

METHODS OF TREATING SURFACES WITH IONIC ORGANOSILICON COMPOSITIONS

This invention relates to methods of water proofing inorganic surfaces with an aqueous solution containing an ionic organosilicon compound. Additionally, the present invention is directed to an inorganic surface treated with an aqueous solution containing an ionic organosilicon compound such that a water resistant film covers the inorganic surface.

Water resistance is an important issue in many types of construction including masonry and concrete. Resistance to water is of great importance since moisture absorption and its movement in these types of materials cause or contributes to problems such as expansion, shrinkage, cracking, staining, mildew, lowered resistance to freezing and thawing, chemical attack, corrosion of reinforcing steel, and damage to structures from settling. Due to these problems, various techniques have been used to render these types of surfaces water resistant including surface treatment of structures with water repellents. Water repellents that have been used in the past include oils, waxes, soaps, and resins. These repellants have been applied to surfaces by brush, roller, air spray, or airless spray techniques. One type of water repellent that has been used is organosilicon compounds. These compounds in organic solvents have been found to be useful for providing water resistance to brick, concrete, stucco, or terrazo surfaces.

As discussed in U.S. Pat. No. 5,073,195, the contents of which are hereby incorporated by reference, application of organosilicon compounds to surfaces for water proofing is well known in the art. The use of organosilicones such as alkyltrialkoxo compounds for imparting water resistance has been known for at least 30 years. Traditionally, application of these compounds was carried out in flammable solvents such as ethanol, methanol and various liquid hydrocarbons. During application, volatile organic compounds (VOC) were heavily emitted. Due to these

problems, significant efforts were employed to formulate a nonflammable composition for imparting water resistance to masonry and concrete surfaces. The first approach attempted included various water emulsions containing organosilicon compounds. However, these formulations failed to provide water resistance comparable to the solvent based compositions. In recognition of the shortcomings associated with the water emulsion formulation, formulations were developed to make alkyltrialkoxysilanes water soluble. Formulations of this type utilize water soluble amino and quaternary ammonium organosilanes along with alkyltrialkoxysilanes of the traditional formulations. The intent of these formulations was to exploit the soluble organosilanes to solubilize the alkyltrialkoxysilanes, which provided the water repellent characteristic.

In addition to water resistance, numerous types of construction materials benefit from treatment with an antimicrobial agent. Antimicrobial agents are chemical compositions that prevent microbial contamination and deterioration of materials. Possibly the most prevalent group of antimicrobials is quaternary ammonium compounds. The use of low level (1% or lower) quaternary ammonium silanes as antimicrobial agents is well known and taught in a wide variety of United States patents including U.S. Pat. Nos. 3,560,385; 3,794,736; and 3,814,739. Due to their antimicrobial qualities, their application is beneficial for a variety of surfaces, substrates, instruments and applications. Examples of such uses are described in U.S. Pat. Nos. 3,730,701; 3,794,736; 3,860,709; 4,282,366; 4,504,541; 4,615,937; 4,692,374; 4,408,996; and 4,414,268; the contents of which are hereby incorporated by reference. Application of an aqueous solution containing a quaternary ammonium silane is discussed in U.S. Pat. Nos. 4,921,701 and 5,169,625.

Relevant to the present invention are U.S. Pat. 5,209,775, 5,421,866, 5,695,551, CA 2,115,622 and JP 3,159,975. These patents are directed to water dispersible or water emulsion water repellent compositions of silicon compounds. The compositions disclosed in these patents contain (1) alkylalkoxy silane or siloxanes; (2) a water

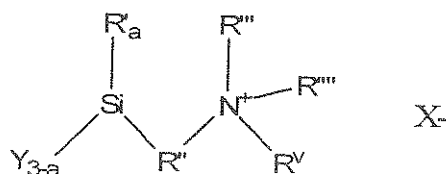
soluble silane; and (3) either aminosilane or quaternary ammonium silane. The role of soluble silane, aminosilane or ionic quaternary ammonium silane, in these compositions is to stabilize the alkylalkoxysilane, siloxane, or other water insoluble polymers in water.

The use of hydrophobic water insoluble silanes as water repellents in various organic solvents such as alcohols and hydrocarbons has been traditionally preferred due to their superior performance. However, the principal limitations of these solvent type compositions include their inherent toxicity and flammability. While providing an ecological improvement over solvent based treatments, the existing organosiloxane emulsions and water dispersible silanes or siloxanes do not compare well with existing solvent-base silanes, silane/siloxanes combinations or siloxanes in terms of stability, penetration depth, and the beading effect of the treated substrate. Additionally, the use of surfactants may cause rewetting of the surface.

Therefore, there remains a need for an aqueous water proofing treatment capable of providing at least equally efficient water resistance as treatments utilizing solvent based compositions. Accordingly, it is an object of the present invention to provide a method of treating surfaces with an aqueous solution; wherein the treated surface exhibits water resistance at least equal to that provided by solvent based treatments. Additionally, it is an object of this invention to provide the following three highly desired requirements for providing long term hydrophobicity on inorganic substrates: (1) application of a safer and environmentally acceptable aqueous solution, (2) imparting molecular level hydrophobicity and (3) reactivity with a substrate to provide long term performance.

SUMMARY

In one aspect, there is provided a method of treating an inorganic surface comprising applying to the surface an aqueous solution consisting essentially of at least one ionic organosilicon compound selected from the formula:



wherein:

Y is RO where R is an alkyl radical of one to four carbon atoms, $(\text{CH}_2\text{CH}_2\text{O})_n\text{H}$ where n has a value of one through ten, $(\text{CH}_3\text{OCH}_2\text{CH}_2\text{O})$, or $(\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_2)$; a has a value of zero, one and two;

R' is a methyl or ethyl radical;

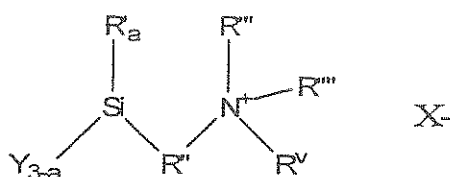
R'' is an alkylene group one to four carbon atoms;

R''', R'''' and R^v are alkyl groups containing one to twenty two carbon atoms, wherein at least one such group is larger than eight carbon atoms, $-\text{CH}_2\text{C}_6\text{H}_5$, $-\text{CH}_2\text{CH}_2\text{OH}$, $-\text{CH}_2\text{OH}$, and $-(\text{CH}_2)_x\text{NHC(O)R}^{\text{vi}}$ wherein x has a value of from two to ten and R^{vi} is a perfluoroalkyl radical having one to twelve carbon atoms; and

X is chloride, bromide, fluoride, iodide, acetate or tosylate;

wherein the inorganic surface has functional groups that will bond with silanols.

