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(54) Title: SURFACE MODIFIED ELECTRICAL INSULATION SYSTEM

(57) Abstract: Surface modified electrical insulation system having a super hydrophobic surface, the insulation system comprising a hardened or cured synthetic polymer composition which contains at least one filler material and optionally further additives, characterized in that the at least one filler material is selected from the group of filler materials comprising inorganic oxides, inorganic hydroxides and inorganic oxyhydroxides, and the surface of the electrical insulation system is present in the form of a structured surface with its micro-scale and nano-scale features, whereby said surface is covered with a liquid hydrophobic compound; and method of producing said electrical insulation system.



Surface modified electrical insulation systemField of the Invention

The present invention refers to a surface modified electrical insulation system comprising a selected filler material containing synthetic polymer composition, the surface of said electrical insulation system being super hydrophobic. The present invention also refers to a method of producing the surface modified electrical insulation system having a super hydrophobic surface.

State of the Art

For outdoor electrical insulations it is generally required that such electrical insulations have a hydrophobic surface which allows dirt and pollution deposited on the surface to be removed by rain, resulting in a self-cleaning effect. Such self-cleaning surfaces are made for example from silicone rubber or hydrophobic cycloaliphatic epoxy resin compositions. These materials are classed as hydrophobic meaning that they have a surface contact angle with water within the range of about 90°-140°. The efficiency of this self-cleaning effect can be increased by increasing the surface contact angle with water further to be higher than 140°. A surface having a surface contact angle with water higher than 140° is commonly referred to as a super hydrophobic surface. It is known to achieve these high surface contact angles by applying a so called Lotus Effect coating to the insulation material. In order to obtain a super hydrophobic surface the outermost surface layer has to be hydrophobic and the layer preferably has to be structured in a micro- or nano-range thickness.

WO 2006/044642 discloses a method of applying Lotus Effect materials as a super hydrophobic protective coating for external electrical insulation system applications. The Lotus effect material deposited forms a secondary coating as an additional

layer on the substrate material whereby the substrate material has no influence on the surface properties provided by the secondary coating material. An important disadvantage of applying a secondary coating is that the durability of the coated material is often dependent on the level of adhesion of the coating to the substrate. A further disadvantage is that the properties of the coating, for example the dielectric behavior and the UV-stability, will inevitably differ from those of the substrate. To overcome this problem, WO 2006/044642 proposes to add UV stabilizers and flame retardants to the Lotus Effect material.

Summary of the Invention

It has now been found that it is possible to produce a surface of an electrical insulator which exhibits the Lotus Effect and at the same time has substantially the same properties, for example the dielectric behavior and UV-stability, as the bulk material of the electrical insulator. Further the interface problem caused by a separate coating is eliminated. According to the present invention, this is achieved by treating the surface of the insulator so that a "structured surface" of the insulator is obtained. A structured surface means that the surface is in a native state, i.e. the surface of the insulator is present with its micro-scale and nano-scale features. These features are required for producing therefrom the Lotus Effect according to the present invention. A structured surface of an insulator material is obtained for example by sand-blasting the surface of the substrate material. The structured surface of the insulator material is treated with a liquid hydrophobic compound. Such liquid hydrophobic compound may be for example a liquid polysiloxane, whereby a thin layer of the hydrophobic compound is formed on the surface, said surface thereby becoming super hydrophobic. The liquid hydrophobic compound further may be an amphiphilic compound whereby the structured surface of the insulator material is treated with the amphiphilic compound for a time long enough until a self-assembled monolayer (SAM) surface

is formed. Also a combined treatment of the structured surface is possible, i.e. that the structured surface is treated with an amphiphilic compound and subsequently with a liquid hydrophobic compound, for example a liquid polysiloxane.

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The treatment with a liquid hydrophobic compound, such as a liquid polysiloxane, can be achieved either by treating the structured surface directly with the hydrophobic compound or by incorporating the hydrophobic additive into the substrate, or by combining both methods. The liquid hydrophobic material can diffuse from the inside of the insulator composition to the surface of the insulator and form a thin layer of the liquid hydrophobic material on the structured surface rendering said surface super hydrophobic.

