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(57) **Abrégé/Abstract:**

The present invention relates to mixtures of conducting organic polymers and reaction products of polyfunctional organosilanes, conducting organic-inorganic hybrid materials obtained therefrom, and their use for coating surfaces.



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Conducting organic-inorganic hybrid materials

Abstract

- 5 The present invention relates to mixtures of conducting organic polymers and reaction products of polyfunctional organosilanes, conducting organic-inorganic hybrid materials obtained therefrom, and their use for coating surfaces.

Conducting organic-inorganic hybrid materials

5 The present invention relates to mixtures of conducting organic polymers and reaction products of polyfunctional organosilanes, conducting organic-inorganic hybrid materials obtained therefrom, and their use for coating surfaces.

10 Glass moulded parts and plastics moulded parts become electrostatically charged by friction or application of charges, for example electron beams in TV picture tubes. As a result of these charges the moulded parts rapidly become covered with dust due to attraction of dust, which is undesirable in practice. There is therefore the need to protect these moulded parts against electrostatic charging. This protection can be achieved for example by coating the moulded parts with an antistatic coating. Following the definition given in ISO 2878, antistatic materials are understood to be those having surface resistances of between $50 \text{ k}\Omega/\square$ and $100 \text{ M}\Omega/\square$. Conducting materials are defined as those having surface resistances of $< 50 \text{ k}\Omega/\square$.

20 With sufficiently conducting materials, in addition to the antistatic effect a screening effect against electromagnetic radiation, as is emitted for example from cathode ray tubes, is also achieved. For an effective radiation screening the surface resistance must be less than $3 \text{ k}\Omega/\square$.

25 For practical use these coatings must also have a sufficient mechanical strength and adhesion. Especially in the case of glass as carrier, the layers must be sufficiently scratch-resistant in order to avoid damage to the coating when cleaning the coated surfaces and thus loss of the antistatic and/or conducting effect.

Electrically conducting polymers, for example polythiopenes, for producing antistatic and/or conducting coatings are known from the literature. Examples thereof may be found in EP-A 440 957 and DE-OS 42 11 459.

30

The use of these polythiophene salts for giving glass an antistatic finish is described in DE-OS 42 29 192. It has been found however that these coatings are not sufficiently scratch-resistant in practice for some applications.

5 Scratch-resistant coatings based on hydrolysed siloxanes are known from EP-A 17 187. These however are not compatible with preparations of polythiophene salts.

10 Poly-3,4-ethylenedioxythiophene-containing coatings on image screens are described in WO 96/05606. In order to improve the scratch resistance of the coatings and obtain anti-reflecting properties, layers of SiO_2 and/or TiO_2 obtained for example from metal alkoxides are applied thereto via the sol-gel process.

15 A disadvantage is that already with layer thicknesses that are only slightly more than 100 nm, the transmission falls below 60%. The layer must therefore have exactly the same thickness over the whole surface. The reproducible application of such thin coatings is however technically difficult..

20 A further disadvantage of this process is that conducting coatings having the required scratch resistance can only be obtained if the conducting layer is provided with at least one scratch-resistant covering layer. To obtain suitable coatings having anti-reflecting properties it is necessary to apply up to four different layers in succession. This is technically extremely complicated. Also, with each additional layer there is an increasing danger that the overall laminar composite will exhibit a defect.

25

The present invention provides mixtures which, when applied to suitable substrates, produce after removal of the solvents firmly adhering, conducting coatings having improved scratch resistance and transmission of visible light.

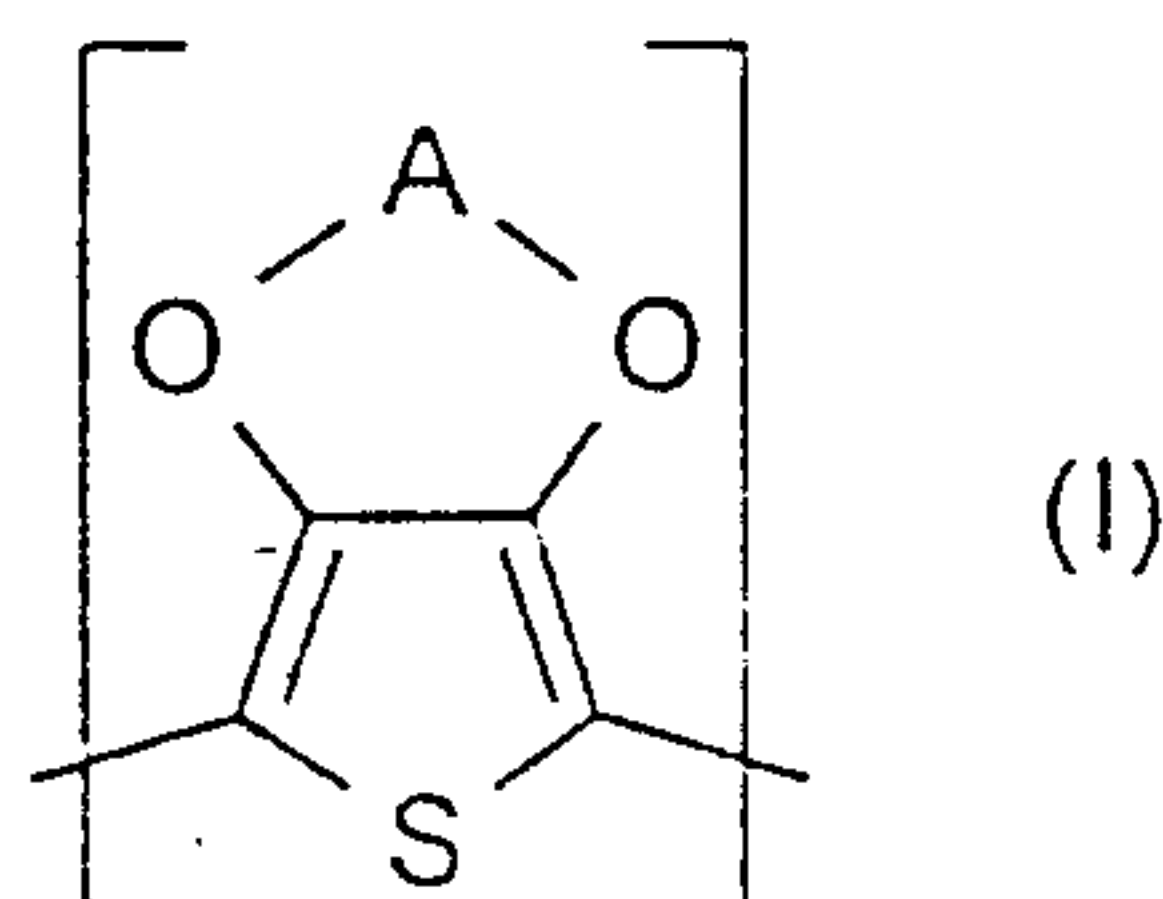
It has now been found that the aforementioned requirements can be fulfilled if mixtures of conducting organic polymers with reaction products of polyfunctional organosilanes and optionally further components such as metal alkoxides, metal oxides or metal oxide-hydroxides are used.

