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(54) Title: SELF-CLEANING UV REFLECTIVE COATING

(57) Abrégé/Abstract:
A photo-catalytic overcoat on a UV reflective paint layer is employed to maintain high reflectance for long periods of time by continuously removing organic films when exposed to UV light. Advantageously, nano-particles comprising the photo-catalytic overcoat are composed of a semiconductor material that lead to the production of oxygen and hydroxyl free radicals when illuminated with UV light in the presence of water vapor. Some of these free radicals oxidize organic surface films, converting the surface films into gaseous H_2O and CO_2. This reduces the amount of organic deposits on the surface of the reflective paint layer.

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(54) Title: SELF-CLEANING UV REFLECTIVE COATING

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SELF-CLEANING UV REFLECTIVE COATING

FIELD OF THE INVENTION

[0001] The present invention relates to ultra-violet light (UV) reflective coatings and, in particular, to a self-cleaning UV reflective coating.

BACKGROUND OF THE INVENTION

[0002] Often Ultra-Violet (UV) light is used to remove unwanted organic material, such as viruses, bacteria and other bio-aerosols, from air or water. In the applicant's previously filed US Patent Application, Serial No. 09/822,886 (hereby incorporated herein by reference), an air purifier is described that uses UV light. Contaminated air enters such a device and is subject to UV light from one or more lamp sources. The air that leaves such a device is significantly reduced in unwanted organic material.

[0003] To increase efficiency, the UV produced by the sources within the air purifier is preferably not absorbed by the inner surfaces but, rather, is reflected. Often inner surfaces of such air purifiers are made of aluminum to provide a suitable amount of UV reflection. However, it is known in UV air purifiers that, as a consequence of the actions of the purifier, organic deposits (or films) may be formed on various surfaces within the purifier, including the UV light reflective surfaces. Such air purifiers rely on those surfaces to maintain high reflectance for maximum efficacy. Normally however, as the organic deposits build up, the reflectance of these surfaces is reduced.

[0004] Traditionally, the build up of organic deposits has not been a concern of those who own and operate air purification devices of the type described above. However, where such a build up is enough to reduce the reflectance of the inner surfaces and thereby the efficacy of the filter, is becomes clear that a need exists for a surface that can maintain high reflectance in a UV purifying environment for a longer period of time than provided by typical surfaces.

SUMMARY OF THE INVENTION

[0005] A photo-catalytic overcoat on a UV reflective surface is employed to maintain high reflectance for long periods of time by continuously removing organic films when exposed to UV light. Advantageously, the photo-catalytic overcoat is composed of nano-particles that cover a small proportion of the UV reflective surface. The nano-particles are made of a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with UV light in the presence of water. Some of these free radicals oxidize surface films, converting the surface films into gaseous H_2O and CO_2. This reduces the amount of organic deposits on the surface of the reflective paint layer.

[0006] In accordance with an aspect of the present invention there is provided a coating for a UV reflective substrate. The coating includes a plurality of nano-particles of a photo-catalytic material on the substrate, where the photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with UV light in the presence of oxygen.

[0007] In accordance with another aspect of the present invention there is provided a method of applying a self-cleaning UV reflective coating to a substrate. The method includes spraying the substrate with a plurality of nano-particles of a photo-catalytic material, where the photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with UV light in the presence of oxygen.

[0008] In accordance with a further aspect of the present invention there is provided an ultra-violet light reflective coating for a substrate. The coating includes a layer of ultra-violet light reflective paint and a plurality of nano-particles of a photo-catalytic material on the layer, where the photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with ultra-violet light in the presence of water.

[0009] In accordance with a still further aspect of the present invention there is provided a method of applying a self-cleaning UV reflective coating to a substrate. The method includes coating the substrate with a reflective paint and before the

reflective paint dries, spraying the reflective paint with nano-particles of a photo-catalytic material, where the photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with ultra-violet light in the presence of water.

[0010] In accordance with an even further aspect of the present invention there is provided an ultra-violet irradiating device. The device includes a source of ultra-violet light, a substrate having an ultra-violet light reflective surface and a plurality of nano-particles of a photo-catalytic material on the surface of the substrate, where the photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with ultra-violet light in the presence of oxygen.

[0011] In accordance with still another aspect of the present invention there is provided a solution for use in coating a UV reflective surface including about one percent-by-weight of titanium oxide particles.