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An essential feature of the present invention further is that the insulation material contains an inorganic filler such as silica or alumina which is at least partly exposed to the surface and is put in its native form by the sand-blasting process.

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Self-assembled monolayers (SAM) are formed from so called amphiphilic molecules, that is of molecules which are preferring a different chemical surrounding on either end of the molecule. Typical examples are compounds, resp. molecules, which on one end are water repellent, i.e. are hydrophobic by having a water repellent end group, and on its other end are hydrophilic by having an affinity to water at this other end. By applying self-assembled monolayers (SAM) to a surface, the surface properties such as the surface energy can be altered and a hydrophilic surface can thereby be transformed into a hydrophobic surface.

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Description of the Invention

The present invention is defined in the claims. The present invention refers to a surface modified electrical insulation system having a super hydrophobic surface, the insulation system

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comprising a hardened or cured synthetic polymer composition which contains at least one filler material and optionally further additives, characterized in that:

- 5 (i) said synthetic polymer is selected from electrically insulating thermoplastic and duroplastic polymers;
- (ii) the at least one filler material is selected from the group of filler materials comprising inorganic oxides, inorganic hydroxides and inorganic oxyhydroxides,
- 10 (iii) the at least one filler material is present in the insulation system in an amount within the range of about 60% to 80% by weight calculated to the total weight of the insulation system; and
- (iv) the surface of the electrical insulation system is present in the form of a structured surface with its micro-scale and nano-scale features, whereby said structured surface
15 has been covered with a liquid hydrophobic compound.

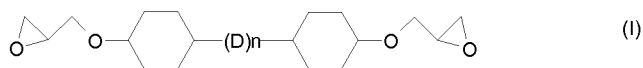
Said liquid hydrophobic compound with which the structured surface of the electrical insulation system has been covered or
20 treated, resp. which is covering the structured surface of the electrical insulation system, is preferably selected from liquid organopolysiloxanes, and preferably selected from cyclic organopolysiloxanes and/or low molecular weight oligomeric organopolysiloxanes. Further, said structured surface covered with a
25 liquid hydrophobic compound may be covered with a self-assembled monolayer (SAM) composed from at least one amphiphilic compound, wherein said self-assembled monolayer (SAM) optionally may be additionally covered with a liquid hydrophobic compound.

30 The present invention further refers to a method of producing said surface modified electrical insulation system having a super hydrophobic surface. The present invention further refers to the use of said surface modified electrical insulation system as an insulation system in electrical articles. The present invention

further refers to the electrical articles comprising said surface modified electrical insulation system.

The surface modified electrical insulation system according to the present invention comprises a hardened or cured synthetic polymer composition. Said polymer may be selected from polymers known in the art of being used in electrical insulator compositions, such as polyesters, for example poly(methyl-methacrylate), or poly(alkylacrylonitrile), or duroplastic polymers such as polyurethanes or epoxy resin compositions. Preferred are epoxy resin compositions, preferably cycloaliphatic epoxy resin compounds. Said epoxy resin compositions generally contain the epoxy resin, a hardener, a curing agent to accelerate the curing process, as well as further additives. These compounds are known per se.

Cycloaromatic and cycloaliphatic epoxy resin compounds may be used within the scope of the present invention. Preferred are cycloaliphatic epoxy resin compounds. Such epoxy resin compounds contain at least two 1,2-epoxy groups per molecule. Epoxy resin compounds useful for the present invention comprise unsubstituted glycidyl groups and/or glycidyl groups substituted with methyl groups. These glycidyl compounds have an epoxy value (equiv./kg) preferably of at least three, preferably at least four and especially at about five or higher, preferably about 5.0 to 6.1. Preferred are for example optionally substituted epoxy resins of formula (I):



