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METHOD AND MEANS FOR INCORPORATING FUNCTIONALITY INTO AN ARTICLE, AND THE ARTICLE SO PRODUCED

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(57) This invention is in the field of production of coated articles comprising glass or other brittle materials, wherein the treated article exhibits one or a plurality of functionalities. More specifically, the present invention is in the field of the production of articles with, e.g., improved strength, color, impact resistance, and decreased transmission of infrared and ultraviolet radiation by the application of silane-containing solutions to the surface of an article in order to produce an item with a surface coating containing silicon, oxygen, and carbon.

CLAIM

1. A coating formed by the deposition from a solution containing at least one silane onto a glass substrate, characterized by the impartation of at least one functionality, as hereinbefore defined, to the substrate, wherein the silane comprises $[R''(CH_2)_m]_n-Si(XR')_{4-n}$3 where n is from 0 to 3, m is from 0 to 6, X is chosen from the group consisting of oxygen, nitrogen and sulfur, R' is hydrogen or a substituted or unsubstituted saturated or unsaturated hydrocarbon group

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of between 1 and about 10 carbon atoms, and R" is chosen from the group consisting of substituted or unsubstituted cyclic and acyclic saturated and unsaturated hydrocarbons of between 1 and about 10 carbon atoms.

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COMPLETE SPECIFICATION
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Invention Title:

METHOD AND MEANS FOR INCORPORATING FUNCTIONALITY INTO AN ARTICLE, AND THE ARTICLE SO PRODUCED

Our Ref : 226442
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The following statement is a full description of this invention, including the best method of performing it known to applicant(s):

6006

METHOD AND MEANS FOR INCORPORATING FUNCTIONALITY INTO AN ARTICLE, AND THE ARTICLE SO PRODUCED

BACKGROUND OF THE INVENTION

Field of the Invention. This invention is in the field of production of coated articles comprising glass or other brittle materials, wherein the treated article exhibits one or a plurality of functionalities. More specifically, the present invention is in the field of the production of articles with, e.g., improved strength, color, impact resistance, and decreased transmission of infrared and ultraviolet radiation by the application of silane-containing solutions to the surface of an article in order to produce an item with a surface coating containing silicon, oxygen, and carbon.

Description of the Prior Art. Brittle materials generally exhibit some properties the magnitudes of which are less than desirable such as, e.g., tensile strength, impact resistance, and ability to screen the contents from inimical radiation. This manifestation can arise as the result of such factors as imperfections or small amounts of impurities in either the body or the surface of an article made of that material, or the properties inherent in the material itself. Some methods of addressing this situation include preparation of multi-layer structures to provide an article with its surface under compressive stress, and surface treatments such as polymer overcoats both to protect the surface from flaws and to provide a small additional measure of support.

It has been noted that glass is intrinsically one of the strongest materials known to man. Theoretically, standard silicate glasses should be able to support stresses as high as 14 to 20 gigapascals (2 to 3 million pounds per square inch [psi]). In practice, however, the strengths typically obtained are on the order of 70 megapascals (MPa), about 10,000 psi. The explanation of the discrepancy between predicted and measured values is the existence of surface flaws or cracks. These flaws essentially fracture the siloxane network (Si-O-Si), which is the backbone of the glass. This damage to the glass acts to concentrate any applied force, to the extent of causing catastropic failure of the glass article, typically at much lower stresses than otherwise expected. While described here for glass, this same theory can be applied to a wide variety of brittle materials not demonstrating significant plastic deformation prior to failure.

In the case of a glass container, the surface flaws or defects can originate from many sources, ranging from unmelted batch materials to scratches produced by sliding across hard surfaces, including other glass articles. In a typical container-manufacturing facility for example, the glass articles can be heavily damaged by handling from the moment they are formed. Contact with particulates and moisture in the air, other bottles, guide rails and other handling equipment, and the conveyor on which they are transported, can lead to large decreases in the strength of the container due to the flaws produced.

Researchers have long sought a means to alleviate the problems with practical glass strength. Many modifications to the forming and handling process have led to increases in the strength, but even these advances in handling still leave flaws in the surface. For this reason, considerable research effort has been directed at reducing the effect of flaws after they are inevitably formed on the object. The processes can generally be grouped into three main categories: surface treatments, thermal treatments, and surface coatings. This invention is an example of the latter, a coating being applied to the surface of the article after the strength has already been compromised.

Those skilled in the art will realize that by increasing the strength of a brittle article such as, e.g., glass, a lesser amount of material is needed in order to form an article of substantially equivalent strength and general mechanical performance. Thus, in the specific case of a glass bottle, for instance, the bottle can be lighter in weight than its untreated counterpart, or be of the same mass while exhibiting generally higher resistance to impact fracture or stress failure.

