An alternative offline coating method is to use sol-gel coating on ATO glass. However, the sol-gel coating requires special treatment of glass and extended curing time. In addition, this method does not offer good self-cleaning effects, as such a coating process results in less photo-catalytic activity of the material.

Tri-functional glass capable of filtering solar-radiation in both the UV and IR spectrum range and exhibiting self-cleaning functions have been less explored. Despite the fact that an online coating method is able to produce multifunctional glass, there are still issues associated with the difficulty in controlling the thickness and high production cost by this method.

Considering the drawbacks of the present technology to manufacture tri-functional glass, there is a need to provide a film coating on a surface, such as glass or plastic, that overcomes or at least partially ameliorates, one or more of the disadvantages described above.

Summary

There is provided a film for coating a surface, the film comprising a first layer of first core shell nanoparticles, wherein the core of the first core shell nanoparticles comprises a first oxide of a metal or an alloy thereof, selected to absorb UV- and IR- radiation; and wherein the shell of the first core shell nanoparticles comprises a first silane, the first core shell nanoparticle being dispersed in a first transparent substrate. In one aspect, the present disclosure refers to a film for coating a surface, the film comprising a first layer of first core shell nanoparticles, wherein the core of the first core shell nanoparticles comprises a first oxide of a metal or an alloy thereof, selected to absorb UV- and IR- radiation; and the shell of the first core shell nanoparticles comprises a first silane, the first core shell nanoparticle being dispersed in a first transparent substrate; a second layer of second core shell nanoparticles, wherein the core of the second core shell nanoparticles comprises a second oxide of a metal or an alloy thereof, selected to catalyze the degradation of organic molecules; and the shell of the second core shell nanoparticles comprises a second silane, the second core shell nanoparticles being dispersed in a second transparent substrate.

In an example, the film as described herein further comprises a second layer of second core shell nanoparticles, wherein the core of the second core shell nanoparticles comprises a second oxide of a metal or an alloy thereof, selected to catalyze the degradation of organic molecules; and, the shell of the second core shell nanoparticles comprises a second silane, the second core shell nanoparticles being dispersed in a second transparent substrate.

Advantageously, the film may be capable of reducing transmittance of solar radiation, both in the UV- and IR range. That is, the film may be capable of absorbing solar radiation, both in the UV- and IR-range, while permitting the transmittance of radiation in the visible range. Advantageously, the film may be capable of reducing the transmission of heat by absorbing IR radiation and decreasing the transmittance of IR radiation. Advantageously, the film may be capable of reducing transmittance of harmful UV-radiation by absorbing UV-radiation. Further

advantageously, the film may be capable of permitting transmittance of radiation in the visible range, therefore ensuring that there is no dimming of visible light transmitted through the film.

More advantageously, the film may also have self-cleaning capabilities. The film may be capable of photo-catalysing the degradation of organic dirt or organic molecules, thereby maintaining a clean surface on the film without requiring physical scrubbing or wiping of the surface.

Advantageously, the film comprising the second layer may be multifunctional. That is, by having a second layer of second core shell nanoparticles, the film may simultaneously be capable of self-cleaning, reducing the transmission of UV-radiation and reducing the transmission of IR-radiation. Further advantageously, the properties of the two films may result in synergistic enhancement of the advantageous properties of each film disclosed above.

Further advantageously, the film may be clear, transparent, smooth and uniform. More advantageously, the film may be thin, and the thickness of the film may be uniform, compared to conventional films where it is difficult to control the thickness and uniformity of the films. Further advantageously, the thickness of the film may be easily varied depending on the required performance of the film. These properties of the film (transparent, clear, uniform, smooth and thin) may make the film suitable for applications on transparent and surfaces such as window glass and plastics.

There is provided a method for coating a surface with a film, the method comprising the steps of: (a) providing a first core shell nanoparticle; (b) mixing the first core shell nanoparticle with a solvent and a substrate to form a first coating solution; (c) contacting the first coating solution with the surface to form a first layer of film; and, (d) heating the first layer of film on the surface with infra-red radiation to obtain a cured first layer of film for coating a surface. In another aspect, the present disclosure refers to a method for coating a surface with a film, the method comprising the steps of: (a) providing a first core shell nanoparticle; (b) mixing the first core shell nanoparticle with a solvent and a substrate to form a first coating solution; (c) contacting the first coating solution with the surface to form a first layer of film; (d) heating the first layer of film on the surface with infra-red radiation to obtain a cured first layer of film for coating a surface; (e) providing a second core shell nanoparticle; (f) mixing the second core shell nanoparticle with a solvent and a substrate to form a second coating solution; and (g) vaporizing the second coating solution; and (h) depositing vapors of the second coating solution onto the first layer of the film to provide a second layer of film; to obtain a cured second layer of film for coating a surface.

Advantageously, the method may enable fast vaporization of the solvent and therefore fast curing of the film by using IR-irradiation. Further advantageously, the IR-irradiation may be achieved by using an IR-heating lamp. Advantageously, by intermittently turning the IR-heating lamp on and off, the surface temperature of the film may be tuned and controlled. Further advantageously, the IR-heating lamp may be rotated over the coated surface to reduce accumulated heat at a specific area of the coated surface. Advantageously, a faster curing process may be achieved when the temperature of the surface is kept at optimal temperature at the same time maintaining the flowability of the coating solution. Advantageously, the method as disclosed above using infra-red radiation may overcome the disadvantages of conventional curing processes which typically take longer than 12 hours to complete.