D = -O-, -SO₂-, -CO-, -CH₂-, -C(CH₃)₂-, -C(CF₃)₂-
n = zero or 1

Compounds of formula (I) wherein D is -(CH₂)- or [-C(CH₃)₂-] are preferred. Further cycloaliphatic epoxy resins to be used within

the scope of the present invention further are for example hexahydro-o-phthalic acid-bis-glycidyl ester, hexahydro-m-phthalic acid-bis-glycidyl ester or hexahydro-p-phthalic acid-bis-glycidyl ester. Preferred cycloaliphatic epoxy resin compounds are liquid
5 at room temperature or when heated to a temperature of up to about 65°C. Preferred cycloaliphatic epoxy resin compounds are for example Araldite® CY 184 (Huntsman Advanced Materials Ltd.), a cycloaliphatic epoxy resin compound (diglycidylester) having an epoxy content of 5.80-6.10 (equiv/kg) or Araldite® CY 5622
10 (Huntsman Advanced Materials Ltd.), a modified epoxy resin compound (diglycidylester) having an epoxy content of 5.80-6.10 (equiv/kg). Araldite® CY 5622 is a hydrophobic cycloaliphatic epoxy formulation for hydrophobicity transfer and recovery in outdoor epoxy resin compositions. A hydrophobic cycloaliphatic
15 epoxy formulation means that the filler material has been pre-treated with a silane or a silane additive has been added to the composition.

The epoxy resin composition to be cured comprises generally the
20 epoxy resin, the hardener and the curing agent. Hardeners are for example hydroxyl and/or carboxyl containing polymers such as carboxyl terminated polyester and/or carboxyl containing acrylate- and/or methacrylate polymers and/or carboxylic acid anhydrides. Useful hardeners are further aliphatic, cycloaliphatic
25 polycarbonic acids. Preferred anhydrides are liquid cycloaliphatic anhydrides with a viscosity at 25°C of about 70-80 mPa s. Such a liquid cycloaliphatic anhydride hardener is for example Aradur® HY 1235 (Huntsman Advanced Materials Ltd.). The optional hardener can be used in concentrations within the range of 0.2 to
30 1.2, equivalents of hardening groups present, e.g. one anhydride group per 1 epoxide equivalent.

The inorganic filler has an average grain size as known for the use in electrical insulation systems and is generally within the
35 range of 1 µm (micron) up to 3 mm. Preferred is an average grain

size within the range of about 5 μm to 300 μm , preferably from 10 μm to 100 μm , or a selected mixture of such average grain sizes. Preferred is a filler material with a high surface area.

5 The filler material is selected from filler materials which have a structured surface after sand-blasting. It has been found that such a structured surface has surprisingly strong binding forces towards the liquid hydrophobic compound. The structured surface is also able to chemically react with the hydrophilic end of an
10 amphiphilic molecule so that a self-assembled monolayers (SAM) is formed. For achieving this effect, the mineral filler is preferably selected from the group of filler materials comprising inorganic oxides, inorganic hydroxides and inorganic oxyhydroxides, preferably silica, quartz, known silicates, aluminium oxide,
15 aluminium trihydrate [ATH] and titanium oxide. Preferred are silica, quartz, aluminium oxide and aluminium trihydrate [ATH], preferably silica, aluminium oxide and aluminium trihydrate [ATH] and preferably silica. Said filler materials, each time have a minimum SiO_2 -content, resp. a minimum Al_2O_3 -content, of about 95-
20 98% by weight, preferably of about 96-98% by weight.

The inorganic filler is present in the synthetic polymer composition within the range of about 60% by weight to about 80% by weight, preferably within the range of about 60% by weight to
25 about 70% by weight, and preferably at about 65% by weight, calculated to the total weight of the synthetic polymer composition.

The surface of the electrical insulation system is present as a structured surface in its native state with its micro-scale and
30 nano-scale features. Such a structured surface can be made by sand-blasting the surface of the insulation until substantially all the micro and nano-scale features are formed.

According to an embodiment of the present invention the surface
35 of the electrical insulation system being present in the form of

a structured surface is covered with a liquid hydrophobic compound. Such liquid hydrophobic compound is preferably selected from liquid organopolysiloxanes, preferably from cyclic organopolysiloxane and/or low molecular oligomeric organopolysiloxane.