In another aspect, there is provided an article comprising an inorganic surface having a hydrophobic layer bonded to said surface said hydrophobic layer comprising a polycondensate of a water soluble ionic organosilicon compound according to the formula:



wherein:

Y is RO where R is an alkyl radical of one to four carbon atoms, $(\text{CH}_2\text{CH}_2\text{O})_n\text{H}$ where n has a value of one through ten, $(\text{CH}_3\text{OCH}_2\text{CH}_2\text{O})$, or $(\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_2)$; a has a value of zero, one and two;

R' is a methyl or ethyl radical;

R'' is an alkylene group one to four carbon atoms;

R''', R'''' and R^v are alkyl groups containing one to twenty two carbon atoms, wherein at least one such group is larger than eight carbon atoms, $-\text{CH}_2\text{C}_6\text{H}_5$, $-\text{CH}_2\text{CH}_2\text{OH}$, $-\text{CH}_2\text{OH}$, and $-(\text{CH}_2)_x\text{NHC(O)R}^{\text{vi}}$ wherein x has a value of from two to ten and R^{vi} is a perfluoroalkyl radical having one to twelve carbon atoms; and X is chloride, bromide, fluoride, iodide, acetate or tosylate.

The disclosure is directed to method of treating inorganic surfaces with aqueous compositions including ionic organosilicon compounds and various inorganic treated surfaces. Surprisingly, it has been found that the application of water soluble

ionic organosilicon compounds, which until the present disclosure have only been used in small quantities to solubilize silanes, to inorganic surfaces provides the treated surface with an excellent hydrophobic property. The present disclosure satisfies the aforementioned requirements by applying an aqueous solution comprising an ionic organosilicon compound, which has an ionic group, a hydrophobic group and at least one alkoxy group on silicon.

The present disclosure exclusively utilizes ionic organosilicon compounds as the main or sole component for imparting water repellency upon surface treatment of inorganic substrates. The methods of the present disclosure comprise the application of all aqueous solutions consisting essentially of at least one ionic organosilicon compound to inorganic surfaces thereby imparting water resistance to the surface. Although desiring not to be held to the following explanation, it is believed that upon drying of the aqueous ionic organosilicon solution; the molecular packing on the surface is such that the ionic group which enables solubility in water is buried deep within the structure after the silane forms chemical bonds with the inorganic surface. Accordingly, after application a treated surface may be characterized as a long term water repellant coating. Thus, there are differences between what is taught in accordance with the concept of the present disclosure and what is disclosed in the prior art as evidenced by the several patents noted and discussed above.

DETAILED DESCRIPTION OF THE INVENTION

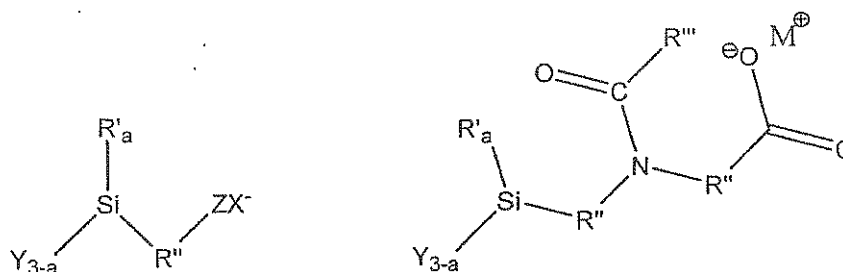
The present invention now will be described more fully hereinafter, in which some, but not all embodiments of the inventions are described. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements.

Suitable surface treating compositions for utilization in the present invention are formed by mixing together water and an ionic organosilicon compound. Ionic

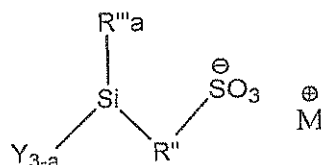
organosilicon compounds in accordance with the present invention include organosilanes having a formula selection from the group consisting of;



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wherein each formula:

- 15 Y is RO where R is an alkyl radical of one to four carbon atoms, $(\text{CH}_2\text{CH}_2\text{O})_n\text{OH}$ where n has a value of one through ten, $(\text{CH}_3\text{OCH}_2\text{CH}_2\text{O})$, or $(\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_2\text{O})$; a has a value of zero, one and two;
 R' is a methyl or ethyl radical;
 R'' is an alkylene group one to four carbon atoms;

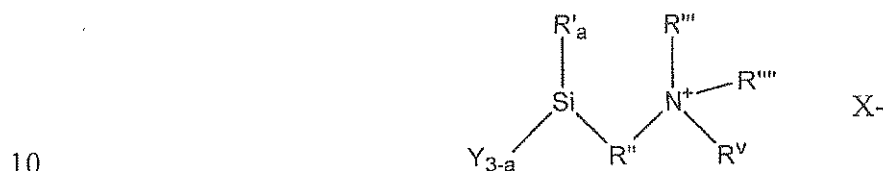
R''' , R'''' and R^v are alkyl groups containing one to twenty two carbon atoms, wherein at least one such group is larger than eight carbon atoms, $-\text{CH}_2\text{C}_6\text{H}_5$, $-\text{CH}_2\text{CH}_2\text{OH}$, $-\text{CH}_2\text{OH}$, and $-(\text{CH}_2)_x\text{NHC(O)}R^{\text{vi}}$ wherein x has a value of from two to ten and R^{vi} is a perfluoroalkyl radical having one to twelve carbon atoms;

5 X is chloride, bromide, fluoride, iodide, acetate or tosylate and

Z is a positively charged aromatic pyridinium ring of formula $\text{C}_5\text{H}_6\text{N}^+$

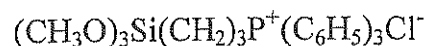
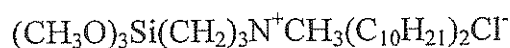
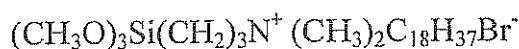
M is Na, K, or Li or H.

