**[0053]** In some embodiments, the alkoxyalkylsilane $[CH_3(CH_2)_a]_bSiR_c[alkoxy]_d$ is chemically converted from alkylsilane $[CH_3(CH_2)_a]_bSiR_cX_d$ by mixing and heating the alkylsilane in the correspondent solvent(s) (e.g. methanol, ethanol, isopropanol and water). The mixture of the thereof chemical agents is preferred to be stirred at elevated temperature equal to or between 50 to 100 °C for about 1 hour to 7 days in an acidic environment ($pH \leq 1$) and the solutions were neutralized with KOH (may contain up to 15% (w/w) of water) until the pH reached equal to or between 6 and 8. The hydrophobic solutions were used directly or further diluted in an appropriate solvent (e.g. methanol, ethanol, isopropanol, denatured ethanol, water, etc.).

**[0054]** In some embodiments, the target surface of materials may be activated before the deposition of the organic/inorganic composite solution. The surface activation may be achieved by reaction with ozone, oxygen, hydrogen peroxide, halogens, other reactive oxidizing species, or combinations thereof. The purpose is to create an energetically reactive surface, increase the concentration of free radicals and to bind molecules on the surface covalently. In some embodiments, the surface activation may be achieved by ozone plasma generated by intense UV light. In other embodiments, surface activation may be achieved by plasma treatment. In yet another embodiment, surface activation may be achieved by ozone generation using a corona discharge, flame, or plasma.

**[0055]** In some embodiment, as a nonlimiting example, the organic/inorganic composite solution may be deposited on the surface of wood or masonry materials by spraying, misting, doctor-blading, padding, foaming, rolling or inkjet printing. As another nonlimiting example, the materials may be dipped into the solution for a set period of time equal to or between about 1 second and 24 hour. The solvent may then be removed from the materials, and the materials may be dried or cured at a set temperature equal to or between about 25 and 200 °C. In certain

## CLAIMS

What is claimed is:

1. A method for treating a substrate for improved soil-resistance, stain-resistance, weather-resistance, or fungal-resistance, the method comprising:

selecting a substrate to be coated, wherein the substrate is selected from a porous material;

preparing a composite solution, wherein the composite solution is prepared by mixing at least water, acid, first solvent, base chemical reagent, plasticizer and bonding agent,

wherein further the base chemical reagent is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_4$, where M = Si, Al, Ti, In, Sn or Zr, and R comprises hydrogen, a substituted or unsubstituted alkyl,

the bonding agent is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_x R'_y R''_z$ (M = Si, Al, In, Sn or Ti; x is the integer 1, 2 or 3; y is the integer 0, 1 or 2; z is the integer 1, 2 or 3, provided that the sum of x, y and z equals 4), where R comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof; R′ comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof and R″ comprises a substituted or unsubstituted epoxy or glycidoxy, and

the plasticizer is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_{4-x}R'_x$ (M = Si, Al, In, Sn or Ti; x is the integer 1, 2 or 3), where R comprise hydrogen, a substituted or unsubstituted alkyl or derivatives thereof and R′ comprise a substituted or unsubstituted alkyl, a substituted or unsubstituted alkenyl, a substituted or unsubstituted alkynyl, a substituted or unsubstituted aryl or derivatives thereof;

stirring the composite solution at an elevated temperature in a range of 50-100 °C;

utilizing the composite solution to coat the substrate and penetrate into the porous material; and

drying or curing the substrate to allow a composite coating to form on the substrate that improves soil-resistance, stain-resistance, weather-resistance, or fungal-resistance.

2. The method of claim 1, wherein the porous material is selected from wood or masonry material, and the composition coating formed on the substrate does not change the pigmentation and reflectivity of the substrate before coating.

3. The method of claim 1, wherein the composite solution comprises 3-8 vol. % of the water, 20-30 vol. % of the first solvent, 40-60 vol. % of the base chemical reagent, 10-15 vol. % of the plasticizer, and 1-5 vol. % of the bonding agent, and

diluting the composite solution further with a second solvent to a final concentration of 60 to 100 vol. %.