Some approaches to improving the strength of glass include Aratani et al., U.S. 4,859,636, wherein metal ions in the surface of glass are exchanged with ions of a larger radius to develop a surface compressive stress. Poole et al., U.S. 3,743,491, also develop a surface compressive stress, but provide a polymer overcoat to protect the surface from further abrasion.

Hashimoto et al., U.S. 4,891,241, treat the surface of the glass with a silane coupling agent followed by a polymer coating containing acryloyl and/or methacryloyl groups, followed by irradiation or thermal treatment to polymerize the molecules containing those groups.

While the patents described above each provide improvement to the strength of the glass so treated, they are not without shortcomings. Some of these treatments require longer times than available during manufacturing, necessitating off-line processing. There are also concerns related to worker safety and health. The use and handling of solvents, as well as the acrylate and methacrylate compounds, are of concern to the manufacturer, both from the standpoint of health and safety, and with respect to the treatment or disposal of spent materials.

Further to the foregoing, the problem of suitably treating an article for parameters other than, or in addition to, strength has heretofore required steps which may border on the uneconomical. For instance, the inclusion of a coloring medium as a coating in addition to a strengthening agent generally requires the installation of additional machinery on, e.g., a bottle-production line, with concomitant capital and labor expense. As used in this specification, the term "color" means a clear and tinted portion of the visible spectrum, or an opaque portion of the visible spectrum whether black, white or any other tint.

Other properties whose utility in brittle, and particularly glass, articles is recognized include those obtained by the use of, e.g., materials to modify the transmission of ultra-violet (UV) radiation, materials to improve the appearance of scuffed or abraded articles, lubricants and others, both individually and in combinations of two or more of the additives designed to impart the desired characteristic, or functionality.

SUMMARY OF THE INVENTION

The present invention comprises single or multi-purpose coatings and articles having coatings with one or a plurality of functions, by application of silane solutions to the surface of brittle objects, where the silane solutions comprise material having the chosen characteristics. The silane solutions comprise monomers and oligomers having silanol groups (SiOH), derived from silanes with at least one hydrolyzable moiety connected to silicon, and preferably containing three such groups.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of this invention is a glass article with a coating containing silicon, oxygen and carbon, achieved by application of a silane solution to the surface of the article; the article can have a previously deposited layer consisting of or containing materials such as, e.g., a tin-, titanium-, silicon- or other metal-oxide or metal-nitride layer, or mixtures of such materials with or without other ingredients such as dopants to modify electrical conductivity.

Another preferred embodiment of this invention comprises the production of coated brittle articles having at least one improved characteristic, by applying to the surface of the article an aqueous solution of a silane, where the silane has a plurality of alkoxy groups attached to silicon and at least one hydrocarbyl moiety bonded to silicon, and the solution can incorporate at least one group the action of which provides one or more selected functions, and thereafter curing the coating on the article. As used in this specification, the term "function" or "functionality" is used to mean a characteristic of a substrate or article which is decorative, useful or necessary for the utility of that substrate or article. Non-limiting examples of function or functionality are color, increased strength, ability to block or modify (including reflection and refraction) radiation in various parts of the electromagnetic spectrum, scratch resistance, and the ability to mask visible surface damage.

Irrespective of the presence of other functionality before or after the application of the silane solutions described herein, the silane solutions are useful in providing chosen functions to the substrate, including, without limitation herein, increased mechanical strength, a visual colorant, camouflage coating, a UV radiation modifier, a surface lubricant, an infra-red (IR) absorber or screen, reflective or anti-reflective coating for any portion of the electromagnetic spectrum from UV through IR radiation, or any combination of desired properties. As used in this specification, a "camouflage" coating is defined as a coating the application of which improves the appearance of a substrate which has been subjected to handling or other wear in such fashion as to affect deleteriously the visual appearance of an article. The impartation of modified UV- or IR-radiation characteristics comprehends increasing or decreasing the transparency of a coated article to UV or IR radiation, or changing the net refractive index of the coated substrate.

The most-preferred embodiment of this invention is the production of coated silicate-glass articles having at least one improved function or characteristic by applying to the surface of the article an aqueous solution of a silane. Examples include, e.g., lubricity of a surface, strength of a glass bottle or ceramic sheet, and diminished UV transmission into a transparent container. One or more improved characteristics can be combined by incorporating the molecular structure giving rise to that characteristic into the silane molecule or molecules, or by admixing a solution having other effective ingredients with the silane solution.