5

The present invention accordingly provides mixture containing:

- A) preparations of polythiophenes,
- 10 B) reaction products of polyfunctional organosilanes,
- C) optionally reaction products of alkoxides of the elements B, Al, Si, Sn, Ti, Zr,
- 15 D) optionally metal oxides or metal oxide-hydroxides of the elements B, Al, In, Si, Sn, Ti, Zr,
- E) Solvents

20



25

As component A), there are preferably used preparations of polythiophenes such as are described in DE-OS 42 11 459, EP-A 339 340 and EP-A 440 957. The preparations contain polythiophene salts of the type polythiophene^{m+}, An^{m-}, wherein the polythiophene cation polythiophene^{m+} contains positively charged or uncharged units of the formula (I),
 30 wherein

A denotes a C_1 - C_4 -alkylene radical optionally substituted with C_1 - C_{20} alkyl-,
- CH_2OH or C_6 - C_{14} -aryl groups. The number of units in the polythiophene
cation may be between 5 and 100.

5

An^{m-} denotes a polyanion.

Examples of polyanions that may be used according to the invention are the anions
of polymeric carboxylic acids such as polyacrylic acids, polymethacrylic acids,
10 polymaleic acids, as well as anions of polymeric sulfonic acids such as
polystyrenesulfonic acids and polyvinylsulfonic acids. These polycarboxylic acids
and polysulfonic acids may also be copolymers of vinylcarboxylic acids and
vinylsulfonic acids with other polymerisable monomers such as acrylic acid esters
and styrene.

15

The mean molecular weight \overline{M} of the polymeric acids from which are derived the
polyanions that may be used according to the invention is 1000 to 2,000,000,
preferably 2000 to 500,000. The polymeric acids or their alkali salts are
commercially available or can be prepared by methods known per se, such as those
20 described for example in Houben-Weyl: "Methoden der organischen Chemie", Vol.
E20, "Makromolekulare Stoffe", Part 2, p.1141 ff.

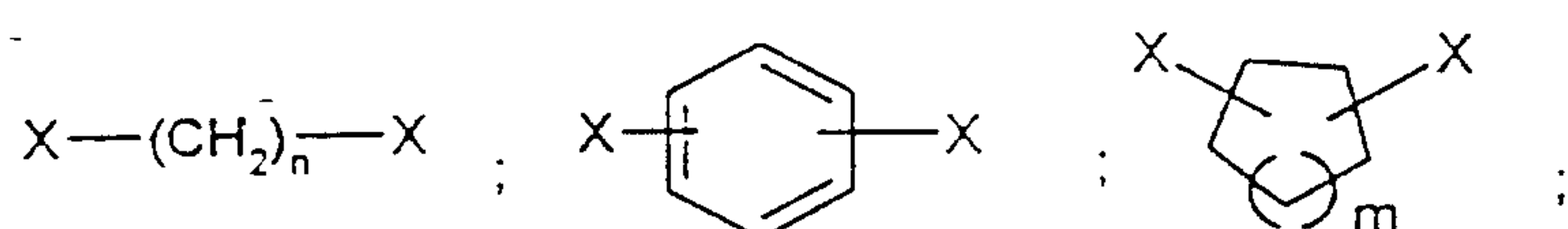
The mixtures according to the invention contain as component B) reaction products
of polyfunctional organosilanes. Polyfunctional organosilanes within the context of
25 the invention are those that contain at least 2, preferably at least 3 silicon atoms per
molecule, that in each case contain 1 to 3 alkoxy or hydroxyl groups, and that are
coupled via at least one Si-C bond to a structural unit joining two silicon atoms.

Bonding structural units within the context of the invention may in the simplest case
30 be linear or branched C_1 to C_{10} -alkylene chains, C_5 to C_{10} -cycloalkylene radicals,
aromatic radicals such as phenyl, naphthyl or biphenyl, or also combinations of

