⁺, YAlO₃:Eu³⁺, Y₃Al₅O₁₂:Eu³⁺, Y₄Al₂O₉:Eu³⁺,
 Y₃Al₅O₁₂:Mn⁴⁺, YAlO₃:Sm³⁺, YAlO₃:Tb³⁺, Y₃Al₅O₁₂:Tb³⁺, YAsO₄:Eu³⁺, YBO₃:Ce³⁺,
 YBO₃:Eu³⁺, YF₃:Er³⁺, Yb³⁺, YF₃:Mn²⁺, YF₃:Mn²⁺, Th⁴⁺, YF₃:Tm³⁺, Yb³⁺, (Y,Gd)BO₃:Eu,
 (Y,Gd)BO₃:Tb, (Y,Gd)₂O₃:Eu³⁺, Y_{1.34}Gd_{0.60}O₃(Eu,Pr), Y₂O₃:Bi³⁺, YOBr:Eu³⁺, Y₂O₃:Ce,
 Y₂O₃:Er³⁺, Y₂O₃:Eu³⁺(YOE), Y₂O₃:Ce³⁺, Tb³⁺, YOCl:Ce³⁺, YOCl:Eu³⁺, YOF:Eu³⁺, YOF:Tb³⁺,
 Y₂O₃:Ho³⁺, Y₂O₂S:Eu³⁺, Y₂O₂S:Pr³⁺, Y₂O₂S:Tb³⁺, Y₂O₃:Tb³⁺, YPO₄:Ce³⁺, YPO₄:Ce³⁺, Tb³⁺,
 YPO₄:Eu³⁺, YPO₄:Mn²⁺, Th⁴⁺, YPO₄:V⁵⁺, Y(P,V)O₄:Eu, Y₂SiO₅:Ce³⁺, YT₂O₄, YT₂O₄:Nb⁵⁺,
 YVO₄:Dy³⁺, YVO₄:Eu³⁺, ZnAl₂O₄:Mn²⁺, ZnB₂O₄:Mn²⁺, ZnBa₂S₃:Mn²⁺,
 (Zn,Be)₂SiO₄:Mn²⁺, Zn_{0.4}Cd_{0.6}S:Ag, Zn_{0.6}Cd_{0.4}S:Ag, (Zn,Cd)S:Ag, Cl, (Zn,Cd)S:Cu,
 ZnF₂:Mn²⁺, ZnGa₂O₄, ZnGa₂O₄:Mn²⁺, ZnGa₂S₄:Mn²⁺, Zn₂GeO₄:Mn²⁺, (Zn,Mg)F₂:Mn²⁺,
 ZnMg₂(PO₄)₂:Mn²⁺, (Zn,Mg)₃(PO₄)₂:Mn²⁺, ZnO:Al³⁺, Ga³⁺, ZnO:Bi³⁺, ZnO:Ga³⁺,
 ZnO:Ga, ZnO-CdO:Ga, ZnO:S, ZnO:Se, ZnO:Zn, ZnS:Ag⁺, Cl⁻, ZnS:Ag, Cu, Cl, ZnS:Ag, Ni,
 ZnS:Au, In, ZnS-CdS (25-75), ZnS-CdS (50-50), ZnS-CdS (75-25), ZnS-CdS:Ag, Br, Ni,
 ZnS-CdS:Ag⁺, Cl⁻, ZnS-CdS:Cu, Br, ZnS-CdS:Cu, I, ZnS:Cl⁻, ZnS:Eu²⁺, ZnS:Cu, ZnS:Cu⁺, Al³⁺,
 ZnS:Cu⁺, Cl⁻, ZnS:Cu, Sn, ZnS:Eu²⁺, ZnS:Mn²⁺, ZnS:Mn, Cu, ZnS:Mn²⁺, Te²⁺, ZnS:P,
 ZnS:P³⁻, Cl⁻, ZnS:Pb²⁺, ZnS:Pb²⁺, Cl⁻, ZnS:Pb, Cu, Zn₃(PO₄)₂:Mn²⁺, Zn₂SiO₄:Mn²⁺,
 Zn₂SiO₄:Mn²⁺, As⁵⁺, Zn₂SiO₄:Mn, Sb₂O₂, Zn₂SiO₄:Mn²⁺, P, Zn₂SiO₄:Ti⁴⁺, ZnS:Sn²⁺,
 ZnS:Sn, Ag, ZnS:Sn²⁺, Li⁺, ZnS:Te, Mn, ZnS-ZnTe:Mn²⁺, ZnSe:Cu⁺, Cl oder ZnWO₄.