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The liquid hydrophobic compound as a cyclic organopolysiloxane is composed of units of the chemical formula $-\text{Si}(\text{R})(\text{R})\text{O}-$, which form a ring composed with preferably 4 to 12 such units.

Generally such cyclic organopolysiloxane is a mixture of such cyclic compounds as is known to the expert in the art. Preferred are cyclic organopolysiloxanes with 4 to 8 such organosiloxy units. The substituent R in formula $-\text{Si}(\text{R})(\text{R})\text{O}-$ preferably means independent of each other linear, branched or cyclic alkyl or phenyl, the alkyl residue having preferably with 1 to 8 carbon atoms, optionally being substituted by chlorine and/or fluorine; preferably phenyl, $(\text{C}_1\text{-C}_4)$ -alkyl which optionally is substituted by fluorine; preferably phenyl, 3,3,3-trifluoropropyl, monofluoromethyl, difluoromethyl, trifluoromethyl, or unsubstituted $(\text{C}_1\text{-C}_4)$ -alkyl; preferably methyl.

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The liquid hydrophobic compound as a low molecular oligomeric organopolysiloxane is composed of units of the chemical formula $-\text{Si}(\text{R})(\text{R})\text{O}-$, which are end-stopped by terminal endgroups of the formula $-\text{OSi}(\text{R})_3-$, wherein R has the meaning as given for the substituent R in cyclic polysiloxane compounds herein above. Low molecular liquid oligomeric organopolysiloxanes generally represent a mixture of such compounds and may contain up to 50 units of $-\text{Si}(\text{R})(\text{R})\text{O}-$, preferably about 8 to 20 such units. This is known to the expert in the art.

30

The liquid hydrophobic compound may be added to the structured surface as such without a solvent or be dissolved in a suitable solvent such as any organic solvent, preferably an aliphatic hydrocarbon with low boiling point, and be applied to the structured surface of the electrical insulation system whereby

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the solvent subsequently is evaporated. The liquid hydrophobic compound is applied in a quantity so that a layer with a thickness within the nano range or micro range is formed.

5 The liquid hydrophobic compound preferably is incorporated into the bulk of the electrical insulator system. The liquid hydrophobic compound is then able to diffuse from the bulk to the structured surface of the insulator yielding a super hydrophobic surface as well as hydrophobicity recovery. In this case, a separate
10 addition of the hydrophobic compound to the surface is recommended, however, not absolutely necessary. The amount of the liquid polysiloxane compound, when incorporated into the bulk of the insulator system is within the range of preferably 0.1% to 5% by weight, preferably 0.5% to 5% and especially about 1% by
15 weight, calculated to the total weight of the insulator composition.

A preferred embodiment of the invention is that the liquid hydrophobic compound is incorporated into the bulk of the electrical
20 insulator system. The surface of the insulator is then sand-blasted to yield a structured surface. To said structured surface of the electrical insulation system is then applied a liquid hydrophobic compound so that said surface becomes covered with a thin layer of said liquid hydrophobic compound.

25 A further embodiment of the invention is that the liquid hydrophobic compound is incorporated into the bulk of the electrical insulator system. The surface of the insulator is then sand-blasted to yield a structured surface. Said structured surface of
30 the electrical insulation system is then covered with a self-assembled monolayer (SAM) composed from at least one amphiphilic compound as described herein above. Optionally a liquid hydrophobic compound is subsequently applied to the surface of the electrical insulation system which has been pretreated with a
35 self-assembled monolayer.

The structured surface of the electrical insulation system, therefore, may either be covered with a liquid hydrophobic compound; or be covered with a self-assembled monolayer (SAM) composed from at least one amphiphilic compound; or be covered with a self-assembled monolayer together with a liquid hydrophobic compound. The self-assembled monolayers have a thickness within the nano-range or micro range, which is known per se; said thin coat being electrically non-conductive.