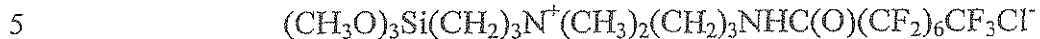
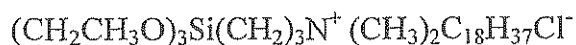
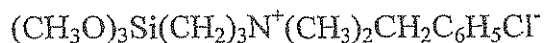
In one preferred embodiment, the ionic organosilicon compounds of the formula:



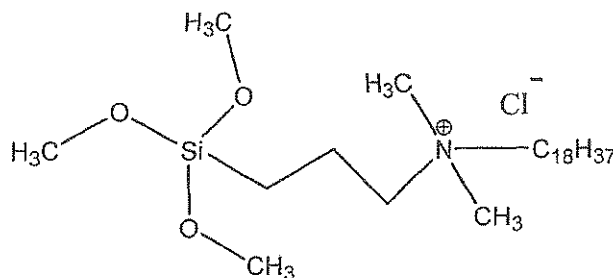
in which R is a methyl or ethyl, a has a value of zero, R'' is propylene; R''' is methyl or ethyl; R'''' and R^v are alkyl groups containing one to twenty two wherein at least one such group is larger than eight carbon atoms and X is chloride, acetate or tosylate; may be dissolved in water to form an aqueous solution. Aqueous solutions comprising these ionic organosilicons may be applied to inorganic surfaces for imparting water resistance.

Specific examples of such ionic organosilicon compounds within the scope of the present invention are represented by the formulas:

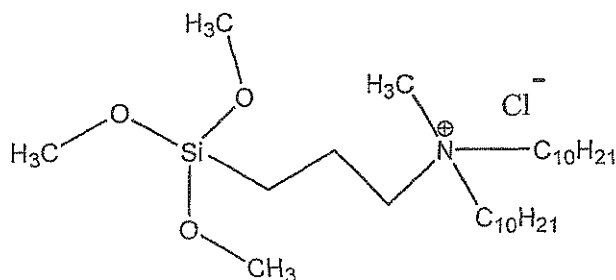




In one alternative embodiment, the ionic organosilicon compounds corresponding to the formulas 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium chloride, 3-(trimethoxysilyl)propylmethyldidecyl ammonium chloride, and 3-(trimethoxysilyl)propyldimethylhexadecyl ammonium chloride are especially
 10 suitable for aqueous solutions for application to inorganic surfaces in accordance with the present invention. Structures for these ionic organosilicon compounds are as follows:

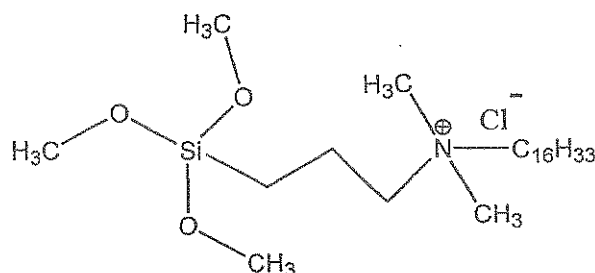


15 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium chloride;



3-(trimethoxysilyl)propylmethyldidecyl ammonium chloride; and

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3-(trimethoxysilyl)propyldimethylhexadecyl ammonium chloride.

5 The compositions in accordance with the present invention are made by dissolving an ionic organosilicon in water. Additionally, more than one ionic organosilicon compound can be dissolved in water to formulate an aqueous composition comprising more than one ionic organosilicon compound. Furthermore, some compositions in accordance with the present invention may also include known

10 excipients such as for example wetting agents, surfactants, and antimicrobial agents. These compositions comply with the local state and federal regulations regarding volatile organic content (VOC) with desired application dosage and can be applied to a wide variety of surfaces by any known means including for example by brush, roller, air spray, and airless spray techniques. After an aqueous composition

15 comprising an ionic organosilicon is applied and allowed to dry, a treated surface is obtained comprising a protective water resistant layer bonded to the substrate. Although desiring not to be held to the following explanation, it is believed that upon drying the molecular packing on the surface is such that the ionic group which enables solubility in water is buried deep within the structure after the silane forms

20 chemical bonds with the surface. Furthermore, it is believed that the long chain on the central ionic group prohibits water from reaching the soluble ionic part of the molecule. Accordingly, the present invention also provides treated surfaces comprising a unique layer in which the soluble components are shielded from water by long chains attached to the soluble component.

Any surface with functional groups or reactive sites that will bond with the silanols created by hydrolysis of the silane alkoxy groups may be rendered water repellant upon treatment with aqueous solutions of the present invention. Accordingly a treated surface in accordance with the present invention may be characterized as a polycondensate of an ionic organosilicon compound. Some suitable surfaces for example include heavy and light weight concrete, masonry products, gypsum, concrete blocks, cinder blocks, soft mud bricks, sand lime bricks, drain tiles, ceramic tiles, sandstone, plaster, clay bricks, natural stones and rocks, roofing tiles, calcium silicate bricks, cement articles, slag stones and bricks, stucco, limestone, macadam, marble, grouts, mortar, terrazzo, clinker, pumice, terra, cotta, porcelain, adobe, coral, dolomite and asphalt. Non-cement surfaces may be treated with compositions of the present invention including but not limited to perlite, cellular glass, vermiculite, mica, silica and diatomaceous earth.