30 The solvent comprised in said composition comprising the silazane-siloxane
 copolymer is not particularly limited provided that the components of said
 composition have a certain solubility therein. Preferably, said solvent may be a non-
 polar or polar non-protic, preferably organic, solvent.

Preferred examples of suitable solvents may be selected from the group consisting of ethers, cyclic ethers, esters, hydrocarbons, aromatic solvents and any mixture of any of these.

5 Preferred examples of ethers are 1-methoxy-2-propylacetate and di-n-butylether.

A preferred example of a cyclic ether is tetrahydrofuran (THF).

10 Preferred examples of ester are ethyl-acetate and n-butyl-acetate.

Preferred examples of hydrocarbons are n-heptane and cyclohexane.

15 A preferred example of an aromatic solvent may be selected from the group consisting of toluene, ortho-xylene, meta-xylene, para-xylene and any mixture of any of these.

20 Said substrate may be any layer or material on which the composition of the present application as defined above may be deposited. Suitable substrates are not particularly limited in terms of material or shape. An exemplary substrate is an LED chip, i.e. the composition of the present application is directly applied onto an LED chip.

25 The composition comprising said silazane-siloxane copolymer may be deposited on the substrate by any suitable method, for example with an industrial dispensing system.

30 In case the substrate is an LED chip, the composition preferably comprises at least 90 wt% or 95 wt% or 99 wt% or consists, with wt% relative to the total weight of said composition, of the silazane-siloxane copolymer and the light emitting material and is applied directly to the LED chip. Suitable compositions preferably have a viscosity of at least 100 mPa · s and of at most 100,000 mPa · s, determined as described in the test methods. During the deposition of the composition on the substrate the viscosity of the composition may optionally be modified by changing
35 the temperature at which the composition is deposited, for example, between 10°C and 60°C.

5 Another possibility of applying the silazane-siloxane copolymer and the light emitting material directly to the LED chip is by spray coating. A typical spray coating formulation consists of 2-10 wt% silazane-siloxane copolymer, 10-25 wt% light emitting material, 63-88 wt% solvent and 0-2 wt% other additives, with the respective weight percentages of the components of the spray coating formulation adding up to 100 wt%. The solvent is either a pure solvent or a mixture of several solvents, usually a mixture of at least one high boiling and one low boiling solvent.

10 Alternatively, the silazane-siloxane copolymer and the light emitting material may be applied by any other suitable method, such as screen printing or ink-jet printing.

15 After having been applied to the LED the silazane-siloxane copolymer is preferably subjected to a heating step, wherein the material is heated to a temperature of from 100°C to 250°C, preferably from 150°C to 220°C, for a period of from 2 to 48 h, preferably of from 4 to 48 h.

20 Alternatively after having been applied to the LED the silazane-siloxane copolymer may be subjected to a hydrolyzing step in a climate chamber. Preferred hydrolyzing conditions in a climate chamber are 4-24 h at 70-90°C and a relative humidity of 70-90 %.

25 The present process may be applied to a wide range of electronic devices. Preferably, said electronic device may be selected from the group consisting of field-effect transistors (FETs), thin-film transistors (TFTs), integrated circuits (ICs), logic circuits, capacitors, RFID tags (radio frequency identification tags), light emitting diodes (OLEDs), photovoltaic cells (PVs), photodetectors, laser diodes, photoconductors, electrophotographic devices, organic memory devices, sensor devices, charge injection layers, Schottky diodes, planarising layers, antistatic films, conducting substrates and conducting patterns. Most preferably, said electronic device is a light emitting diode.

35 Such light emitting diode may, for example, be used for backlights for liquid crystal displays, traffic light, outdoor displays, billboards, to name only a few non-limiting examples.

5 A typical LED package according to the invention comprises an LED chip, and/or a lead frame and/or gold wire and/or solder (flip chip) and/or the filling material, converter, an encapsulation material comprising the present silazane-siloxane copolymer and a primary and secondary optic. The encapsulation material has the function of a surface protection material against external environmental influences and guarantees long term reliability in particular aging stability. For example, in accordance with the present invention a light emitting diode is constructed similarly to the ones described in US 6,274,924 and 6,204,523.