Further advantageously, the method as disclosed above may overcome the issue of fogging and misting of the film encountered in commercial coating processes. During commercial curing processes, heat is used to shorten the curing process. However, heating usually results in tiny “holes” forming on the surface of the film, and hence the surface of the film is not smooth. Advantageously, by using infra-red radiation in the method as disclosed above, a smooth surface of the film may be achieved.

Advantageously, the method may enable deposition of a second layer of second core shell nanoparticles on a surface using spray-cast coating, where the coating solution is vaporized into a mist through a high power spraying system, leading to the formation of a thin film layer on the

surface. Advantageously, the method may enable the formation of a thin film having a uniform thickness on the surface of the first layer of film.

Advantageously, the method may enable offline production of glass panels, circumventing the need to treat the glass panels during production, before the glass has cooled. This provides flexibility in terms of the manufacture of the coated glass as well as time- and cost-efficiency.

Further advantageously, the method may employ wet-chemistry unlike conventional techniques, which is 4 times more efficient than conventional techniques, resulting in overall cost reduction. Due to the superior dispersibility of the core shell nanoparticles as discussed above, very little nanoparticle loading may be required to achieve the advantageous features as disclosed above. In addition, less solvent may be required to achieve a uniform dispersion, no mechanical stirring of the dispersion is required and the use of a dispersant is not required, resulting in efficient

Claims

1. A film for coating a surface, the film comprising:

a) a first layer of first core shell nanoparticles, wherein the core of the first core shell nanoparticles comprises a first oxide of a metal or an alloy thereof, selected to absorb UV- and IR- radiation; and,

the shell of the first core shell nanoparticles comprises a first silane, the first core shell nanoparticle being dispersed in a first transparent substrate;

b) a second layer of second core shell nanoparticles, wherein the core of the second core shell nanoparticles comprises a second oxide of a metal or an alloy thereof, selected to catalyze the degradation of organic molecules; and,

the shell of the second core shell nanoparticles comprises a second silane, the second core shell nanoparticles being dispersed in a second transparent substrate.

2. The film according to claim 1, wherein the metal is selected from Group 3, Group 4, Group 5, Group 6, Group 10, Group 11, Group 12, Group 13 or Group 15 of the Periodic Table of Elements.

3. The film according to claim 2, wherein the metal is selected from the group consisting of titanium, zinc, tin, antimony or any mixtures thereof.

4. The film according to any one of the preceding claims, wherein the core of the first core shell nanoparticle of the first layer comprises an oxide of a metal alloy.

5. The film according to any one of the preceding claims, wherein the core of the first core shell nanoparticle of the first layer is antimony tin oxide.

6. The film according to any one of the preceding claims, wherein the core of the second core shell nanoparticle of the second layer comprises an oxide of a metal.

7. The film according to any one of the preceding claims, wherein the silane has the following Formula (I):

$$R^1\text{-}(CH_2)_n\text{-}Si(OH)_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{ Formula (I)}$$

wherein,

R1 is selected from the group consisting of amino, glycidyl, mercapto or any mixtures thereof; and,

n is an integer from 1 to 10.

8. The film according to claim 7, wherein R^1 is a mercapto group.

9. The film according to any one of claims 7 and 8, wherein n is 3.

10. The film according to any one of claims 7 to 9, wherein the silane is (3-mercaptopropyl)trimethoxysilane or hydrolyzed (3-mercaptopropyl)trimethoxysilane.

11. The film according to any one of the preceding claims, wherein the silane is dimerized or polymerized.

12. The film according to any one of the preceding claims, wherein the first layer and the second layer independently comprises an organic binder.

13. The film according to claim 12, wherein the organic binder is selected from the group consisting of acrylic, epoxy, polyurethane or any mixtures thereof.

14. The film according to any one of the preceding claims, wherein the first layer and the second layer independently comprises a hardener.

15. The film according to any one of the preceding claims, wherein the thickness of the first layer is in the range of about 1 µm to about 7 µm.

16. The film according to any one of the preceding claims, wherein the thickness of the second layer is in the range of about 25 nm to about 300 nm.

17. The film according to any one of the preceding claims, wherein the first layer comprises the first core shell nanoparticles in the range of about 1 wt% to about 5 wt%.

18. The film according to any one of the preceding claims, wherein the core shell nanoparticles have a diameter in the range of about 10 nm to about 150 nm.

19. A method for coating a surface with a film, the method comprising the steps of:

a. providing a first core shell nanoparticle;

b. mixing the first core shell nanoparticle with a solvent and a substrate to form a first coating solution;

c. contacting the first coating solution with the surface to form a first layer of film;

d. heating the first layer of film on the surface with infra-red radiation to obtain a cured first layer of film for coating a surface;

e. providing a second core shell nanoparticle;

f. mixing the second core shell nanoparticle with a solvent and a substrate to form a second coating solution;

g. vaporizing the second coating solution; and

h. depositing vapors of the second coating solution onto the first layer of the film to provide a second layer of film; to obtain a cured second layer of film for coating a surface.