Self-assembled monolayers (SAM) are either grown from solution or from the gas-phase. The reactive group of the amphiphilic compound chemically reacts with the structured surface of the insulator material thereby forming the self-assembled monolayer. According to the present invention silane-based self-assembled monolayers as obtained from alkyltrichlorosilanes are preferred. Preferred are self-assembled monolayers as obtained from (C₄-C₂₂)-alkyltrichlorosilanes, preferably from (C₁₂-C₂₂)-alkyltrichlorosilanes, for example from octadecyltrichlorosilane (OTS). These silanes chemically bind to hydroxylated surfaces such as hydroxylated silica (SiO₂) or epoxy resin compositions having free reactive groups such as hydroxyl groups by splitting off the chlorine atoms and forming Si-O-Si bonds, which finally results in a self-assembled monolayer being super hydrophobic.

If the self-assembled monolayer is formed from solution various carrier solvents can be used. Preferred carrier solvents for the mentioned trichlorosilanes are generally anhydrous organic solvents, such as benzene, toluene, bicyclohexyl, 2,2,4-trimethylpentane or related solvents.

If the self-assembled monolayer is formed from the gaseous phase, i.e. by chemical vapor deposition, the surface to be treated is for example put into a vacuum chamber at room temperature

together with a vessel containing the silane compound, e.g. the octadecyltrichlorosilane (OTS). The pressure is then decreased below the vapor pressure of OTS, for example to 6.7 mbar (at room temperature). After a period of about 24 hours full surface coverage, i.e. the self-assembled monolayer, is obtained.

As optional additives the composition may further comprise a curing agent (accelerant) for enhancing the polymerization of the epoxy resin with the hardener. Further additives may be selected from wetting/dispersing agents, flexibilizers, plasticizers, antioxidants, light absorbers, pigments, flame retardants, fibers and other additives generally used in electrical applications. These are known to the expert and are not critical for the present invention.

The present invention also refers to a method of producing a surface modified electrical insulation system having a super hydrophobic surface, the insulation system comprising a hardened or cured synthetic polymer composition which contains at least one filler material and optionally further additives, comprising the following steps: (i) providing a hardened or cured synthetic polymer composition including at least one filler and optionally further additives, as defined herein above; (ii) treating the surface of the electrical insulation system so that a structured surface with its micro-scale and nano-scale features is formed, preferably by sand-blasting the surface; and (iii) covering said structured surface with a liquid hydrophobic compound; or with a self-assembled monolayer (SAM) composed from at least one amphiphilic compound; or covering said surface with a self-assembled monolayer (SAM) composed from at least one amphiphilic compound and a liquid hydrophobic compound.

Preferred uses of the surface modified electrical insulation system as defined in the present invention are in power transmission and distribution applications, such as electrical insula-

tions, especially in the field of impregnating electrical coils and in the production of electrical components such as transformers, embedded poles, bushings, high-voltage insulators for indoor and outdoor use, especially for outdoor insulators associated with high-voltage lines, as long-rod, composite and cap-type insulators, sensors, converters and cable end seals as well as for base insulators in the medium-voltage sector, in the production of insulators associated with outdoor power switches, measuring transducers, lead-throughs, and over-voltage protectors, in switchgear construction. The following examples illustrate the invention.

Example 1

(A) Substrate manufacture

The cycloaliphatic epoxy (CEP) formulation used as the insulator material in this example is given in Table 1. All components, except the catalyst, were pre-heated to 45°C. These were then intensively mixed together at ambient pressure with a propeller mixer. The complete mixture was then degassed in a vacuum oven, with mixing, at about 5 mbar, for 20 minutes at 60°C. The mixture was then molded into 6 mm thick plates using steel moulds pre-heated to 90°C and coated with Huntsman QZ13 mould-release agent. A curing cycle of 2 hours at 90°C, followed by 24 hours at 140°C, was applied to ensure complete curing. The surface contact angle of this silica-filled cycloaliphatic epoxy material between the structured surface and water was measured after sand-blasting and cleaning from any dust and was found to be below 90°.