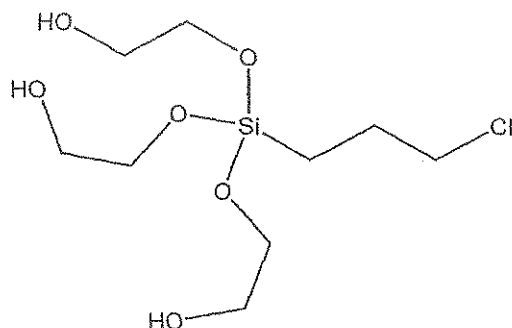
In one embodiment, the aqueous ionic organosilicon composition may include at least about 0.1 weight percent of an ionic organosilicon compound. Additionally, some embodiments may include between about 0.1 and about 10 weight percent of an ionic organosilicon compound while others may comprise between about 10 and 99 weight percent or between about 20 and 60 weight percent of an organosilicon compound.

Example 1

3-[tri-(2-hydroxyethoxy) silyl] propyldimethyloctadecyl ammonium chloride

A two liter, three-necked flask equipped with a condenser, stirrer, thermometer and a distillation head, was charged with 360 grams (six moles) of ethylene glycol. To this solution, 200 grams of 3-chloropropyltrimethoxysilane was added drop-wise at 100° C over a period of two hours. The mixture was heated for six hours at 100° C during which time 101 grams of material, chiefly methanol boiling below 100° C, was recovered. 460 grams of a crude product mixture was obtained.

The major component of the crude product mixture was



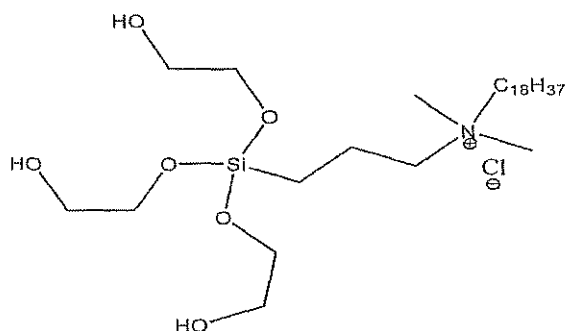
3-chloropropyl-tri-(2-hydroxy-ethoxy) silane.

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In the same reaction configuration, 265 grams (0.9 mole) of octadecyldimethylamine was added to the crude product solution. This mixture was heated to 120° C for 20 hours. After 20 hours the reaction was complete. Titration of a sample of the product mixture showed the chloride ion concentration to be 4.35 %.

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The structure of the major component was



3-[tri-(2-hydroxyethoxy)silyl] propyldimethyloctadecyl ammonium chloride.

The calculated chloride ion concentration for the product mixture was 4.40 %.

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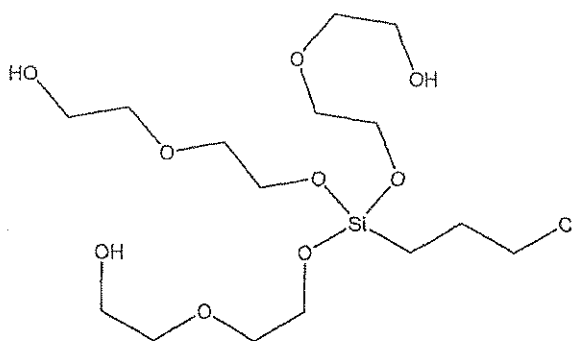
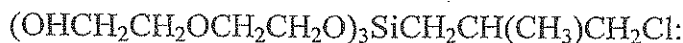
The product was miscible with water in all proportions

Example 2

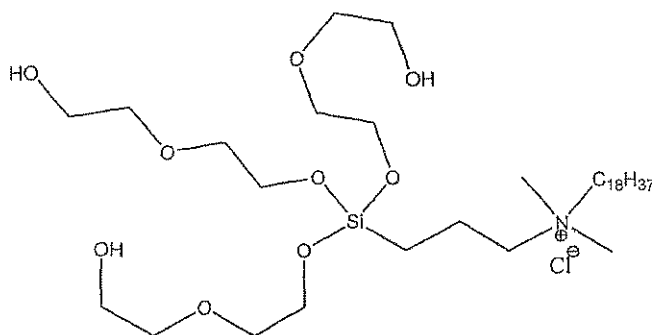
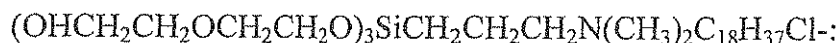
A two liter, three-necked flask equipped with a condenser, stirrer, thermometer and a distillation head, was charged with 636 grams (six moles) of diethylene glycol.

To this solution, 200 grams of -3-chloropropyltrimethoxysilane was added drop-wise at 100° C over a period of two hours. The mixture was heated for six hours at 125° C during which time 101 grams of material, chiefly methanol boiling below 100° C, was recovered. 735 grams of a crude product mixture was obtained.

5 The major component of the crude product mixture was



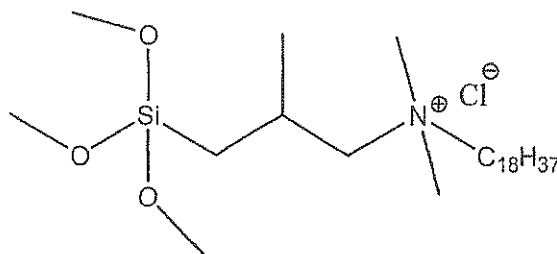
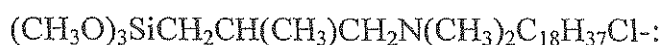
10 In the same reaction configuration, 265 grams (0.9 mole) of octadecyldimethylamine was added to the crude product solution. This mixture was heated to 120° C for 20 hours. After 20 hours the reaction was complete. Titration of a sample of the product mixture showed the chloride ion concentration to be 2.97 %. The structure of the major component was



15 The calculated chloride ion concentration for the product mixture was 3.2 %. The product was miscible with water in all proportions

Example 3**3-(trimethoxysilyl)-2-methylpropyldimethyloctadecyl ammonium chloride**

A two liter, pressure reactor equipped with a stirrer, thermometer, was charged with 225 grams of -3-chloro-2-methylpropyl-trimethoxysilane (1.1 mole), 295 grams of dimethyloctadecylamine (1.0 mole) and 100 grams of methanol. The mixture was heated for 30 hours at 120° C. After 30 hours the reaction was complete. Titration of a sample of the product mixture showed the chloride ion concentration to be 5.62 %. The structure of the major component was



3-(trimethoxysilyl)-2-methylpropyldimethyloctadecyl ammonium chloride.