As used herein, the term "effective ingredients," in the plural or the singular, means a compound or mixture whose composition, including but not limited to a particular molecular structure, imparts generally a desired function to the treated surface. An example of an effective ingredient is an emulsion of high-molecular-weight aliphatic hydrocarbon applied to the surface of a glass container to provide a surface having greater slip than a surface not so treated. In relation to the present invention, the impartation of multiple functionality comprehends the combination of two or more characteristics into or onto a substrate, such as, e.g., improved strength and lubricity to a glass container; lubricity, visual color and UV modification to a bottle, or improved strength and camouflage ability to notch-sensitive plastic. For the purposes of this specification, a "notch-sensitive" plastic is classified as a brittle material.

The coating of this invention can be applied directly onto the previously untreated surface of an article, or applied to an exterior layer, the composition of which is the same as or different from that of the base material. One or a plurality of functionalities of a brittle article are improved by applying to the surface of the article a composition of water and silane, where the silane has a plurality of hydrolyzable groups attached to the silicon, and may have one or more organic moieties attached to the silicon as well. The water is subsequently removed, at least in part, producing a coating containing Si, O, and C. The substrate can be at any temperature above the freezing point of the solution, preferably from about 20 to about 200 degrees Celsius (°C), and most preferably from about 25 to about 130 C.

The silane solution comprises monomers or oligomers containing SiOH groups. Those skilled in the art will understand that the term "silanol" or "-SiOH group" may be technically inexact; for the purposes of this specification, those terms refer to the hydrolysis product of a silicon-containing moiety wherein one or more hydroxyl groups are attached to silicon, even if those hydroxyl groups are only in equilibrium with unreacted species or subsequent reaction products. As used herein, the term "hydrocarbyl" means a carboniferous compound with hydrogen bonded to carbon, and optionally containing substituent groups.

The silane solution contains materials chosen to provide one or more of the desired functions, either as separate materials or as appropriate groups integral with the silane moiety. As noted above, the silane moieties themselves comprise monomers or oligomers containing SiOH groups; material to impart desired functionality can be added to the silane solution, such as, e.g., a lubricity agent. Alternatively or additionally, a colorant can be incorporated into the molecular structure of the silane itself.

The preferred materials of the present invention are silanes containing at least one hydrolyzable group connected to silicon, and preferably containing a plurality of such groups, with a group or material chosen to impart the desired functionality added to the solution or being an integral part of the silane molecule. A preferred embodiment of this invention is the production of a coated article using a solution of a silane having at least two hydrolyzable groups connected to silicon. In the most-preferred embodiment, the silane is one or a plurality of alkoxysilanes, mixed with water to form an aqueous solution of species having silanol and other functional groups; the most-preferred alkoxysilanes are used in concentrations of from about 1 to about 100 percent by weight (wt.%), preferably from about 5 to about 40 wt.%, and most preferably from 7 to about 25 wt.%. It is within the scope and spirit of this invention to apply the silane without dilution.

The silane of this invention has the formula $[R''(CH_2)_m]_nSi(XR')_{4-n}$, where n is from 0 to 3, and m is from 0 to 6; preferably, m is from 0 to 3. When m is 0, the preferred R" hydrocarbon is a straight chain of length between 1 and 3, and, when m is from 2 to six, can be saturated or unsaturated, e.g., methyl, ethyl, vinyl, propyl, allyl, butadienyl and the like. These hydrocarbon chains can be substituted with groups which include, but are not limited to, entities such as straight, branched, and cyclic hydrocarbons, whether saturated or unsaturated; hydrogen; halogens; silicon and substituted silicon groups; hydroxy; carboxy; carboxylate; epoxy; cyano; alkoxy; aminoalkyl; amido; carbamyl; and combinations of these groups. The preferred groups are those which contain hydroxy, epoxy and acryloxy or methacryloxy functionality.

The XR' group is one existing as, or hydrolyzable to, a species which can react with the surface of the article being treated. The surface can contain metal-OH moieties which can condense with XR'; the preferred surface for treatment is glass which contains tin-oxygen or silicon-oxygen bonds.

The X atom can be halogen, oxygen, nitrogen, or sulfur, provided that if X is halogen, its single valence is accounted for by its bond to the silicon atom, and R' cannot be present. X is preferably oxygen. The R' group can be hydrogen, or a saturated or unsaturated hydrocarbon group of between 1 and about 10 carbon atoms, and can include oxygen, nitrogen and sulfur atoms in the chain to give ether, amino and thioether structures, and the like; R' can further include silicon and substituted silicon groups, such that the $[R''(CH_2)_m]_nSi(XR')_{4-n}$ structure is oligomeric; i.e., the R' group can be a repeating unit. The preferred carbon chain length is from 1 to about 3; the most-preferred R' group is methyl.