4. The method of claim 1, wherein the composite solution is prepared under acidic condition where pH is equal to or less than 5.

5. The method of claim 1, wherein the stirring at the elevated temperature is performed for ½ hour to 12 hours.

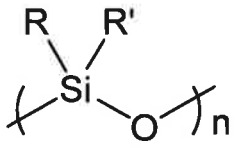
6. The method of claim 1, wherein a degree of polymerization of the composite solution is equal to or less than 100.

7. The method of claim 1, wherein the first solvent is selected from water, methanol, ethanol, n-propanol, isopropanol, n-butanol, isobutanol, ethylene glycol, glycerol acetone, acetonitrile, dioxane, tetrahydrofuran, dimethylformamide, dimethyl sulfoxide or a mixture thereof.

8. The method of claim 1, wherein the composite solution further comprises a chelating agent, wherein the chelating agent is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_x R'_y R''_z$ (M = Si, Al, In, Sn or Ti; x is the integer 1, 2 or 3; y is the integer 0, 1 or 2; z is the integer 1, 2 or 3, provided that the sum of x, y and z equals 4), where R comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof; R′ comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof and R″ comprises a substituted or unsubstituted alky or alkenyl group comprising from 3 to 20 carbon atoms, or

the chelating agent is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_x R'_y R''_z$ (M = Si, Al, In, Sn or Ti; x is the integer 1, 2 or 3; y is the integer 0, 1 or 2; z is the integer 1, 2 or 3, provided that the sum of x, y and z equals 4), where R comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof; R′ comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof and R″ comprises a substituted or unsubstituted amine (including primary, secondary and tertiary) or thiol.

9. The method of claim 1, wherein the composite solution further comprises a viscosity modifier selected from an alkylsiloxane in oligomer/co-oligomer form, polymer/co-polymer form, or a combination thereof having a general formula of




where R and R′ can be the same or different and comprise hydrogen, a substituted or unsubstituted alkyl or derivatives thereof.

10. The method of claim 1, wherein the composite solution further comprises a functional additive that provides UV absorbing or blocking, anti-reflective, anti-abrasion, fire-retardant, conducting, anti-microbial, anti-bacterial, anti-fungal, or pigmentation properties.

11. The method of claim 1 further comprising the steps of:

coating the substrate with a hydrophobic solution, wherein the hydrophobic solution comprises a hydrophobic chemical agent and a third solvent; and

the hydrophobic chemical agent is selected from a fluoroalkylsilane $[CF_3(CF_2)_a(CH_2)_b]_cSiR_dX_e$ (where X = Cl, Br, I or other suitable organic leaving groups, R comprise a substituted or unsubstituted alkyl, a substituted or unsubstituted alkenyl, a substituted or unsubstituted alkynyl, a substituted or unsubstituted aryl or derivatives thereof, a is the integer 0, 1, 2, 3 ... to 20, b is the integer 0, 1, 2, 3... to 10, c is the integer 1, 2, 3, d is the integer 0, 1, 2, 3 and e is the integer 1, 2, 3, provided that the sum of c, d and e equals 4),

the hydrophobic chemical agent is selected from an alkylsilane $[CH_3(CH_2)_a]_bSiR_cX_d$; where X comprise Cl, Br, I or other suitable organic leaving groups, R comprise a substituted or

unsubstituted alkyl, a substituted or unsubstituted alkenyl, a substituted or unsubstituted alkynyl, a substituted or unsubstituted aryl or derivatives thereof, and a is the integer 0, 1, 2, 3... to 20, b is the integer 1, 2 or 3, c is the integer 0, 1, 2, 3 and d is the integer 1, 2 or 3, provided that the sum of b, c and d equals 4,