[0012] Other aspects and features of the present invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In the figures which illustrate example embodiments of this invention:

[0014] FIG. **1** illustrates a cross-section of a self-cleaning UV reflective coating exemplary of an embodiment of the present invention; and

[0015] FIG. **2** illustrates a cross section of a small portion of the coating of FIG. **1** to demonstrate the self-cleaning operation of an embodiment of the present invention.

DETAILED DESCRIPTION

[0016] A cross-section of a self-cleaning UV reflective coating **100** exemplary of the present invention is illustrated in FIG. **1**. A surface **112** of a substrate layer **102** is coated with a primer layer **104**, which layer is then coated with a UV reflective paint layer **106**. The UV reflective paint layer **106** has embedded in its upper surface nano-particles of a photo-catalytic semiconductor material, an exemplary nano-particle of which is indicated at **108**.

[0017] In overview, nano-particles **108** are dispersed over the surface of the UV reflective paint layer **106**. These nano-particles **108** are composed of a photo-catalytic semiconductor material that leads to the production of oxygen and hydroxyl free radicals when illuminated with UV light in the presence of water vapor. Some of these free radicals oxidize surface films, converting the surface films into gaseous H_2O and CO_2. This reduces the amount of the organic deposits on the surface of the reflective paint layer **106**. For minimum catalytic activity, the semiconductor material is ideally highly UV absorbing, however, this necessitates a method of application that minimizes the impact on the reflectance of the UV reflective coating.

[0018] It has long been accepted that UV reflective paint may be made through the use of barium sulfate crystals. See, for instance, United States Patent No. 3,957,675, issued May 18, 1976 to Schutt, hereby incorporated herein by reference, for a discussion of appropriate choices for a binder. Further, consider United States Patent No. 5,246,687, issued September 21, 1993 to Gorre, also hereby incorporated herein by reference, for a preparation of barium sulfate that provides a high purity, which is of particular interest when preparing a UV reflective coating.

[0019] It is also known to use a photo-catalytic semiconductor material, such as TiO_2, to coat surfaces so that the coated surfaces may be self-cleaning. For a full discussion of the self-cleaning properties afforded a surface through the application of TiO_2, see Dr. Akira Fujishima, et al., "TiO_2 Photocatalysis Fundamentals and Applications", BKC, Inc., May 1999. Briefly, the excitation of TiO_2 by UV radiation in

the presence of water vapor leads to the production of OH and O_2^- free radicals according to the following reactions:

$$UV\ (@\ 254\ nm) + TiO_2 \xrightarrow{H_2O} OH + O_2^- .$$

The free radicals then interact with any organic deposits on the coated surface. Where the organic deposits are represented by the character "R", the following reactions describe the combination of these free radicals and organic deposits:

$$nOH + R \Rightarrow xH_2O + yCO_2$$

$$nO_2^- + R \Rightarrow xH_2O + yCO_2 .$$

[0020] When considering a TiO_2 coating on a layer of UV reflective paint, attention must be paid to the properties of TiO_2. In particular, TiO_2 is absorptive of UV. Thus, while historically TiO_2 has proven useful as a self-cleaning coating for ceramic tile, glass and mirrors among other substances, its usefulness in relation to UV reflective coatings was not apparent.

[0021] Returning to FIG. **1**, the reflective paint layer **106** includes particles of a scattering material and a binding material. An exemplary composition consists of about 85 percent-by-weight barium sulfate 300 nm crystals and about 15 percent-by-weight of a 40 percent colloidal silica solution. These materials may be combined in a ball mill for 30 minutes of grinding. The components of the reflective paint layer **106** are chosen so that the reflective paint layer **106** is not reactive with the free radicals formed through the photo-catalytic action of the nano-particles **108**. The scattering material used for the reflective paint layer **106** is selected for maximum scattering of incident optical energy. In choosing a suitable size for the particles (e.g., the 300 nm crystals), consideration must be given to a desired refractive index and the shape of the particles of scattering material. In general, the size for the particles will range from 20% to 200% of the wavelength of the light to be reflected. The binding material, colloidal silica in the above case, for the reflective paint layer **106** is selected for minimum absorbance at the wavelength to be reflected.