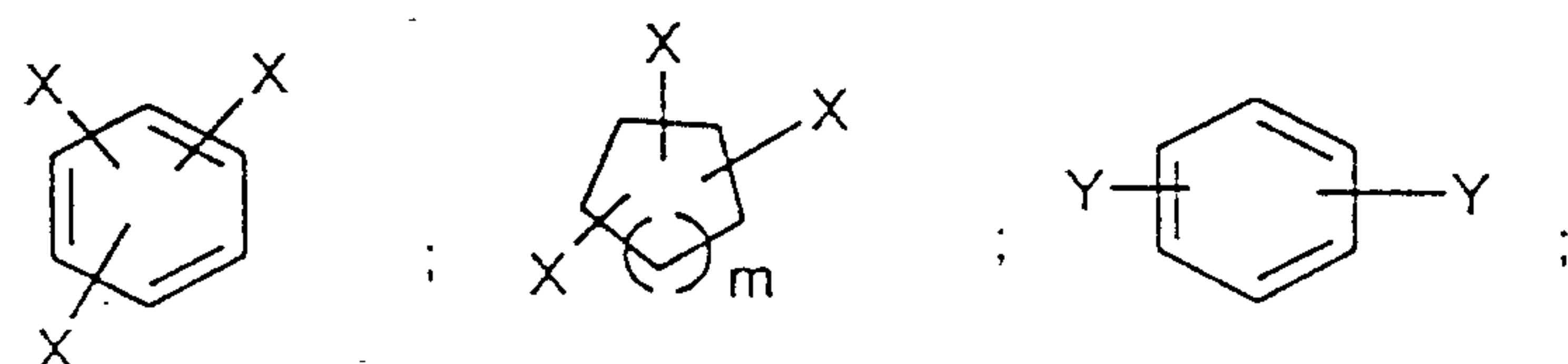
aromatic and aliphatic radicals. The aliphatic and aromatic radicals may also contain hetero atoms such as Si, N, O, S or F. Furthermore, chain, ring or cage siloxanes, for example silsesquioxanes, may be mentioned as coupling structural units.

- 5 Examples of coupling structural units are given hereinafter, wherein X denotes Si atoms that contain 1 to 3 hydrolysable and/or condensation-crosslinking groups, and Y denotes corresponding Si atoms that are bound via an alkylene chain to the coupling structural unit; n denotes a number from 1 to 10, and m denotes a number from 1 to 6:

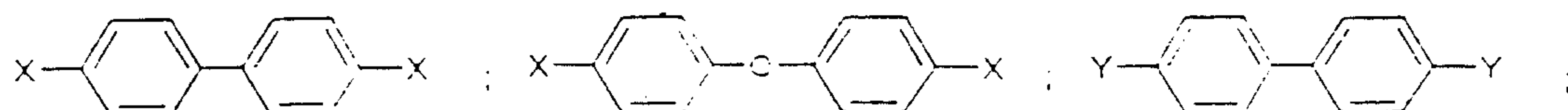
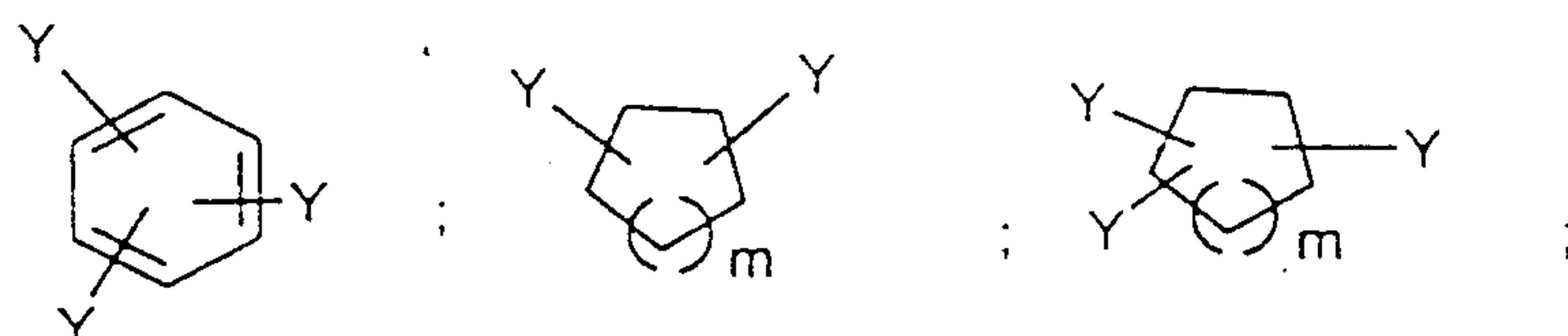
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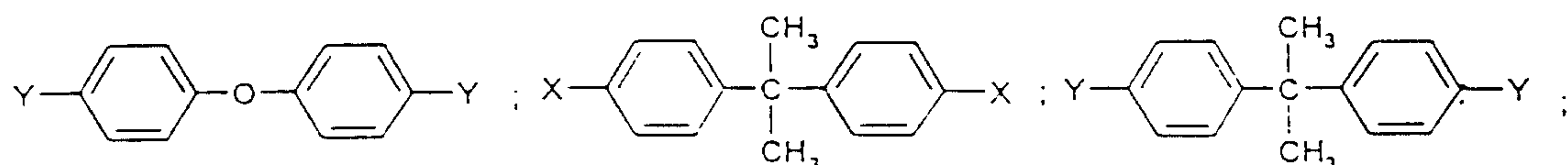
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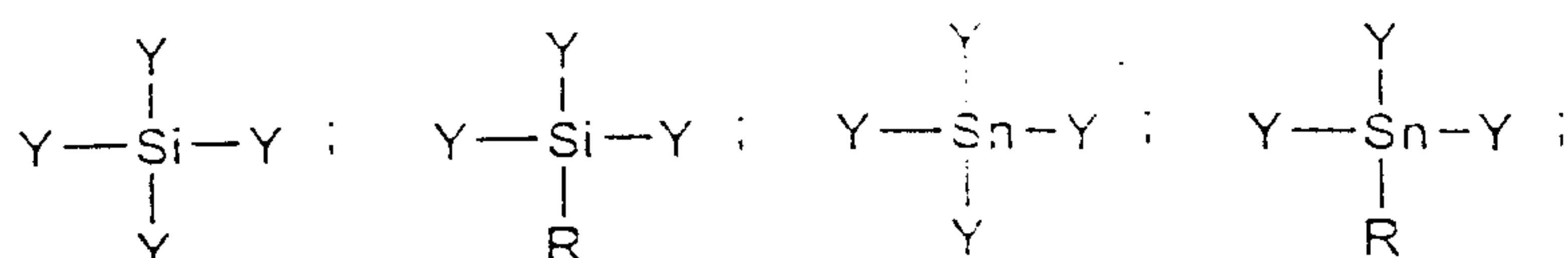
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wherein R is an organic radical, for example alkyl, cycloalkyl, aryl or alkenyl.