Table 1

Components	phr
Huntsman CY 184 (resin)	100
Huntsman HY1235 (hardener)	90
Huntsman DY062 (catalyst)	0.54
Huntsman DW9134 (pigment, TiO ₂)	2.7
Quarzwерke W 12EST (filler)	359

Araldite® CY 184: Cycloaliphatic epoxy resin (Huntsman)

Aradur®HY1235: modified cycloaliphatic anhydride (Huntsman)

Accelerator DY062: liquid tertiary amine

W12 EST: SiO₂ (Quarzwerte GmbH)

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(B) Sand-blasting and treatment with octadecyltrichlorosilane

The cured cycloaliphatic epoxy resin insulation material prepared in this Example 1, Chapter (A), was sand-blasted and cleaned from any remaining dust. The obtained structured surface was then
10 treated by immersing it in a solution of octadecyltrichlorosilane (OTS) in bicyclohexyl with a concentration of 4 mMol per liter of bicyclohexyl, at ambient temperature and pressure, under an argon atmosphere, for 24 hours, so that a self-assembled mono-layer which was chemically bonded to the exposed surface was formed.
15 The resulting surface had a surface contact angle to distilled water of greater than 140°.

Example 2

Cured hydrophobic cycloaliphatic epoxy resin insulation material
20 was prepared in an analogous manner as described in Example 1. The surface was then sand-blasted and cleaned from any dust. The hydrophobic additive, i.e. a cyclic dimethylsiloxane with an average of 6 to 8 dimethylsiloxy-units, was then added to the surface. The insulation material was then heated to 80°C to
25 improve migration of the hydrophobic additive over the surface of the material and then cooled back to room temperature. The hydrophobic additive within the epoxy also dispersed over the structured surface. The resulting surface had a surface contact angle to distilled water of greater than 140°. The composition of
30 the hydrophobic cycloaliphatic epoxy resin insulation material is given in Table 2.

Table 2

Components	phr
Huntsman CY 5622 (resin)	100
Huntsman HY1235 (hardener)	82
Huntsman DY062 (catalyst)	0.54
Huntsman DW9134 (pigment, TiO ₂)	2.7
Quarzwerte W 12EST (filler)	344

Araldite® CY 5622: Hydrophobic cycloaliphatic epoxy resin
5 (Huntsman) containing a liquid polydimethylsiloxane.

Claims

1. Surface modified electrical insulation system having a super hydrophobic surface, the insulation system comprising a hardened or cured synthetic polymer composition which contains at least one filler material and optionally further additives, characterized in that:

- (i) said synthetic polymer is selected from electrically insulating thermoplastic and duroplastic polymers;
- (ii) the at least one filler material is selected from the group of filler materials comprising inorganic oxides, inorganic hydroxides and inorganic oxyhydroxides,
- (iii) the at least one filler material is present in the insulation system in an amount within the range of about 60% to 80% by weight calculated to the total weight of the insulation system; and
- (iv) the surface of the electrical insulation system is present in the form of a structured surface with its micro-scale and nano-scale features, whereby said structured surface is covered with a liquid hydrophobic compound.

2. Electrical insulation system according to claim 1, characterized in that said liquid hydrophobic compound covering the structured surface of the electrical insulation system is selected from liquid organopolysiloxanes, preferably from cyclic organopolysiloxanes and/or low molecular weight oligomeric organopolysiloxanes.

3. Electrical insulation system according to claim 1, characterized in that said liquid hydrophobic compound covering the structured surface of the electrical insulation system is a self-assembled monolayer (SAM) composed from at least one amphiphilic compound.

4. Electrical insulation system according to claim 1, characterized in that said liquid hydrophobic compound covering the structured surface of the electrical insulation system is a self-assembled monolayer (SAM) composed from at least one amphiphilic

compound, wherein said self-assembled monolayer (SAM) is additionally covered with a liquid hydrophobic compound, which is selected from liquid organopolysiloxanes, preferably from cyclic organopolysiloxanes and/or low molecular weight oligomeric organopolysiloxanes.