the hydrophobic chemical agent is selected from an alkoxyfluoroalkylsilane $[CF_3(CF_2)_a(CH_2)_b]_cSiR_d[alkoxy]_e$ (where [alkoxy] comprise methoxy, ethoxy, propoxy, isopropoxy, butoxy, isobutoxy, or a combination thereof; R comprise a substituted or unsubstituted alkyl, a substituted or unsubstituted alkenyl, a substituted or unsubstituted alkynyl, a substituted or unsubstituted aryl or derivatives thereof, a is the integer 0, 1, 2, 3 ... to 20, b is the integer 0, 1, 2, 3... to 10, c is the integer 1, 2, 3, d is the integer 0, 1, 2, 3 and e is the integer 1, 2, 3, provided that the sum of c, d and e equals 4, or

the hydrophobic chemical agent is selected from an alkoxyalkylsilane $[CH_3(CH_2)_a]_bSiR_c[alkoxy]_d$; where [alkoxy] comprise methoxy, ethoxy, propoxy, isopropoxy, butoxy, isobutoxy, or a combination thereof; R comprise a substituted or unsubstituted alkyl, a substituted or unsubstituted alkenyl, a substituted or unsubstituted alkynyl, a substituted or unsubstituted aryl or derivatives thereof, and a is the integer 0, 1, 2, 3... to 20, b is the integer 1, 2 or 3, c is the integer 0, 1, 2, 3 and d is the integer 1, 2 or 3, provided that the sum of b, c and d equals 4.

12. The method of claim 11, wherein the third solvent is selected from toluene, benzene, xylene, trichloroethylene, 1,2-dichloroethane, dichloromethane, chloroform, carbon tetrachloride, tetrachloroethylene, *n*-propyl bromide, diethyl ether, acetone, diisopropyl ether, methyl-*t*-butyl ether, petroleum ethers, petroleum hydrocarbons, methanol, ethanol, *n*-propanol,

isopropanol, n-butanol, isobutanol, acetone, acetonitrile, dioxane, tetrahydrofuran, tetrachloroethylene, dimethylformamide, dimethyl sulfoxide, or water.

13. The method of claim 11, wherein the fluoroalkylsilane is selected from trichloro(3,3,3-trifluoropropyl)silane, dichloro-methyl(3,3,3-trifluoropropyl)silane, chloro-dimethyl(3,3,3-trifluoropropyl)silane, trichloro(1*H*,1*H*,2*H*,2*H*-perfluorobutyl)silane, dichloro-methyl(1*H*,1*H*,2*H*,2*H*-perfluorobutyl)silane, chloro-dimethyl(1*H*,1*H*,2*H*,2*H*-perfluorobutyl)silane, trichloro(1*H*,1*H*,2*H*,2*H*-perfluorohexyl)silane, dichloro-methyl(1*H*,1*H*,2*H*,2*H*-perfluorohexyl)silane, chloro-dimethyl(1*H*,1*H*,2*H*,2*H*-perfluorohexyl)silane, trichloro(1*H*,1*H*,2*H*,2*H*-perfluorooctyl)silane, dichloro-methyl(1*H*,1*H*,2*H*,2*H*-perfluorooctyl)silane, chloro-dimethyl(1*H*,1*H*,2*H*,2*H*-perfluorooctyl)silane, trichloro(1*H*,1*H*,2*H*,2*H*-perfluorodecyl)silane, dichloro-methyl(1*H*,1*H*,2*H*,2*H*-perfluorodecyl)silane, chloro-dimethyl(1*H*,1*H*,2*H*,2*H*-perfluorodecyl)silane, trichloro(1*H*,1*H*,2*H*,2*H*-perfluorododecyl)silane, dichloro-methyl(1*H*,1*H*,2*H*,2*H*-perfluorododecyl)silane, or chloro-dimethyl(1*H*,1*H*,2*H*,2*H*-perfluorododecyl)silane;