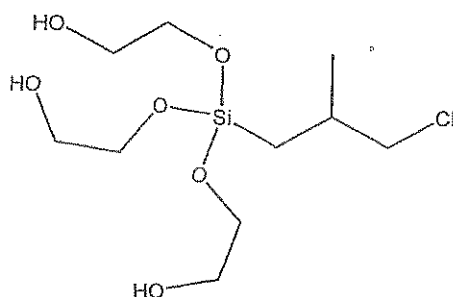
The calculated chloride ion concentration for the product mixture was 5.71 %.

The product was miscible with water in all proportions.

Example 4**3-[tri-(2-hydroxyethoxy)silyl]-2-methylpropyldimethyloctadecyl ammonium chloride**

A Two liter, three-necked flask equipped with a condenser, stirrer, thermometer and a distillation head, was charged with 360 grams (six moles) of ethylene glycol. 212 grams of -3-chloro-2-methylpropyl-trimethoxysilane was added drop-wise to the solution at 100° C over a period of two hours. The mixture was heated for six hours at 100° C during which time 101 grams of material, chiefly methanol boiling below 100° C, was recovered. 470 grams of crude product mixture was obtained. The structure of the major trans-esterified product was

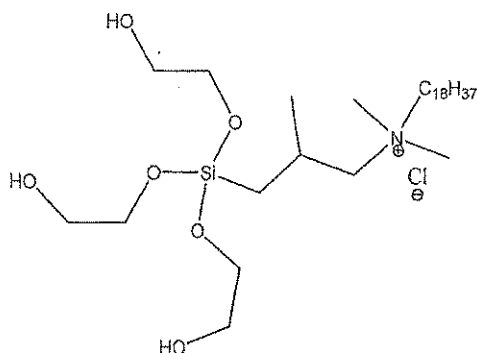




3-chloro-2-methylpropyl-tri-(2-hydroxy-ethoxy) silane.

In the same reaction configuration, 265 grams (0.9 mole) of octadecyldimethylamine was added to the crude product solution. The mixture was heated to 120° C for 20 hours. After 20 hours the reaction was complete. Titration of a sample of the product mixture showed the chloride ion concentration to be 4.17 %.

The structure of the major component was



3-[tri-(2-hydroxyethoxy)silyl]-2-methylpropyldimethyloctadecyl ammonium chloride.

The calculated chloride ion concentration for the product mixture was 4.32 %.

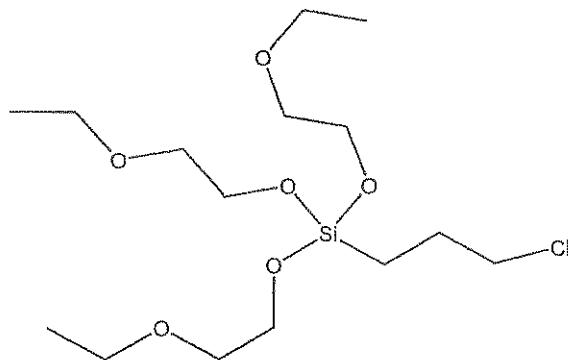
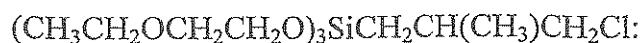
The product was miscible with water in all proportions.

Example 5

A two liter, three-necked flask equipped with a condenser, stirrer, thermometer and a distillation head, was charged with 540 grams (six moles) of ethyleneglycolmonoethyl ether. To this solution, 200 grams of -3-chloropropyltrimethoxysilane was added drop-wise at 100° C over a period of two hours. The mixture was heated for six hours at 125° C during which time 101 grams

of material, chiefly methanol boiling below 100° C, was recovered. 735 grams of a crude product mixture was obtained.

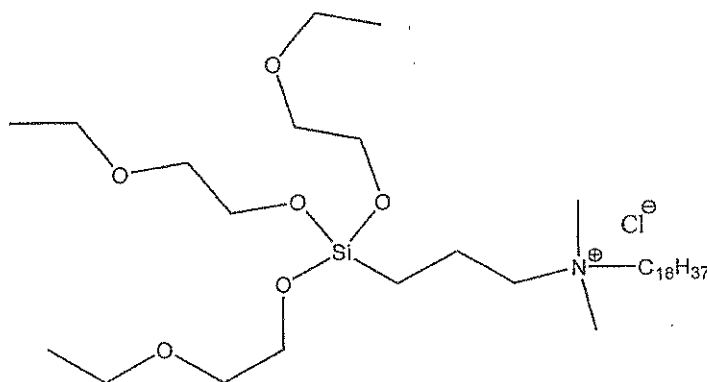
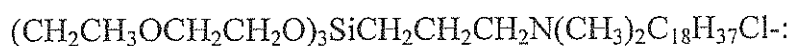
The major component of the crude product mixture was



3-Chloropropyltri(2-ethoxyethoxy)silane

In the same reaction configuration, 265 grams (0.9 mole) of octadecyldimethylamine was added to the crude product solution. This mixture was heated to 120° C for 20 hours. After 20 hours the reaction was complete. Titration of a sample of the product mixture showed the chloride ion concentration to be 3.45 %.