5. Electrical insulation system according to any one of the claims 1-4, characterized in that the synthetic polymer is selected from polymers being used in electrical insulator compositions, preferably being selected from polyesters, preferably poly(methyl-methacrylate), or poly(alkylacrylonitrile), or from duroplastic polymers, preferably from polyurethanes or epoxy resin compositions.

6. Electrical insulation system according to claim 5, characterized in that the synthetic polymer is selected from epoxy resin compositions, preferably from cycloaliphatic epoxy resin compositions.

7. Electrical insulation system according to any one of the claims 1-6, characterized in that the inorganic filler is selected from filler materials which have a structured surface after sand-blasting, preferably selected from the group of filler materials comprising inorganic oxides, inorganic hydroxides and inorganic oxyhydroxides, preferably silica, quartz, known silicates, aluminium oxide, aluminium trihydrate and titanium oxide, preferably silica, quartz, aluminium oxide and aluminium trihydrate, preferably silica, aluminium oxide and aluminium trihydrate and preferably silica.

8. Electrical insulation system according to claim 7, characterized in that the inorganic filler material, each time has a minimum SiO_2 -content, resp. a minimum Al_2O_3 -content, of about 95-98% by weight, preferably of about 96-98% by weight.

9. Electrical insulation system according to any one of the claims 1-8, characterized in that the inorganic filler is present in the synthetic polymer composition within the range of about

60% by weight to about 80% by weight, preferably within the range of about 60% by weight to about 70% by weight, and preferably at about 65% by weight, calculated to the total weight of the synthetic polymer composition.

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10. Electrical insulation system according to any one of the claims 1-9, characterized in that the inorganic filler has an average grain size within the range of 1 μm up to 3 mm, preferably within the range of about 5 μm to 300 μm , preferably from 10 μm to 100 μm , or a selected mixture of such average grain sizes.

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11. Electrical insulation system according to any one of the claims 1-10, characterized in that said structured surface has been made by sand-blasting the surface of the insulation until substantially all the micro and nano-scale features have been formed.

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12. Electrical insulation system according to any one of the claims 1-11, characterized in that the liquid hydrophobic compound is a cyclic organopolysiloxane which is composed of units of the chemical formula $-\text{Si}(\text{R})(\text{R})\text{O}-$, which form a ring, preferably of 4 to 12 such units, preferably of 4 to 8 such units, wherein the substituent R independent of each other means a linear, branched or cyclic alkyl or phenyl, the alkyl residue having preferably 1 to 8 carbon atoms, optionally being substituted by chlorine and/or fluorine; preferably phenyl, (C_1-C_4) -alkyl which optionally is substituted with fluorine; preferably phenyl, 3,3,3-trifluoropropyl, monofluoromethyl, difluoromethyl, trifluoromethyl, or unsubstituted (C_1-C_4) -alkyl; preferably methyl.

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13. Electrical insulation system according to any one of the claims 1-11, characterized in that the liquid hydrophobic compound is a low molecular oligomeric organopolysiloxane which is composed of units of the chemical formula $-\text{Si}(\text{R})(\text{R})\text{O}-$, which

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are end-stopped by terminal endgroups of the formula $-\text{OSi}(\text{R})_3-$, wherein R has the meaning as given in claim 12.

14. Electrical insulation system according to any one of the claims 1-13, characterized in that the liquid hydrophobic compound is incorporated into the bulk of the electrical insulator system, preferably in a amount within the range of 0.1% to 5% by weight, preferably 0.5% to 5% and especially about 1% by weight, calculated to the total weight of the insulator composition.

15. Electrical insulation system according to any one of the claims 1-14, characterized in that the liquid hydrophobic compound is incorporated into the bulk of the electrical insulator system and the structured surface of the insulator has been treated with a liquid hydrophobic compound.

16. Electrical insulation system according to any one of the claims 1-14, characterized in that the liquid hydrophobic compound is incorporated into the bulk of the electrical insulator system and the structured surface of the insulator is covered with a self-assembled monolayer composed from at least one amphiphilic compound.