Examples of polyfunctional organosilanes are compounds of the general formula (II)



where

$i = 2$ to 4 , preferably $i = 4$,

10

$n = 1$ to 10 , preferably $n = 2$ to 4 , particularly $n = 2$, and

$R^3 =$ alkyl or aryl,

15 $R^5 =$ alkyl or aryl, preferably $R^5 =$ methyl,

$a = 1$ to 3 ,

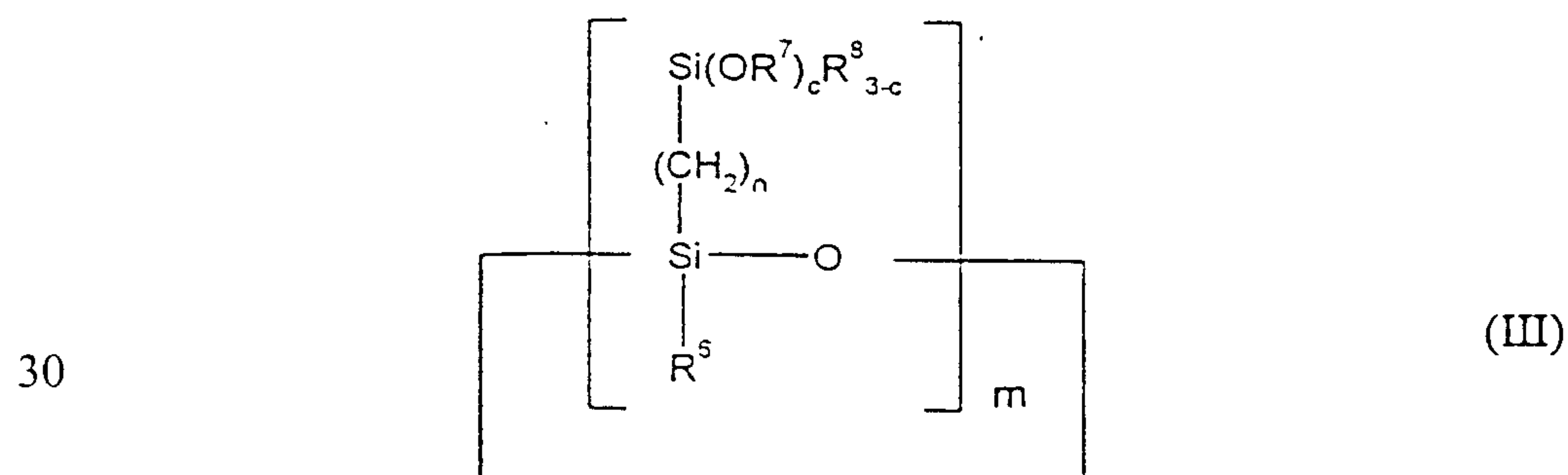
wherein

20

$R^4 =$ alkyl, aryl, preferably $R^4 =$ methyl, ethyl, isopropyl;

in the case where $a = 1$, R^4 may also be hydrogen.

25 Further examples are cyclic compounds of the general formula (III)



30

where

$m = 3$ to 6 , preferably $m = 3$ or 4 ,

5 $n = 2$ to 10 , preferably $n = 2$,

$R^6 =$ C_1 - C_6 alkyl or C_6 - C_{14} aryl, preferably $R^6 =$ methyl, ethyl, particularly preferably $R^6 =$ methyl,

10 $R^8 =$ alkyl, aryl, preferably $R^8 =$ methyl,

$c =$ up to 3 , wherein

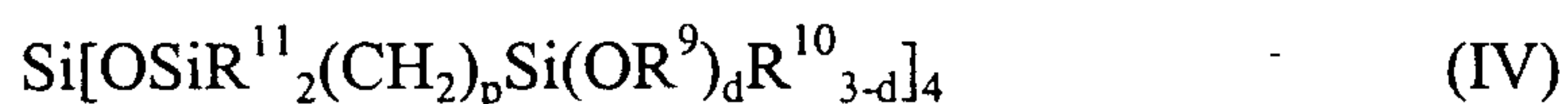
$R^7 =$ alkyl, aryl, preferably $R^7 =$ methyl, ethyl, isopropyl;

15

in the case where $c = 1$, R^7 may also be hydrogen.

Further examples of polyfunctional organosilanes are compounds of the general formula (IV)

20



where $p = 1$ to 10 , preferably $p = 2$ to 4 , particularly preferably $p = 2$,

25 $R^{11} =$ alkyl, aryl, preferably $R^{11} =$ methyl,

$R^{10} =$ alkyl, aryl, preferably $R^{10} =$ methyl,

$d =$ 1 to 3 , wherein

30

$R^9 =$ alkyl, aryl, preferably $R^9 =$ methyl, ethyl, isopropyl;

in the case where $d = 1$, R^9 may also be hydrogen.

Examples of polyfunctional organosilanes according to the invention are also silanols such as $\text{Si}[(\text{CH}_2)_2\text{Si}(\text{OH})(\text{CH}_3)_2]_4$ and cyclo- $[\text{OSiMe}((\text{CH}_2)_2\text{Si}(\text{OH})\text{Me}_2)]_4$,
5 or alkoxides such as cyclo- $[\text{OSiMe}((\text{CH}_2)_2\text{Si}(\text{OEt})_2\text{Me})]_4$ and cyclo- $[\text{OSiMe}((\text{CH}_2)_2\text{Si}(\text{OMe})\text{Me}_2)]_4$.

The mixtures according to the invention may contain as component C) reaction products of alkoxides of the elements B, Al, Si, Sn, Ti, Zr.