In the silane of this invention having the formula heretofore described, R' can, as noted, be a repeating unit. The repeat unit is preferably $[R''(CH_2)_m]_pSi(XR')_{3-p}$, formed by condensation of silanol groups, wherein R" has substituent groups chosen from the group consisting of hydroxyl, epoxy, methacryloxy, acryloxy, 4-hydroxybutyramido, 2-hydroxyamino, and dialkylacetal, p is from 1 to 2, and the other parameters are as defined above.

In a preferred embodiment of this invention, either or both R' and R" can contain or incorporate one or any combination groups for the impartation of strengthening, UV-modifying, IR-screening, or other functionality to the substrate. Where the R' group incorporates the functionality, that group may hydrolyze off from the parent silane molecule, but nevertheless remain as part of the resultant solution used to treat the substrate.

In the utility of this invention, the silane solution is prepared and allowed to stand for a period of time which can range upward from about ten minutes. While not wishing to be bound by theory, it is surmised that this aging period permits the silane molecule to hydrolyze at least partially, to provide SiOH groups which may be transient or in equilibrium with other molecular species in the solution. The SiOH groups can then interact with each other or with groups on the surface of the treated substrate.

The aged solution is applied to the surface of the substrate by spraying, brushing, dipping, immersion, or any method which will serve to provide one or a plurality of effective coatings, including, e.g., multiple dipping or spraying. The application can be at any temperature convenient to the particular process; in the case of, e.g., glassware, application of the silane solution is preferably done at the exit, or cold, end of the annealing lehr. The resultant coating is then cured by the any one or a combination of standing at ambient temperature, or the application of energy such as, e.g., IR or UV. The preferred method of curing is by heating the coated article at from about 50 to 250 degrees centigrade.

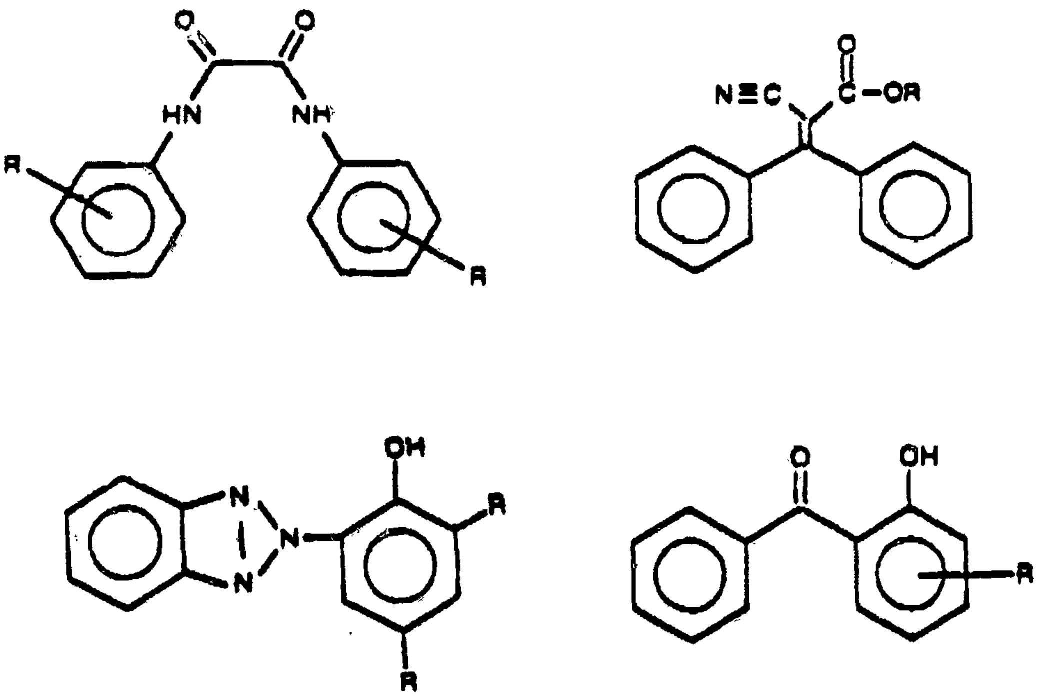
Upon the application of the basic molecule or its hydrolyzate to the surface of the material to be coated, the resulting exterior surface serves as a material which provides the chosen one or several enhancement properties through the composite structure of substrate and coating. If the group is attached to or incorporated into R', that group may be hydrolyzed off the parent silane molecule, but will nevertheless be present in the coating applied to the substrate.