The structure of the major component was



3-[tri-(2ethoxyethoxy)silyl]propyldimethyloctadecyl ammonium chloride

The calculated chloride ion concentration for the product mixture was 3.52 %.
The product was miscible with water in all proportions

Example 6

[0001] Multiple aqueous solutions ranging from 0.1 to 5.0 weight percent of 3-(trimethoxysilyl)propyldimethyloctaldecyl ammonium chloride were prepared by dissolution in tap water. The substrates treated included a piece of a concrete block, a cement sheet, a sand face plaster, and sandstone. These materials were weighed and dried in an oven at 100° C until a constant weight was reached. The pieces were then weighed and placed in 1-cm of water for 1 hour, weighed again, and dried in a 100° C oven until a constant weight was reached. At which time, the individual pieces were weighed, soaked in the water repellent solution for 20 second and then dried, and finally reweighed. The treated samples were placed in 1-cm of water for 1 hour and weighed. The percent water exclusion for each experiment is provided in Table-I; wherein the percent water exclusion was calculated in the following manner:

$$\frac{(\text{water pickup of untreated substrate} - \text{water pickup of treated substrate}) \times 100}{\text{Water pickup of untreated substrate.}}$$

Table-I: (%) Water exclusion with different concentrations

Concentration	Water exclusion (%)							
	0.1	0.5	1.0	1.5	2.0	2.5	3.5	5.0
Concrete Block	60	68	72	82	87	89	85	82
Cement Sheet	59	67	73	88	87	89	88	83
Sand face Plaster	70	73	75	82	86	90	89	83
Sand Stone	69	76	78	93	93	92	91	91

These results reveal that 1.5 – 3.5 weight percent solutions provide excellent hydrophobicity for most substrates.

Example 7

Standard M20 block samples were used for testing. The standard size bricks were cut into three equal parts for testing. The sandstone pieces were 7-cm X 6-cm X 7-cm. An untreated control was included for comparison and to calculate water exclusion. The samples were cleaned with a wire brush and cloth. The pieces were weighed and dried in an oven at 100° C until a constant weight was reached. The water uptake was determined by the procedures established according to ASTM D-6489. The pieces were weighed and placed in 1-cm of water for 24 hours, weighed again and dried in a 100° C oven until a constant weight was reached. The pieces were then treated with a water repellent as described in example 6. After soaking in 1-cm of water for 24 hours and the pieces were weighed again. Water uptake, percent water absorption (water uptake X 100/ Weight of dry piece) and % water exclusion were calculated by:

$$\frac{(\text{water uptake of control} - \text{water uptake of treated sample}) \times 100}{\text{water uptake of control}}$$

A 2.5 weight percent solution of 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium chloride was prepared by dissolving in tap water. Three samples of each substrate were treated by dipping the sample for 20 seconds. The samples were allowed to cure for 24 hours. They were further dried in an oven at 100° C for one hour. After removal from the oven, the samples were allowed to attain room temperature before measurements were taken. Water uptake was determined using ASTM method D6489. The calculated results of the average of three samples are summarized in Table-II

Table-II Water exclusion based on ASTM D6489

Substrate	% Water Exclusion
Concrete Block (M20)	89
Brick	90
Sandstone	85
Cement Sheet	80

Example 8**Rilem hydraulic water penetration test (Test II.4)**

A 2.5 % solution of 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium chloride was prepared by dissolving in tap water. Three samples of each substrate were treated by dipping the sample in the aqueous solution for 20 seconds. The samples were allowed to cure for 24 hours. Then they were further dried in an oven at 100° C for one hour. The samples were allowed to attain room temperature before measurements were taken. An uptake tube was affixed to substrate's surface by interposing a strip of caulk between the circular brim of the tube and the surface of the masonry material with applied pressure. Water was then added to the opening in the tube until it reached the zero graduation mark. The quantity of water absorbed by the substrate in 20 minutes is read from the graduation marks on the tube. The data is provided in Table-III which shows milliliters (mls) lost in 20 minutes.

Table-III Rilem hydraulic water penetration test (Test II.4)

Substrate	Untreated Water Loss in 20 minutes ml	2.5 %Treated Water Loss in 20 minutes ml
Concrete Block (M20)	8.0	0.2
Brick	40	0.2
Sandstone	20	0.1
Cement Sheet	10	0.3

Example 9**Depth of Penetration**

A 2.5 % solution of 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium chloride was prepared by dissolving in tap water. Three samples of each substrate were treated by dipping the sample in the aqueous solution for 20 seconds. The samples were allowed to cure for 24 hours. Then they were further dried in an oven at 100° C for one hour. The samples were allowed to attain room temperature before

measurements were taken. Each sample was split longitudinally using a hammer and chisel. One half of each sample was placed fractured surface down in a water soluble dye solution. Only the untreated portion of each sample absorbed the solution and became stained. The depth of penetration was measured from the surface down to the stained region. The average penetration is provided in Table-IV.

Table-IV Depth of Penetration

Substrate	2.5 % Treatment Depth of Penetration mm	Treatment Time (Seconds)	Amount of Solution Absorption(%)
Concrete Block (M20)	6	20	1
Brick	10	20	2
Sandstone	3	20	0.3

Example 10

Capillary Absorption Test

After conditioning, samples of treated and untreated concrete cubes were taken for further experimentation. Initial weights of all the cubes were recorded. The weighed samples were placed in a container on a porous support made from a pack of filter papers. The thickness of the pack was approximately 1cm. The pack of filter papers ensures immediate and continuous contact between water and only the surface on which the samples were resting. Tap water was slowly poured into the container until the paper was completely saturated. The water level was not allowed to rise beyond the top border of the pack. For reducing evaporation of water, the container was covered with a glass sheet.

For assessing the capillary water absorption, the samples were removed from the container after one hour. After wiping the surface in contact with water with a damp cloth, each sample was weighed. The results obtained are provided in Table-V.