The alkoxides that may be used in the preparation of the mixtures according to the
10 invention preferably correspond to the general formula $\text{M}(\text{OR})_y$, where y has the value 3 if M denotes boron or aluminium, and y has the value 4 if M denotes silicon, tin, titanium or zirconium. Examples of alkoxides that may be added in the preparation of the mixtures according to the invention in order to improve the scratch resistance of coatings produced therefrom are $\text{Si}(\text{OEt})_4$, $\text{Al}(\text{O}^i\text{Pr})_3$ or
15 $\text{Zr}(\text{O}^i\text{Pr})_4$, preferably $\text{Si}(\text{OEt})_4$. By adding titanium alkoxides, for example $\text{Ti}(\text{O}^i\text{Pr})_4$ or $\text{Ti}(\text{O}^n\text{Bu})_4$, the refraction index of the conducting, organic-inorganic hybrid material produced from the mixtures according to the invention can be increased. During the production process of the mixtures according to the invention, solvolysis products and condensation products are formed from the alkoxides, for example by
20 reaction with the solvent, polyfunctional organosilanes, polythiophene preparations, catalysts or by self-condensation. In order to reduce the reactivity of readily hydrolysable and condensable metal alkoxides and to avoid the formation of deposits, these metal alkoxides may first of all already be reacted with water before they react with the polyfunctional organosilanes. These solvolysis products and
25 condensation products form the component C) of the mixtures according to the invention.

Details of the hydrolysis and condensation of polyfunctional organosilanes and their mixtures with metal oxides may be found for example in DE-OS 196 03 242, German Patent Application 196 03 241.5 and WO 94/06807.

The polyfunctional organosilanes are reacted with water in the presence of a catalyst, preferably in a solvent, for example an alcohol, and optionally in the presence of metal alkoxides. Inorganic or organic acids, for example formic acid, are used as catalysts. The solvolysis and condensation products of the polyfunctional organosilanes form the component B) of the mixtures according to the invention.

The mixtures according to the invention may contain as component D) metal oxides or metal oxide-hydroxides of the elements B, Al, In, Si, Sn, Ti or Zr. Mixed metal oxides, for example indium-tin oxides (ITO) may also be used. In order to obtain transparent coatings, particles with primary particle sizes in the range from 1 to 50 nm are preferably used. Their incorporation in the mixtures according to the invention is best achieved by adding the particles as a dispersion in a solvent, for example water or alcohols. A dispersion of SiO_2 (primary particle size ca. 9 nm) in isopropanol may be mentioned by way of example.

By adding fillers such as glass powder, calcium carbonate, calcium sulfate, barium sulfate or layer-type silicates (talcum, kaolin, mica), the conductivity of the amorphous organic-inorganic hybrid materials obtainable from the mixtures according to the invention may be improved still further.

The mixtures according to the invention are prepared from the reactive solutions obtained by reacting polyfunctional organosilanes or their mixtures with alkoxides, metal oxides or metal oxide-hydroxides, by adding preparations of polythiophenes while stirring. In order to obtain homogeneous mixtures the components are preferably diluted with solvents that are at least partially water-miscible, since the polythiophene preparation can in general only be prepared as a dilute aqueous solution and with the latter homogeneous mixtures can as a rule only be obtained in a narrow range in the reactive solution.

It is moreover also possible to add the corresponding monomers, for example 3,4-ethylenedioxythiophene to the reaction solution and to polymerise it, for example in the presence of iron sulfonate.

As solvents with which the reaction solutions may be diluted before adding the polythiophene preparations, there may be mentioned by way of example alcohols such as methanol, ethanol, isopropanol, n-butanol, sec.-butanol, ethylene glycol or glycerol, ketones such as acetone or methyl ethyl ketone, and amides such as N,N-
5 dimethylformamide or N-methylpyrrolidone. Mixtures of two or more solvents may also be used.

Preferably the amount of polythiophene salts in the mixtures according to the invention is 0.1 to 20 wt.%, preferably 1 to 10 wt.%, referred to the sum of the components A), B) and C).

10 The mixtures according to the invention contain solvents as component E). These solvents serve to produce a homogeneous mixture of the individual components. The mixtures according to the invention may contain as solvents water, inorganic acids such as hydrochloric acid, or organic solvents. Organic solvents may for example include alcohols such as methanol, ethanol, isopropanol, n-butanol, sec.-
15 butanol, ethylene glycol or glycerol, ketones such as acetone or methyl ethyl ketone, amides such as N,N-dimethylformamide or N-methylpyrrolidone, or organic acids such as formic acid. Generally the mixtures according to the invention contain a mixture of solvents, since the components necessary for preparing the mixtures according to the invention are mostly used in dissolved form.

20 In a particular embodiment an organosilane of the formula $\text{Si}[(\text{CH}_2)_2\text{Si}(\text{OH})(\text{CH}_3)_2]_4$ is first of all reacted in the presence of tetraethyl orthosilicate (1 mole:4moles) in ethanol with water and formic acid to prepare the mixtures according to the invention; after one hour's reaction time the reaction mixture is diluted with n-butanol and ethylene glycol and an aqueous solution is added to a preparation of
25 poly-3,4-ethylenedioxythiophene / polystyrenesulfonic acid.

Inorganic-organic hybrid materials are obtained by removing the solvent from the mixtures according to the invention. These hybrid materials can be used for example as an antistatic and/or conducting surface coating.

For this purpose the mixtures according to the invention are applied to surfaces; after the evaporation of the solvents and the hardening of the formed organic-inorganic hybrid material, conducting, scratch-resistant coatings are obtained.

5 The coating of surfaces with the mixtures according to the invention may be effected by conventional techniques, for example spraying, application with a doctor blade, dipping, flow coating or spin coating.

The applied-layer of inorganic-organic hybrid material will preferably have a thickness of 20 nm to 100 μm , particularly preferably a thickness of 100 nm to 10 μm . The conductivity of the layers is preferably 0.2 to $10^8 \Omega/\square$, particularly
10 preferably 100 to $10^8 \Omega/\square$.

The coatings are hardened at temperatures of 15°C to 250°C, preferably 50°C to 200°C, particularly preferably 100°C to 200°C.