For the impartation of lubricity to a brittle article coated in accordance with this invention, either or both R' and R" are six or more carbons, and include $-(CH_2)_8CH_3$, $-(CH_2)_{18}CH_3$, $-CH_2CH_2(CF_2)_5CF_3$ and similar structures for providing a slippery or lubricating exterior to the substrate.

Similarly, R' and R" can comprise the structures shown in Table 1 for materials which provide modification of UV characteristics. In these structures, R is alkyl or aryl from 1 to 10 carbons.

Table 1

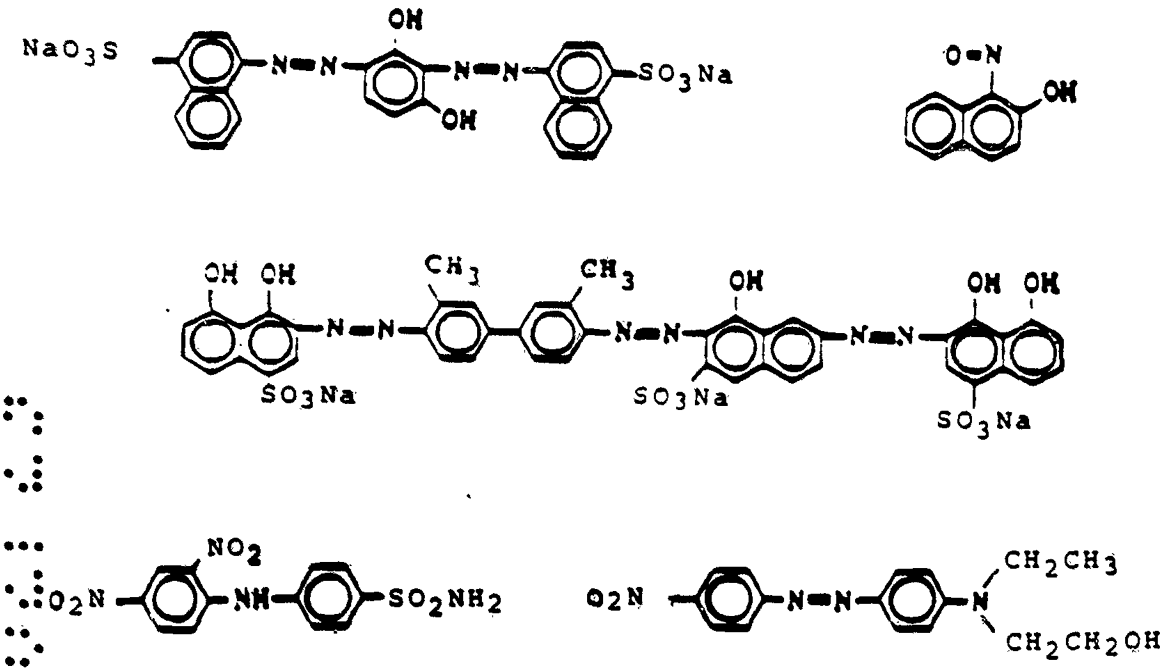
UV-Modifying Structures



Groups such as *para*-nitrosonaphthol and similar electron-rich structures provide chromophoric properties in this invention. Those groups include the materials shown in Table 2.

Table 2

Chromophoric Groups



As used in this specification, the term "solution" includes chemical solutions, suspensions, emulsions, and mixtures, any of which may exhibit complete or incomplete intermixing.

The aqueous silane solution is deposited onto the article surface by spraying, dripping, dipping, painting, or any other techniques suited to application of liquids, vapors, or aerosols. After deposition on the surface, what appears to be a condensation reaction leading to the formation of siloxane (Si-O-Si) bonds is induced by, e.g., microwave, IR, or UV irradiation or exposure to ambient or elevated temperatures at, above, or below atmospheric pressure.

Although not necessary to the utility of this invention, it is theorized that in silicate materials, notably glass, the polysiloxane linkage occurs within the coating, as well as between the coating and the surface. The silane coating, after bonding to the surface, can act, *inter alia*, to heal cracks in the surfaces by forming an Si-O-Si network across the flaw surfaces. The formation of the siloxane bonds in the region of the flaws apparently acts to provide an increase in the breaking stress of the article, e.g., a beer bottle or the like. Observed increases in strength by the application of the silane solutions of this invention have been over 350%.

By the use of the silane solutions of this invention, the incorporation into the coating on the article of a molecular portion having, e.g. a significant opacity to UV provides protection against degradation of the contents of the bottle.

The substrate can be at any temperature above the freezing point of the solution, preferably from about 20 to about 200°C, and most preferably from about 25 to about 130 C.

Those skilled in the art will realize that other compounds can be added to the silane solution for the purpose of improving the wetting, as with surfactants. The nonionic surfactants are especially useful in this regard.