Table-V Capillary Absorption

Substrate	Untreated Amount water absorbed (%)	2.5 % Treatment Amount of water absorbed (%)
Concrete Block (M20)	5	<0.1
Brick	10	<0.1

Example 11

Standard M20 block samples were used for additional testing. An untreated control was included for comparison and to calculate water exclusion. The samples were cleaned with a wire brush and cloth. The pieces were weighed and dried in an oven at 100° C until a constant weight was reached. The water uptake was determined by the procedures established according to the ASTM D-6489. The pieces were weighed and placed in 1-cm of water for 24 hours, weighed again and dried in a 100° C oven until a constant weight was reached. A 2.5 weight % solution of 3-(trimethoxysilyl)propylmethyldidecyl ammonium chloride was prepared by dissolving in tap water. Three samples were treated by dipping in the aqueous solution for 20 seconds. The samples were allowed to cure for 24 hours. Then they were further dried in an oven at 100° C for one hour. The samples were allowed to attain room temperature before measurements were taken. Water uptake, percent water absorption (water uptake X 100/ Weight of dry piece) and % water exclusion were calculated by:

$$\frac{(\text{water uptake of control} - \text{water uptake of treated sample}) \times 100}{\text{water uptake of control}}$$

The average water exclusion calculated for three samples was 87%.

Example 12

Standard M20 block samples were used for additional testing. An untreated control was included for comparison and to calculate water exclusion. The samples were cleaned with a wire brush and cloth. The pieces were weighed and dried in an oven at 100° C until a constant weight was reached. A 2.5 weight % solution of 3-

(trimethoxysilyl) propyldimethylhexadecyl ammonium chloride was prepared by dissolving in tap water. Three samples were treated by dipping in the aqueous solution for 20 seconds. The samples were allowed to cure for 24 hours. Then they were further dried in an oven at 100° C for one hour. The samples were allowed to attain room temperature before measurements were taken. Water uptake, percent water absorption (water uptake X 100/ Weight of dry piece) and % water exclusion were calculated by.

$$\frac{(\text{water uptake of control} - \text{water uptake of treated sample}) \times 100}{\text{water uptake of control.}}$$

The average water exclusion calculated for three samples was 85%.

Example 13

Standard M20 block samples were used for additional testing. An untreated control was included for comparison and to calculate water exclusion. The samples were cleaned with a wire brush and cloth. The pieces were weighed and dried in an oven at 100° C until a constant weight was reached. A 2.5 weight % solution was prepared by dissolving the product obtained from example 1, in tap water. Three samples were treated by dipping in the aqueous solution for 20 seconds. The samples were allowed to cure for 48 hours. Then they were further dried in an oven at 100° C for one hour. The samples were allowed to attain room temperature before measurements were taken. Water uptake, percent water absorption (water uptake X 100/ Weight of dry piece) and % water exclusion were calculated by:

$$\frac{(\text{water uptake of control} - \text{water uptake of treated sample}) \times 100}{\text{water uptake of control.}}$$

The average water exclusion calculated for three samples was 91%.

Example 14

Standard M20 block samples were used for additional testing. An untreated control was included for comparison and to calculate water exclusion. The samples were cleaned with a wire brush and cloth. The pieces were weighed and dried in an

oven at 100° C until a constant weight was reached. A 2.5 weight % solution was prepared by dissolving the product obtained from example 2, in tap water. Three samples were treated by dipping in the aqueous solution for 20 seconds. The samples were allowed to cure for 5 days. Then they were further dried in an oven at 100° C for one hour. The samples were allowed to attain room temperature before measurements were taken. Water uptake, percent water absorption (water uptake X 100/ Weight of dry piece) and % water exclusion were calculated by:

$$\frac{(\text{water uptake of control} - \text{water uptake of treated sample}) \times 100}{\text{water uptake of control.}}$$

The average water exclusion calculated for three samples was 81%.

Example 15

Standard M20 block samples were used for additional testing. An untreated control was included for comparison and to calculate water exclusion. The samples were cleaned with a wire brush and cloth. The pieces were weighed and dried in an oven at 100° C until a constant weight was reached. A 2.5 weight % solution was prepared by dissolving the product obtained from example 4, in tap water. Three samples were treated by dipping in the aqueous solution for 20 seconds. The samples were allowed to cure for 48 hours. Then they were further dried in an oven at 100° C for one hour. The samples were allowed to attain room temperature before measurements were taken. Water uptake, percent water absorption (water uptake X 100/ Weight of dry piece) and % water exclusion were calculated by:

$$\frac{(\text{water uptake of control} - \text{water uptake of treated sample}) \times 100}{\text{water uptake of control.}}$$

The average water exclusion calculated for three samples was 93%.

Example 16

Standard M20 block samples were used for additional testing. An untreated control was included for comparison and to calculate water exclusion. The samples were cleaned with a wire brush and cloth. The pieces were weighed and dried in an

oven at 100° C until a constant weight was reached. A 2.5 weight % solution was prepared by dissolving the product obtained from example 5, in tap water. Three samples were treated by dipping in the aqueous solution for 20 seconds. The samples were allowed to cure for 48 hours. Then they were further dried in an oven at 100° C for one hour. The samples were allowed to attain room temperature before measurements were taken. Water uptake, percent water absorption (water uptake X 100/ Weight of dry piece) and % water exclusion were calculated by:

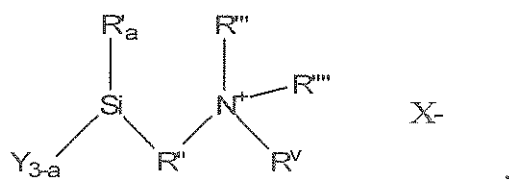
$$\frac{(\text{water uptake of control} - \text{water uptake of treated sample}) \times 100}{\text{water uptake of control}}$$

The average water exclusion calculated for three samples was 93%.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation

I CLAIM:

1. A method of treating an inorganic surface comprising applying to the surface an aqueous solution consisting essentially of at least one ionic organosilicon
5 compound selected from the formula:



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wherein:

- 15 Y is RO where R is an alkyl radical of one to four carbon atoms, $(\text{CH}_2\text{CH}_2\text{O})_n\text{H}$ where n has a value of one through ten, $(\text{CH}_3\text{OCH}_2\text{CH}_2\text{O})$, or $(\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_2)$;

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a has a value of zero, one and two;

R' is a methyl or ethyl radical;

R'' is an alkylene group one to four carbon atoms;

R''', R'''' and R^v are alkyl groups containing one to twenty two carbon atoms,

5 wherein at least one such group is larger than eight carbon atoms, -CH₂C₆H₅, -CH₂CH₂OH, -CH₂OH, and -(CH₂)_xNHC(O)R^{vi} wherein x has a value of from two to ten and R^{vi} is a perfluoroalkyl radical having one to twelve carbon atoms; and

X is chloride, bromide, fluoride, iodide, acetate or tosylate;

wherein the inorganic surface has functional groups that will bond with silanols.