Surfaces of moulded parts and films of inorganic or organic materials such as plastics may for example be coated with the mixtures according to the invention.
15 Examples of suitable plastics are those based on polyethylene, polypropylene, polyesters such as polyethylene terephthalate and polyethylene naphthalate, polystyrene, polycarbonate, ABS, polyacrylate, polyacrylonitrile, cellulose derivatives such as cellulose acetate, polyamides, polyvinyl chloride, optionally glass fibre-reinforced epoxy resins, as well as copolymers or blends of the
20 aforementioned polymers.

The mixtures according to the invention are particularly suitable for coating inorganic moulded parts of materials such as glass or ceramics, for example materials containing aluminium oxide, silicon carbide or silicon nitride.

25 The mixtures according to the invention are preferably used for the antistatic and/or conducting coating of glass cathode ray tubes.

Examples

A ca. 1.3% poly-3,4-ethylenedioxythiophene/polystyrene sulfonate solution (PEDT/PSS) in water is used as conducting organic polymer.

5 The polyfunctional organosilanes that are used, for example $\text{Si}[(\text{CH}_2)_2\text{Si}(\text{OH})(\text{CH}_3)_2]_4$ or *cyclo*- $[\text{OSiMe}((\text{CH}_2)_2\text{Si}(\text{OEt})_2\text{Me})]_4$, were prepared by hydrosilylation of tetravinyl silane or *cyclo*- $[\text{OSiMe}(\text{C}_2\text{H}_5)]_4$ with HSiClMe_2 or HSiCl_2Me , followed by hydrolysis and alcoholysis. Further details may be found in DE-OS 196 03 242 and German Patent Application 196 03 241 5.

10 The surface resistance was measured according to the details given in DIN IEC 93. For this purpose two 5 mm wide and 5 cm long conducting silver strips were applied at a distance of 5 cm apart to the sample surface. The conducting silver strips were hardened, unless otherwise stated, by heating for 15 minutes at 160°C.

The pencil hardness was measured according to the instructions given in ASTM D 3363.

15 **Example 1**

(a) 20 g of $\text{Si}[(\text{CH}_2)_2\text{Si}(\text{OH})(\text{CH}_3)_2]_4$, 50 ml of ethanol, 40 ml of tetraethyl orthosilicate (TEOS), 10 ml of water and 6 ml of formic acid were combined in this order while stirring and then stirred for a further 90 minutes.

20 (b) 40 ml of ethylene glycol, 40 ml of n-butanol and 40 ml of the PEDT/PSS solution were added while stirring to 40 ml of the solution from (a). Three glass plates were spray coated with this homogeneous mixture, using nitrogen as carrier gas. The coatings were then immediately dried for 15 minutes at 160°C; after drying, the surface resistance was measured.

Sample	Surface resistance [Ω/\square]	Layer thickness
1	15000	< 0.5 μm
2	12000	1.4 μm
3	12000	not measured

All films were transparent.

- (c) The mixture prepared according to (b) was stored for 2 days in a refrigerator (ca. 4°C), following which no change was observed. The homogeneous mixture was then applied by means of a doctor blade (wet film thickness 120 μm) to a glass plate and the surface resistance was measured.

Sample	Surface resistance [Ω/\square]	Surface thickness
4	2200	4.8 μm

The coating was crack-free, transparent and homogeneous.

Example 2

- (a) 10 g of $\text{Si}[(\text{CH}_2)_2\text{Si}(\text{OH})(\text{CH}_3)_2]_4$, 25 ml of ethanol, 20 ml of TEOS (tetraethyl orthosilicate), 5 ml of water and 3 ml of formic acid were combined in this order while stirring. After ca. 10 minutes the reaction mixture was filtered through normal filter paper and stirred for a further 80 minutes.
- (b) 40 ml of ethylene glycol, 40 ml of n-butanol and 60 ml of the aqueous PEDT/PSS solution (previously filtered through cotton wool) were added

while stirring vigorously to 40 ml of the lacquer solution from (a) and the whole was stirred for 10 minutes. The homogeneous mixture thus obtained was sprayed on glass plates using nitrogen as carrier gas, and the coating was hardened for 15 minutes at 160°C.

5

Sample	Surface resistance [Ω/\square]	Layer thickness	Transmission (400-700 nm)	Pencil hardness
1	4200	1.7 μm	>83%	> 7H
2	5500	1.1 μm	>90%	> 7H

Both films were transparent.

Example 3

- (a) 25 g of a 36.5% solution of cyclo-[OSiMe((CH₂)₂Si(OH)Me₂)]₄, 12.5 ml of TEOS, 3.2 ml of water and 2 ml of formic acid were combined in this order while stirring, and the mixture was then stirred for a further 75 minutes. A clear, colourless solution was obtained.
- (b) The lacquer solution obtained according to (a) was diluted according to the Table by stirring with solvents, and finally mixed with the aqueous PEDT/PSS solution. Films of the homogeneous mixtures thus obtained were applied with a doctor knife in a wet film thickness of 120 μm to glass plates; these were dried for 10 minutes at room temperature and then for 15 minutes at 160°C.

Sample	1	2	3	4
Laquer solution of (a) [ml]	1	1	1	1
Ethylene glycol [ml]	0.5	0.5	-	1
1-butanol [ml]	0.5	1	-	-
NMP [ml]	0.5	-	1	-
2-butanol [ml]	0.5	-	1	-
1-propanol [ml]	0.5	-	-	1
PEDT/PSS [ml]	1	0.5	1	1
Pencil hardness	> 7 H	> 6 H	> 7H	> 7H
Surface resistance [$k\Omega/\square$]	40	188	80	39

The conducting silver strips were hardened for 1 hour at 160°C. All films were crack-free, transparent and homogeneous.

Example 4

- 5 (a) 10 g of $\text{Si}[(\text{CH}_2)_2\text{Si}(\text{OH})(\text{CH}_3)_2]_4$, 25 ml of ethanol, 20 ml of tetraethyl orthosilicate (TEOS), 5 ml of water and 3 ml of formic acid were combined in this order while stirring, and then stirred for a further 90 minutes.
- (b) 40 ml of ethylene glycol, 40 ml of n-butanol and 40 ml of the PEDT/PSS solution were added while stirring to 20 ml of the solution from (a).
- 10 (c) 60 ml of ethylene glycol, 60 ml of n-butanol and 60 ml of the PEDT/PSS solution were added while stirring to 20 ml of the solution from (a).