As noted herein, compounds can be added to the silane solution, which compounds are capable of interaction with the silanol group to form a copolymer structure or to form inter-penetrating structures which can be used in conjunction with the silanes. As noted above, unsaturation and other molecular functionality can be incorporated into the monomeric silane structure, or added to the solution in which the silane is present. Monomers which result in polymeric structures, such as, e.g., amino-formaldehyde, epoxies, and poly-acrylates can be especially useful.

In the examples given hereinbelow, the methods of preparing and testing samples are well known to those skilled in the art, and, forming no part of the invention as such, will not be detailed.

Strengthening

Example I.

In this example, soda-lime glass rods are indented with a Vickers diamond to produce approximately 50-micro-meter (um) flaws in the surface. These rod samples are tested in bending and have average strengths of 56 MPa. Samples with identical flaws are spray-coated with a solution of 10 percent by weight (wt.%) of vinyl trimethoxysilane (VTMO) in water. The solution contains enough sulfuric acid to adjust the pH to between 3.0 and 3.4. The samples are thereafter heat-treated for 15 minutes (min.) at 200°C, and tested in bending. The average strength of these samples is found to increase from 56 MPa to 90 MPa.

Example II.

Example II is a modification of Example I. In this example, the samples are again indented rods, and the solution is 10 wt.% VTMO, acidified as set forth in Example I. This solution also contains 0.75 wt.% of a nonionic surfactant. After curing, the indented samples increase in strength from 56 MPa to 93 MPa.

Example III.

Example III is identical to Example I, with the exception that the silane used is methyltrimethoxysilane (MTMO). The control samples have an average strength of 62 MPa. Upon coating and curing, the bend strength increases to 96 MPa.

Example IV.

Example IV is a duplication of Example II, using MTMO. The average control strengths are again 62 MPa, but the strengthened samples average 103 MPa.

Examples V and VI.

Examples V and VI are duplicates of Examples I and II, respectively, with the exception that the silane used is methacryloxypropyltrimethoxysilane (MPTMO). For these examples, the average control strength is 60 MPa.

These coated samples are thermally cured as described above, but are also subjected to an additional UV irradiation in order to enhance the curing. The strengthened samples for Example V attain an average strength of 126 MPa, while those for Example VI reach 124 MPa.

Example VII.

Rectangular bars are cut from a flat disc of Al_2O_3. Half of the samples as cut are broken by bending by an Instron testing machine with a crosshead speed of 50 millimeters per minute. The average strength of the samples is 23,340 psi, equal to 163 MPa.

The balance of the samples are spray-coated with a 10% solution of CETMO containing 0.025 wt.% of a nonionic surfactant and 0.025 wt.% of polyethylene emulsion. The solution is aged for two hours at room temperature prior to its application to the surface of the bar.

The samples are thermally cured after spray-coating. The cure is 15 minutes at 125°C followed by 10 min. at 225°C. The average strength of the treated samples is 28,230 psi, or 198 MPa; the increase in strength of the treated material over the untreated samples is 21%.

Camouflage

Eample VIII.

Bottles which have been handled through a sufficient number of normal cleaning and refilling cycles to present a generally scuffed and worn appearance, are coated with a silane solution consisting of three silanes in in a solution of 10% total silanes in water. The 1:1:1 solution consists of glycidoxypropyl-trimethoxysilane (GPTMO), 2-(3,4-epoxycyclohexyl)ethyltrimethoxysilane (CETMO), and methyltrimethoxysilane (MTMO). The amount of each silane is about 3.33 wt.%. The solution contains enough sulfuric acid to bring the pH to between 3.0 and 3.4. A nonionic surfactant is added in the amount of 0.75 wt.% in order to increase wetting. The bottles so coated have the visual appearance of bottles which have been through only a minimal number of cleaning and refilling cycles.

Modification of UV Transmission

Example IX.

2-Hydroxy benzophenone, a molecule having the ability to screen UV, is incorporated into a GPTMO molecule. 1.85 grams (g) of that compound are added to 10 g of VTMO in solution, and the solution is allowed to stand at room temperature for 24 hours. The aged material is applied to a sheet of glass by dipping as set forth in Example I. After curing, the samples show a diminution in UV transmission.

Example X.

2-Hydroxy benzophenone in alcohol solution is added to the solution described with respect to Example I, and the resultant material applied to a sheet of glass as set forth in Example II. The cured samples show substantially the same diminution of transmission of UV radiation as noted in Example IX.

Lubricity

Example XI.