the alkylsilane is selected from chlorosilane, dichlorosilane, trichlorosilane, chlorotrimethylsilane, dichlorodimethylsilane, trichloromethylsilane, chlorophenylsilane, dichlorophenylsilane, trichlorophenylsilane, chloromethylphenylsilane, chlorodimethylphenylsilane, dichloromethylphenylsilane, chlorodimethylphenethylsilane, dichloromethylphenethylsilane, trichlorophenethylsilane, chlorodimethyloctylsilane, dichloromethyloctylsilane trichlorooctylsilane, chlorodimethyldodecylsilane, dichloromethyldodecylsilane, trichlorododecylsilane, chlorodecyldimethylsilane,

dichlorodecylmethylsilane, trichlorodecylsilane, chlorodimethyloctadecylsilane, dichloromethyloctadecylsilane, trichlorooctadecylsilane, chlorodimethylthexylsilane, dichloromethylthexylsilane, trichlorothexylsilane, allyldichloromethylsilane, allylchlorodimethylsilane, allyltrichlorosilane, (cyclohexylmethyl)chlorodimethylsilane, (cyclohexylmethyl)dichloromethylsilane, or (cyclohexylmethyl)trichlorosilane;

the alkoxyfluoroalkylsilane is selected from trimethoxy(3,3,3-trifluoropropyl)silane, triethoxy(3,3,3-trifluoropropyl)silane, tripropoxy(3,3,3-trifluoropropyl)silane, triisopropoxy(3,3,3-trifluoropropyl)silane, trimethoxy(1*H*,1*H*,2*H*,2*H*-perfluorobutyl)silane, triethoxy(1*H*,1*H*,2*H*,2*H*-perfluorobutyl)silane, tripropoxy(1*H*,1*H*,2*H*,2*H*-perfluorobutyl)silane, triisopropoxy(1*H*,1*H*,2*H*,2*H*-perfluorobutyl)silane, trimethoxy(1*H*,1*H*,2*H*,2*H*-perfluorohexyl)silane, triethoxy(1*H*,1*H*,2*H*,2*H*-perfluorohexyl)silane, tripropoxy(1*H*,1*H*,2*H*,2*H*-perfluorohexyl)silane, triisopropoxy(1*H*,1*H*,2*H*,2*H*-perfluorohexyl)silane, trimethoxy(1*H*,1*H*,2*H*,2*H*-perfluorooctyl)silane, triethoxy(1*H*,1*H*,2*H*,2*H*-perfluorooctyl)silane, tripropoxy(1*H*,1*H*,2*H*,2*H*-perfluorooctyl)silane, triisopropoxy(1*H*,1*H*,2*H*,2*H*-perfluorooctyl)silane, trimethoxy(1*H*,1*H*,2*H*,2*H*-perfluorodecyl)silane, triethoxy(1*H*,1*H*,2*H*,2*H*-perfluorodecyl)silane, tripropoxy(1*H*,1*H*,2*H*,2*H*-perfluorodecyl)silane, triisopropoxy(1*H*,1*H*,2*H*,2*H*-perfluorodecyl)silane, trimethoxy(1*H*,1*H*,2*H*,2*H*-perfluorododecyl)silane, triethoxy(1*H*,1*H*,2*H*,2*H*-perfluorododecyl)silane, tripropoxy(1*H*,1*H*,2*H*,2*H*-perfluorododecyl)silane, or triisopropoxy(1*H*,1*H*,2*H*,2*H*-perfluorododecyl)silane; and

the alkoxyalkylsilane is selected from trimethoxyisobutylsilane, triethoxyisobutylsilane, dimethoxydiisobutylsilane, diethoxydiisobutylsilane, trimethoxyphenylsilane, triethoxyphenylsilane, dimethoxydiphenylsilane, diethoxydiphenylsilane,

dimethoxymethylphenylsilane, diethoxymethylphenylsilane, methoxydimethylphenylsilane, ethoxydimethylphenylsilane, trimethoxy(hexyl)silane, triethoxy(hexyl)silane, tripropoxy(hexyl)silane, triisopropoxy(hexyl)silane, trimethoxy(octyl)silane, triethoxy(octyl)silane, tripropoxy(octyl)silane, triisopropoxy(octyl)silane, trimethoxy(decyl)silane, triethoxy(decyl)silane, tripropoxy(decyl)silane, triisopropoxy(decyl)silane, trimethoxy(dodecyl)silane, triethoxy(dodecyl)silane, tripropoxy(dodecyl)silane, or triisopropoxy(dodecyl)silane.