17. Electrical insulation system according to any one of the claims 1-16, characterized in that the self-assembled monolayer is grown from solution or from gas-phase.

18. Electrical insulation system according to claim 17, characterized in that the self-assembled monolayer is a silane-based self-assembled monolayers as obtained from alkyltrichlorosilanes, preferably obtained from $(\text{C}_4\text{-C}_{22})$ -alkyltrichlorosilanes, preferably from $(\text{C}_{12}\text{-C}_{22})$ -alkyltrichlorosilanes, and preferably from octadecyltrichlorosilane.

19. Method of producing a surface modified electrical insulation system according to any one of the claims 1-18, comprising the following steps: (i) providing a hardened or cured synthetic polymer composition including at least one filler and optionally

further additives, as defined in claim 1; (ii) treating the surface of the electrical insulation system so that a structured surface with its micro-scale and nano-scale features is formed; and (iii) covering said structured surface with a liquid hydrophobic compound; or with a self-assembled monolayer (SAM) composed from at least one amphiphilic compound; or with a self-assembled monolayer (SAM) composed from at least one amphiphilic compound combined with a liquid hydrophobic compound.

20. The use of the surface modified electrical insulation system as defined in any one of the claims 1-18 in power transmission and distribution applications, such as electrical insulations, especially in the field of impregnating electrical coils and in the production of electrical components such as transformers, embedded poles, bushings, high-voltage insulators for indoor and outdoor use, especially for outdoor insulators associated with high-voltage lines, as long-rod, composite and cap-type insulators, sensors, converters and cable end seals as well as for base insulators in the medium-voltage sector, in the production of insulators associated with outdoor power switches, measuring transducers, lead-throughs, and over-voltage protectors, in switchgear construction.

21. Electrical articles comprising a surface modified electrical insulation system as defined in any one of the claims 1-18.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/051656

A. CLASSIFICATION OF SUBJECT MATTER INV. H01B3/46 B05D5/08 H01B3/40		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H01B B05D		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00/34388 A (CIBA SC HOLDING AG [CH]; BEISELE CHRISTIAN [DE]; KAINMUELLER THOMAS [D] 15 June 2000 (2000-06-15) claims 1-22; example 1; table 1 -----	1,2, 5-10, 12-14, 20,21
A	WO 2006/044642 A (GEORGIA TECH RES INST [US]; LI JUN [US]; FAN LIANHUA [US]; WONG CHING-) 27 April 2006 (2006-04-27) cited in the application example 2 -----	1-21
A	WO 00/55254 A (VANTICO AG [CH]; BEISELE CHRISTIAN [DE]) 21 September 2000 (2000-09-21) the whole document -----	1-21
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family		
Date of the actual completion of the international search 2 October 2008		Date of mailing of the international search report 20/10/2008
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Marsitzky, Dirk

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2008/051656

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 0034388	A	15-06-2000	AT 232224 T	15-02-2003
			AU 767776 B2	27-11-2003
			AU 1656000 A	26-06-2000
			BR 9916010 A	04-09-2001
			CA 2351333 A1	15-06-2000
			CN 1329642 A	02-01-2002
			CZ 20012031 A3	14-11-2001
			DE 59904252 D1	13-03-2003
			EP 1141127 A1	10-10-2001
			ES 2190277 T3	16-07-2003
			HK 1039627 A1	04-07-2003
			HU 0200220 A2	29-05-2002
			JP 2002531672 T	24-09-2002
			ZA 200104729 A	03-05-2002
WO 2006044642	A	27-04-2006	CA 2583506 A1	27-04-2006
			EP 1800317 A2	27-06-2007
			US 2006081394 A1	20-04-2006
WO 0055254	A	21-09-2000	CA 2365510 A1	21-09-2000
			EP 1165688 A1	02-01-2002
			ES 2276676 T3	01-07-2007
			JP 2002539313 T	19-11-2002
			US 6638567 B1	28-10-2003