Example XI is identical with Example VIII, with the exception that the silane solution used is CETMO further containing a polyethylene emulsion admixed therewith, and the bottles are not subject to repeated cycles of filling and cleaning. The control samples have a slip angle about 30°; the treated bottles have slip angles of about 10°.

Example XII.

Samples of poly(methylmethacrylate) sheets are spray-coated with a solution of 10 wt.% of CETMO in water, containing also a polyethylene emulsion admixed therewith. The solution contains enough sulfuric acid to adjust the pH to between 3.0 and 3.4. The samples are thereafter heat-treated for 15 min. at 125°C., and then permitted to cool to room temperature. It is determined that the treated samples have lower friction between treated sheets than between untreated sheets.

Color

Example XIII.

A colorant comprising FD&C red #40 and FD&C red #3 is added to the coating solution containing the silanes of Example II, and the resulting material used to coat clear bottles by spraying. Upon heat-curing, the bottles have a uniform red coloring. The bottles also exhibit improved burst strength in comparison with control samples.

Those skilled in the art will understand that the cure step in the method of this invention can be effected by the application of energy of any sort and magnitude sufficient to remove, e.g., water or other non-coating reaction product from the surface of a treated article, provided that such application is not deleterious to either the glass or the coating material. The curing step, being a combined function of energy and time, can include a low magnitude of energy and a relatively long time, or the reverse, an application of energy limited as noted hereinabove, for a relatively short period of time.

Modifications and improvements to the preferred forms of the invention disclosed and described herein may occur to those skilled in the art who come to understand the principles and precepts hereof. Accordingly, the scope of the patent to be issued hereon should not be limited solely to the embodiments of the invention set forth herein, but rather should be limited only by the advance by which the invention has promoted the art.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A coating formed by the deposition from a solution containing at least one silane onto a glass substrate, characterized by the impartation of at least one functionality, as hereinbefore defined, to the substrate, wherein the silane comprises $[R''(CH_2)_m]_n$-$Si(XR')_{4-n}$ where n is from 0 to 3, m is from 0 to 6, X is chosen from the group consisting of oxygen, nitrogen and sulfur, R' is hydrogen or a substituted or unsubstituted saturated or unsaturated hydrocarbon group of between 1 and about 10 carbon atoms, and R" is chosen from the group consisting of substituted or unsubstituted cyclic and acyclic saturated and unsaturated hydrocarbons of between 1 and about 10 carbon atoms.

2. The coating of claim 1, characterized by the impartation of increased strength to the substrate.

3. The coating of claim 1, characterized by the impartation of improved lubricity to the substrate.

4. The coating of claim 1, characterized by the impartation of modified ultraviolet-radiation characteristics to the substrate.

5. The coating of claim 1, characterized by the impartation of color to the substrate.

6. The coating of claim 1, characterized by the impartation of improved appearance to the substrate.

7. The coating of claim 1, characterized by the impartation of modified infrared-radiation characteristics to the substrate.

8. The coating of claim 1, characterized by the impartation of improved reflection to the substrate.

9. The coating of claim 1, characterized by the impartation of improved anti-reflection to the substrate.

10. The coating of claim 1 characterized by the impartation of multiple functionality to the substrate.

11. The coating of any one of claims 1 to 10 wherein the substrate is a silicate glass.

12. The coating of any one of claims 1 to 11 wherein the silane solution is an aqueous solution.

13. The coating of any one of claims 1 to 12 wherein the silane solution is aged.

14. The coating of claim 13 wherein the silane solution is aged for at least one hour.

15. The coating of any one of claims 1 to 14 wherein X is halogen.

16. The coating of any one of claims 1 to 14 wherein R" is a hydrocarbon having from 1 to 3 carbon atoms when m is zero.

17. The coating of any one of claims 1 to 14 wherein m is zero and R" is chosen from the group consisting of methyl, ethyl, propyl, vinyl, allyl, butadienyl, cyclopentyl and cyclohexyl.

18. The coating of any one of claims 1 to 14 wherein n is 1.

19. The coating of any one of claims 1 to 14 wherein R" has substituent groups chosen from the group consisting of hydroxyl, epoxy, methacryloxy, acryloxy, 4-hydroxybutyr-amido, 2-hydroxyamino, and dialkylacetal.

20. The coating of any one of claims 1 to 14 wherein R' contains silicon.

21. The coating of any one of claims 1 to 14 wherein R' is the repeating unit $[R''(CH_2)_m]_pSi(XR'')_{3-p}$, and p is 1 or 2.