14. A composite solution for a substrate to improve soil-resistance, stain-resistance, weather-resistance, or fungal-resistance, the composite solution comprising:

water;

an acid;

a first solvent;

a base chemical reagent, wherein the base chemical reagent is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_4$, where M = Si, Al, Ti, In, Sn or Zr, and R comprises hydrogen, a substituted or unsubstituted alkyl;

a plasticizer, wherein the plasticizer is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_{4-x}R'_x$ (M = Si, Al, In, Sn or Ti; x is the integer 1, 2 or 3), where R comprise hydrogen, a substituted or unsubstituted alkyl or derivatives thereof and R′ comprise a substituted or unsubstituted alkyl, a substituted or unsubstituted alkenyl, a substituted or unsubstituted alkynyl, a substituted or unsubstituted aryl or derivatives thereof; and

a bonding agent, wherein the bonding agent is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_x R'_y R''_z$ (M = Si, Al, In, Sn or Ti; x is the integer 1, 2 or 3; y is the integer 0, 1 or 2; z is the integer 1, 2 or 3, provided that the sum of x, y and z equals 4), where R comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof; R′ comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof and R″ comprises a substituted or unsubstituted epoxy or glycidoxy,

wherein the composite solution is stirred at an elevated temperature in a range of 50-100 °C, and the composite solution is utilized to coat and penetrate into a substrate that is a porous material to form a composite coating that improves soil-resistance, stain-resistance, weather-resistance, or fungal-resistance.

15. The composite solution of claim 14, wherein the porous material is selected from wood or masonry material, and a coating formed with the composition solution does not change the pigmentation and reflectivity of the substrate before coating.

16. The composite solution of claim 14, wherein the composite solution comprises 3-8 vol. % of water, 20-30 vol. % of the first solvent, 40-60 vol. % of the base chemical reagent, 10-15 vol. % of the plasticizer, and 1-5 vol. % of the bonding agent; and the composite solution is further diluted with a second solvent to a final concentration 60 to 100 vol. %.

17. The composite solution of claim 14, wherein the composite solution is stirred at the elevated temperature for ½ hour to 12 hours, and a degree of polymerization of the composite solution is equal to or less than 100.

18. The composite solution of claim 14, wherein the composite solution is prepare under acidic condition with a pH of equal to or less than 5.

19. The composite solution of claim 14, wherein the first solvent is selected from water, methanol, ethanol, n-propanol, isopropanol, n-butanol, isobutanol, ethylene glycol, glycerol acetone, acetonitrile, dioxane, tetrahydrofuran, dimethylformamide, dimethyl sulfoxide or a mixture thereof.

20. The composite solution of claim 14, wherein the composite solution further comprises a chelating agent, wherein the chelating agent is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_x R'_y R''_z$ (M = Si, Al, In, Sn or Ti; x is the integer 1, 2 or 3; y is the integer 0, 1 or 2; z is the integer 1, 2 or 3, provided that the sum of x, y and z equals 4), where R comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof; R′ comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof and R″ comprises a substituted or unsubstituted alky or alkenyl group comprising from 3 to 20 carbon atoms, or

the chelating agent is selected from an alkoxysilane, metal oxide precursor, or a combination thereof having a general formula of $M(OR)_x R'_y R''_z$ (M = Si, Al, In, Sn or Ti; x is the integer 1, 2 or 3; y is the integer 0, 1 or 2; z is the integer 1, 2 or 3, provided that the sum of x, y and z equals 4), where R comprises hydrogen, a substituted or unsubstituted alkyl or derivatives thereof; R′ comprises hydrogen, a substituted or unsubstituted alkyl or derivatives

thereof and R″ comprises a substituted or unsubstituted amine (including primary, secondary and tertiary) or thiol.