10

Examples

Test methods

15

Molecular weights of the polymers were determined by GPC against a polystyrene standard. As eluent a mixture of tetrahydrofuran and 1.45 wt% (relative to the total weight of the eluent) hexamethyldisilazane was used. Columns were Shodex KS-804 and 2 x KS-802 and KS-801. The detector was an Agilent 1260 refractive index detector.

20

Viscosity was determined using a Brookfield Rheometer R/S plus with a Brookfield cone-type spindle RC3-50-1 at a rotation speed of 3 rpm and a temperature of 25°C.

25

Example 1

30

A 2 l flask was charged under nitrogen atmosphere with 1000 g n-heptane, 50 g dichloromethylsilane (available from Sigma-Aldrich) and 30 g silanol-terminated polydimethylsiloxane (molecular weight M_n of 550 g/mol; available from Sigma-Aldrich). At a temperature of 0°C ammonia was slowly bubbled through the solution for 6 h. Precipitation of ammonium chloride was observed. The solid ammonium chloride was removed by filtration, yielding a clear filtrate, from which the solvent was removed by evaporation under reduced pressure. 49 g of a colorless low viscous liquid was obtained.

35

Example 2

To show its usefulness for LED devices, the polymer obtained in Example 1 was blended with phosphor light converter particles (available from Merck KGaA) in weight ratios ranging from 1 : 1 to 1 : 3, and the blend then coated as a 40 µm to 80 µm thick layer onto an LED chip mounted onto an LED package (available from Excelitas). For curing the polymer the LED was then placed on a hotplate at 150°C for 8 hours.

The finished LED was first operated for 24 hours at a starting current of 0.5 A. If no crack formation in the coating of the LED could be detected by microscope the current was raised in steps of 0.1 A, the LED operated for another 24 hours and inspected by microscope until the current for which crack formation could be observed. Because the LED current relates to the temperature of the chip this method gives an indication to the temperature resistance and the longevity of these-produced LEDs.

For the LED of Example 2 the highest current without crack formation was found 1.8 A. For comparison, a reference LED with phenylsilicone as coating material was found to have a value of 1.5 A and a reference LED with Durazane 1033 (an organopolysilazane available from Merck KGaA) was found to have a value of 1.0 A.

The present results clearly show that the polymers of the present application are generally better in temperature resistance and/or longevity than currently used materials, such as for example phenylsilicone or organopolysilazanes.

Claims

1. Method of producing an electronic device, comprising the following steps:
 - (a) obtaining a silazane-siloxane copolymer by reacting an organosilane, an amine and an organosiloxane,
 - (b) providing a composition comprising the silazane-siloxane copolymer obtained in step (a), and
 - (c) applying it to a substrate in an electronic device.
2. Method according to claim 1, wherein the organosilane comprising two halogen end groups, and the organosiloxane comprising two halogen end groups or two hydroxy end groups.
3. Method according to claim 2, wherein the organosilane is of formula (I)

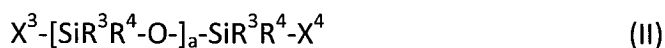


wherein

X^1 and X^2 are at each occurrence independently selected from the group consisting of Cl, Br, I; and

R^1 and R^2 are at each occurrence independently H or a carbyl group.

4. Method according to claim 3, wherein R^1 and R^2 are at each occurrence H or independently alkyl having at least 1 and at most 20 carbon atoms.
5. Method according to any one or more of claims 1 to 4, wherein the organosiloxane is of formula (II)



wherein

X^3 and X^4 are identical and are at each occurrence independently selected from the group consisting of OH, Cl, Br, I;

R^3 and R^4 are at each occurrence independently H or a carbyl group;
and

a is an integer of at least 4 and at most 10,000.

6. Method according to claim 5, wherein R^3 and R^4 are at each occurrence independently alkyl having at least 1 and at most 40 carbon atoms.
7. Method according to claim 5 or claim 6, wherein R^3 and R^4 are methyl.
8. Method according any one or more of claims 5 to 7, wherein a is an integer of at least 4 and at most 500.
9. Method according to any one or more of the preceding claims, wherein the amine is of formula (III)



wherein R^5 is at each occurrence independently H or carbyl.

10. Method according to any one or more of the preceding claims, wherein the amine is ammonia.
11. Method according to any one or more of the preceding claims, wherein the electronic device is an LED chip and the silazane-siloxane copolymer is deposited directly onto the LED chip.
12. Method according to any one or more of the preceding claims, wherein said composition further comprises a light emitting material.
13. Method according to claim 12, wherein the light emitting material is a phosphor.