22. An ~~improved~~ glass article having a coating obtained from the application of at least ~~best~~ one silane thereon so as to impart enhanced projection to a substrate by the coating, wherein the silane comprises $[R''(CH_2)_m]_n$-$Si(XR')_{4-n}$, where n is from 0 to 3, m is from 0 to 6, X is chosen from the group consisting of oxygen, nitrogen and sulfur, R' is hydrogen or a substituted or unsubstituted saturated or unsaturated hydrocarbon group of between 1 and about 10 carbon atoms, and R" is chosen from the group consisting of substituted or unsubstituted cyclic and acyclic saturated and unsaturated hydrocarbons of between 1 and about 10 carbon atoms.

23. The article of claim 22, characterized by the impartation of increased strength to the substrate.

24. The article of claim 22, characterized by the impartation of improved lubricity to the substrate.

25. The article of claim 22, characterized by the impartation of modified ultraviolet-radiation

characteristics to the substrate.

26. The article of claim 22, characterized by the impartation of color to the substrate.

27. The article of claim 22, characterized by the impartation of improved appearance to the substrate.

28. The article of claim 22, characterized by the impartation of modified infrared-radiation characteristics to the substrate.

29. The article of claim 22, characterized by the impartation of improved reflection to the substrate.

30. The article of claim 22, characterized by the impartation of improved anti-reflection to the substrate.

31. The article of any one of claims 22 to 30 wherein the glass contains silicon.

32. A method of imparting at least one functionality, as hereinbefore defined, to a brittle substrate by applying to the surface thereof a coating comprising a solution of at least one silane, and thereafter curing the coating on the substrate, wherein the silane comprises $[R"(CH_2)_m]_nSi(XR')_{4-n}$ where n is from 0 to 3, m is from 0 to 6, X is chosen from the group consisting of oxygen, nitrogen and sulfur, R' is hydrogen or a substituted or unsubstituted saturated or unsaturated hydrocarbon group of between 1 and about 10 carbon atoms, and R" is chosen from the group consisting of substituted or unsubstituted cyclic and acyclic saturated and unsaturated hydrocarbons of between 1 and about 10 carbon atoms.

33. The method of claim 32, characterized by the impartation of increased strength to the substrate.

34. The method of claim 32, characterized by the impartation of improved lubricity to the substrate.

35. The method of claim 32, characterized by the impartation of modified ultraviolet-radiation characteristics to the substrate.

36. The method of claim 32, characterized by the impartation of color to the substrate.

37. The method of claim 32, characterized by the impartation of improved appearance to the substrate.

38. The method of claim 32, characterized by the

impartation of modified infrared-radiation characteristics to the substrate.

39. The method of claim 32, characterized by the impartation of improved reflection to the substrate.

40. The method of claim 32, characterized by the impartation of improved anti-reflection to the substrate.

41. The method of any one of claims 32 to 40 wherein the solution is aged.

42. The method of any one of claims 32 to 41 wherein the coating comprises from about 2 to about 80 wt.% of a silane in solution.

43. The method of claim 42 wherein the coating comprises from about 7 to about 50 wt.% of a silane in solution.

44. The method of any one of claims 32 to 43 comprising dipping the substrate in the silane solution.

45. The method of any one of claims 32 to 43 comprising spraying the substrate with the silane solution.

46. The method of any one of claims 32 to 45 wherein the coated substrate is inorganic.

47. The method of any one of claims 32 to 46 wherein the coated substrate is a glass.

48. The method of claim 47 wherein the glass contains silicon.

49. The method of any one of claims 32 to 48 wherein curing comprises maintaining the coated substrate at an elevated temperature for from 1 minute to 1 hour.

50. The method of any one of claims 32 to 48 wherein curing comprises maintaining the coated substrate at ambient temperature.

51. The method of any one of claims 32 to 48 wherein the cure step comprises applying energy to the coating on the substrate.

52. The method of any one of claims 32 to 48 wherein the cure step comprises heating the coating on the substrate.

53. A coating substantially as hereinbefore described with reference to any one of Examples I to XIII.

54. A method substantially as hereinbefore described

with reference to any one of Examples I to XIII.

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METHOD AND MEANS FOR INCORPORATING FUNCTIONALITY INTO AN ARTICLE, AND THE ARTICLE SO PRODUCED

ABSTRACT OF THE DISCLOSURE

An improvement in the functional properties of a brittle substrate such as glass is achieved by application of an aqueous solution of a silane to the surface of the substrate. The solution comprises monomeric materials containing silanols, and incorporates at least one function such as strength, color and radiation modification. The materials of principal interest are silanes with at least one alkoxy group connected to silicon, and preferably having three alkoxy groups. The alkoxy silanes are dissolved in an aqueous solution in concentrations of from 1 to 100% by weight. After application, the coatings are cured. Coated articles are provided with useful characteristics.

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Case No. 3251