10 2. The method according to Claim 1, wherein said ionic organosilicon comprises between about 0.1 to about 10 weight percent of said aqueous solution.

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3. The method according to Claim 1, wherein said applying step comprises spraying said aqueous solution onto said surface.

4. The method according to Claim 1; wherein said applying step comprises applying the aqueous solution to an inorganic surface.

5 5. The method according to Claim 4; wherein said surface is selected from the group consisting of concrete, masonry products, gypsum, concrete blocks, cinder blocks, soft mud bricks, sand lime bricks, drain tiles, ceramic tiles, sandstone, plaster, clay bricks, natural stones and rocks, roofing tiles, calcium silicate bricks, cement articles, slag stones and bricks, stucco, limestone, macadam, marble, grouts,
10 mortar, terrazzo, clinker, pumice, terra, cotta, porcelain, adobe, coral, dolomite and asphalt.

6. A method according to claim 1, comprising:

i) dissolving the at least one ionic organosilicon compound in water to form an aqueous solution of the ionic organosilicon compound;

15 ii) applying the aqueous solution onto an inorganic surface; and

iii) allowing the aqueous solution to dry so that the at least one ionic organosilicon compound bonds with reactive sites present on the inorganic surface to form a protective hydrophobic layer on said inorganic surface.

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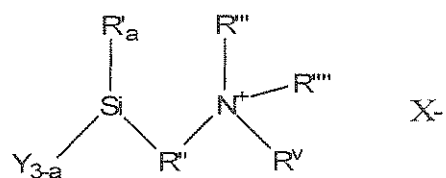
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7. The method according to Claim 6, wherein said at least one ionic organosilicon comprises between about 0.1 and 10 weight percent of said aqueous solution.

8. The method according to Claim 7; wherein said at least one ionic organosilicon is at least one of 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium chloride, 3-(trimethoxysilyl)propylmethyldidecyl ammonium chloride, and 3-(trimethoxysilyl)propyldimethylhexadecyl ammonium chloride.

9. The method according to Claim 8; wherein the step of applying said aqueous solution is selected from the group consisting of at least one of brushing, rolling and spraying said aqueous solution onto said surface.

10. An article comprising an inorganic surface having a hydrophobic layer bonded to said surface said hydrophobic layer comprising a polycondensate of a water soluble ionic organosilicon compound according to the formula:



wherein:

Y is RO where R is an alkyl radical of one to four carbon atoms, $(\text{CH}_2\text{CH}_2\text{O})_n\text{H}$ where n has a value of one through ten, $(\text{CH}_3\text{OCH}_2\text{CH}_2\text{O})$, or $(\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_2)$; a has a value of zero, one and two;

R' is a methyl or ethyl radical;

R'' is an alkylene group one to four carbon atoms;

R''', R'''' and R^v are alkyl groups containing one to twenty two carbon atoms, wherein at least one such group is larger than eight carbon atoms, $-\text{CH}_2\text{C}_6\text{H}_5$, -

CH₂CH₂OH, -CH₂OH, and -(CH₂)_xNHC(O)R^{vi} wherein x has a value of from two to ten and R^{vi} is a perfluoroalkyl radical having one to twelve carbon atoms; and X is chloride, bromide, fluoride, iodide, acetate or tosylate.

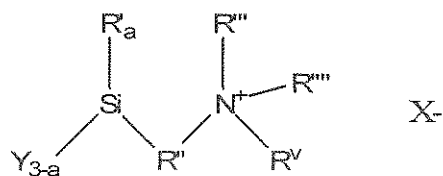
11. The article of Claim 10; wherein said water resistant layer and said inorganic surface are attached by Si-O-Si bonds.

12. The article of Claim 11; wherein said hydrophobic layer further comprises long chain alkyl groups bonded to an ionic group.

13. The article of Claim 12; wherein said long chain alkyl groups are located such that water cannot reach said ionic group.

14. The article of Claim 13; wherein said hydrophobic comprises a polycondensate of at least one of 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium chloride, 3-(trimethoxysilyl)propylmethyldidecyl ammonium chloride, and 3-(trimethoxysilyl)propyldimethylhexadecyl ammonium chloride.

15. The method according to Claim 1; wherein said ionic organosilicon compounds are selected from the formula:



wherein;

Y is RO where R is an alkyl radical of one to four carbon atoms, $(\text{CH}_2\text{CH}_2\text{O})_n \text{H}$ where n has a value of one through ten, ;

5 a has a value of zero, one and two;

R' is a methyl or ethyl radical;

R'' is an alkylene group one to four carbon atoms;

R''', R'''' and R^v are alkyl groups containing one to twenty two carbon atoms, wherein at least one such group is larger than eight carbon atoms, $-\text{CH}_2\text{C}_6\text{H}_5$, -

10 $\text{CH}_2\text{CH}_2\text{OH}$, $-\text{CH}_2\text{OH}$, and $-(\text{CH}_2)_x\text{NHC}(\text{O})\text{R}^{\text{vi}}$ wherein x has a value of from two to ten and R^{vi} is a perfluoroalkyl radical having one to twelve carbon atoms; and

X is chloride, bromide, fluoride, iodide, acetate or tosylate.

16. The method according to claim 15, wherein R'' is an alkylene group with four carbon atoms.

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