The homogeneous mixtures from (b) and (c) were stored for 17 hours in a refrigerator. 3 glass plates were then spray coated, using nitrogen as carrier gas, and immediately afterwards dried for 15 minutes at 160°C. After cooling, the surface resistance was measured. Samples 1 to 3 were prepared using solution (b), samples 4 to 6 using solution (c).

Sample	Surface resistance [Ω/\square]	Layer thickness
1	3400	0.8 μm
2	2400	0.9 μm
3	1700	not measured
4	1500	not measured
5	2500	< 0.5 μm
6	2500	< 0.5 μm

All films were transparent.

Example 5

- (a) 40 ml of ethylene glycol, 40 ml of 1-butanol and 80 ml of the PEDT/PSS dispersion were added while stirring to 40 ml of the lacquer solution prepared according to Example 1 (a).
- (b) ca. 5 mg of mica (Mica W1, manufacturer Norwegian Talc) were added while stirring to 2 ml of the mixture prepared according to (a). After 10 minutes' stirring a film (wet film thickness 120 μm) was applied to a glass plate using a doctor knife and hardened for 15 minutes at 160°C. The surface resistance of the sample was 690 Ω/\square .

Example 6

20 g of cyclo-[OSiMe((CH₂)₂Si(OM)Me₂)]₄, 40 ml of isopropanol, 25.7 g of TEOS
and 4.45 g of 0.1 N hydrochloric acid were combined while stirring and then stirred
for a further hour. The mixture was then diluted with 60 ml of ethylene glycol and
5 22 ml of NMP. 1 ml of the PEDT/PSS dispersion and a further 0.25 ml of ethylene
glycol were then added to 1.3 ml of this solution. After applying the solution to a
glass plate using a doctor blade (wet film thickness 120 µm), the film was hardened
for 1 hour at 140°C after having evaporated the volatile constituents. After
application of the conducting silver and stoving at 160°C (15 minutes) the surface
10 conductivity was measured and was found to be 225 Ω/□. The pencil hardness was 6
H.

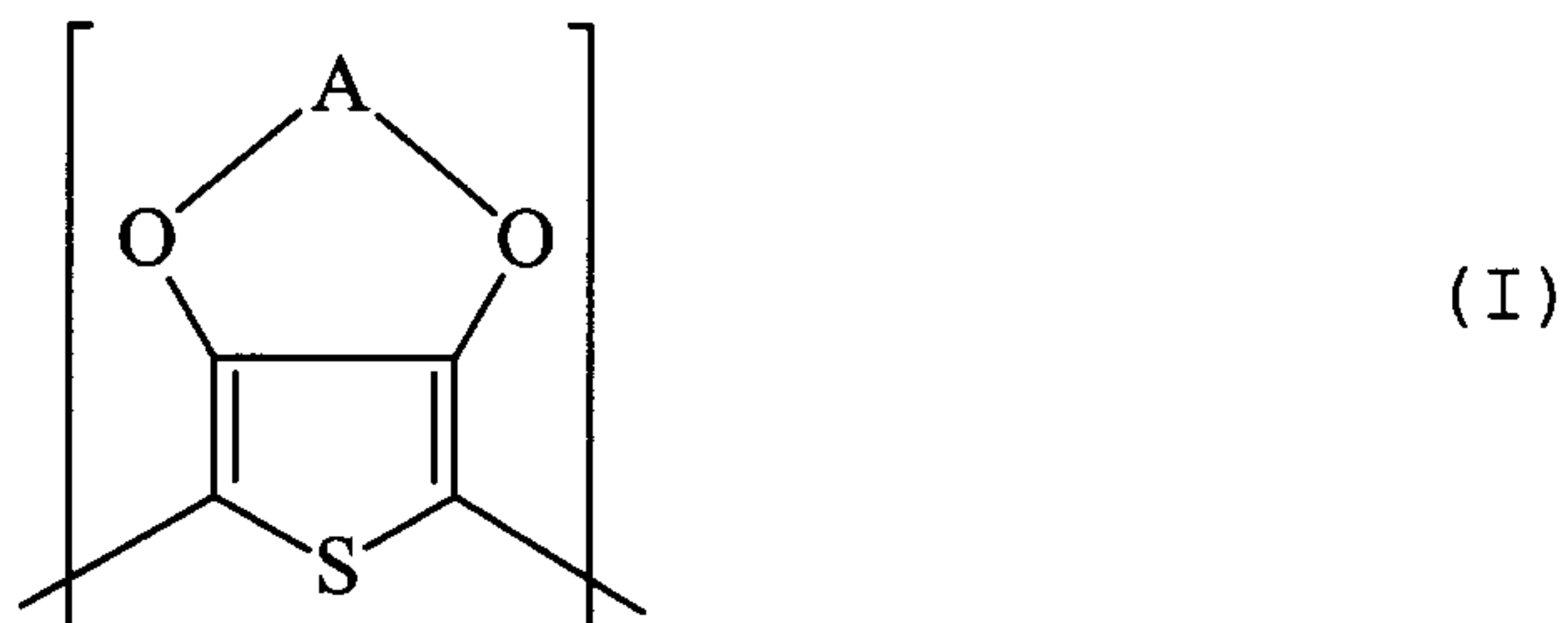
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CLAIMS:

1. A mixture, comprising:

A) a polythiophene preparation comprising polythiophene^{m+}, An^{m-}, wherein polythiophene cation polythiophene^{m+} contains
5 positively charged or uncharged units of general formula (I):

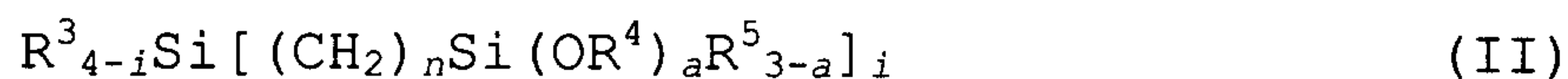


wherein:

10 A represents a C₁-C₄-alkylene radical or a C₁-C₄-alkylene radical substituted with C₁-C₂₀-alkyl, -CH₂OH or C₆-C₁₄-aryl groups; and

An^{m-} represents a polyanion;

B) a reaction product of a polyorganosilane corresponding
15 to the following general formulas:



wherein:

i is 2 to 4,

n is 1 to 10,

20 R³ represents alkyl or aryl,

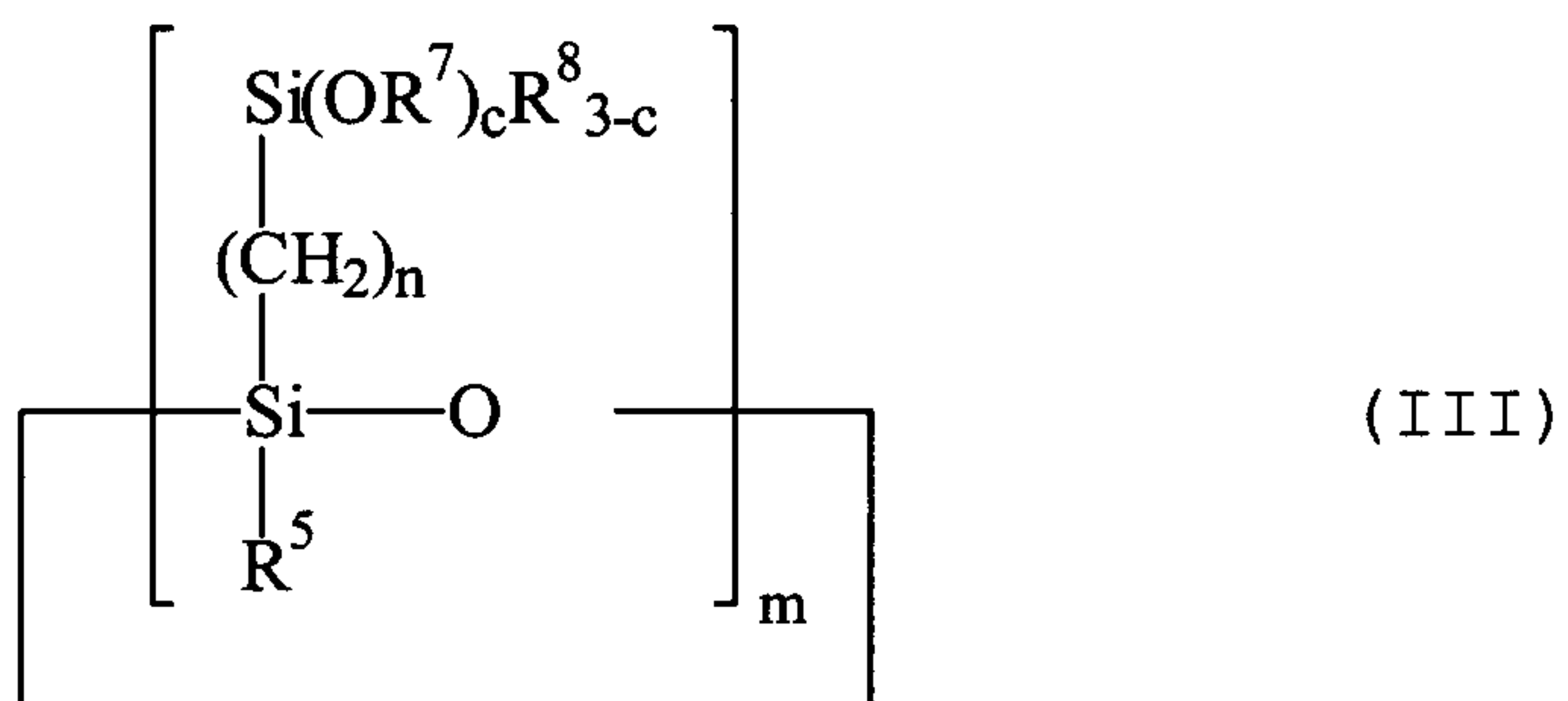
R⁵ represents alkyl or aryl,

a is 1 to 3, and

R⁴ represents alkyl or aryl, provided that when a is 1, R⁴ may also be hydrogen;

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5 wherein:

m is 3 to 6,

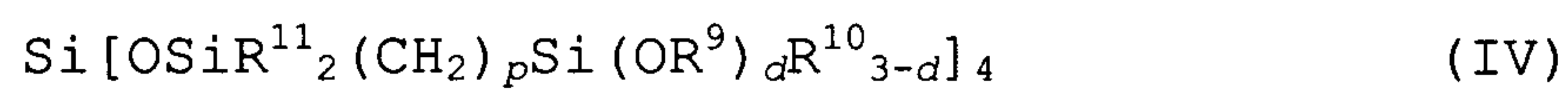
n is 2 to 10,

R⁶ represents C₁-C₆ alkyl or C₆-C₁₄ aryl,

R⁸ represents alkyl or aryl,

10 c is up to 3, and

R⁷ represents alkyl or aryl, provided that when c is 1, R⁷ may also be hydrogen; and



wherein:

15 p is 1 to 10,

R¹¹ represents alkyl or aryl,

R¹⁰ represents alkyl or aryl,

d represents 1 to 3, and

20 R⁹ represents alkyl or aryl, provided that when d is 1, R⁹ may also be hydrogen;

C) optionally a reaction product of an alkoxide of the elements B, Al, Si, Sn, Ti or Zr;

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D) optionally a metal oxide or metal oxide-hydroxide of the elements B, Al, IN, Si, Sn, Ti or Zr; and

E) a solvent.

2. An inorganic-organic hybrid material obtained from
5 the mixture of claim 1 by removing the solvent.

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