[0022] The reflective paint layer **106** may be applied to a substrate **102** of aluminum, galvanized steel or plastic (polyethylene) as follows:

[0023] If the substrate **102** is aluminum, the surface **112** may be pre-cleaned with a phosphoric acid based cleaner, such as ALUMIPREP® 33 marketed by U.S. Paint Corporation of St. Louis, MO, then rinsed with distilled water. The cleaning action may comprise spraying the substrate **102** with the cleaner, washing the substrate **102** with the cleaner or dipping the substrate **102** in the cleaner. Abrasion, for additional cleaning, is optional. Alternatively, the surface **112** can be pre-cleaned with a CO_2 liquid spray. If the substrate **102** is galvanized steel, the surface **112** may be degreased with an organic solvent, such as acetone, or liquid CO_2. If the substrate **102** is plastic, the surface **112** may be pre-cleaned (i.e., sprayed, dipped) with isoproponal, then dried. Additionally, ultrasonic cleaning methods and agitation may be part of the above cleaning processes.

[0024] After preparation of the substrate surface, and before the application of the reflective paint layer **106**, a primer layer **104** may be applied. The primer layer **104**, though not entirely necessary, improves the adhesion of the reflective paint layer **106** to the substrate **102** and protects the substrate **102** from direct oxidization by free radicals. The primer layer **104** may be provided as a 40 percent-by-weight solution of 25 nm colloidal silica solution, spread over the surface **112** in a thin layer preferably 25 to 100 nm thick. This primer layer **104** provides a protective silica film over the underlying surface **112** which protects the surface **112** from direct oxidization by free radicals. If the substrate **102** is plastic, the surface **112** may be coated with a mixture of 25 nm silica solution combined with aluminum powder (10 percent-by-weight) to provide a UV-opaque coating.

[0025] After the surface **112** has been primed as above, the surface **112** is immediately coated with the reflective paint layer **106**. The reflective paint layer **106** is coated on the primer layer **104** by dipping, spraying or brushing to a layer thickness of 100 to 400 µm.

[0026] Before the reflective paint layer **106** is allowed to dry, the reflective paint layer **106** is over coated with the photo-catalytic material as follows:

[0027] A solution of about one percent-by-weight of TiO_2 nano-particles is combined with water with or without a suspension agent such as colloidal silica. This

solution is aerosolized in a collision nebulizer so that nano-particles of TiO_2 are formed at the nozzle of the nebulizer. These nano-particles are sprayed over the surface of the wet reflective paint layer **106**. The spray rate is controlled so that the area coverage of the TiO_2 over the reflective paint layer **106** is less than about one percent.

[0028] Preferably, the nano-particles **108** have a size that is less than one tenth of the UV wavelength to be reflected. For example, where the UV wavelength to be reflected is centered at 254 nm, a nano-particle size of about 25 nm is appropriate, for instance, Titandioxid P 25 from Degussa of Dusseldorf, Germany. This size makes the nano-particles **108** nearly invisible to the UV light. Smaller particles have a further advantage of being closer together than larger particles for the same percentage of surface coverage. This proximity benefits the self-cleaning process in that, in general, the distance the free radicals are required to travel is reduced. The self-cleaning action of the nano-particles **108** may be increased through the use of larger particles or a higher percentage coverage, however, these increases come at the cost of increased UV absorption. In practical terms, the size of particle is limited to a range of 0.5 nm to 1 000 nm while the percentage of coverage may range between 0.01% and 5.0%.

[0029] After coating with the nano-particles, the coating **100** is air dried at about 50°C for 30 minutes, then baked at a temperature in the range from about 50°C to about 350°C for one hour or longer.

[0030] The operation of the coating is illustrated in FIG. **2**. UV light strikes the photo-catalytic nano-particles **108**, in the presence of water vapor, and OH and O_2^- free radicals are created. These free radicals migrate to the surface of the reflective paint layer **106** by normal kinetic processes. Some of these free radicals oxidize surface films (often polymer chains of R groups, here indicated at **210**), thereby converting the polymer chains **210** into gaseous H_2O and CO_2, which drift away. This process tends to remove organic deposits from the surface of the reflective paint layer **106**.

[0031] Since non-soluble materials are used for the preparation of the layers (**104**, **106**), the coating **100** can be made water resistant. This makes the coating **100** suitable for high humidity or underwater applications.

[0032] The coating **100** can be applied to a multi-pass UV reflective cavity for UV exposure of air or water. Such a system takes advantage of the gain equation:

$$G = \frac{1}{1-R}$$

Where G is the optical gain of the cavity and R is the average reflectance of the cavity.

[0033] Such coatings may also be used in UV treated air conditioning and other heating, ventilation and air conditioning components. Such components such as a coil pains and coil blades can be made simultaneously UV reflective, which enhances a germicidal effect, and self-cleaning, which destroys organic deposits left by mold or bacteria.

[0034] In review, nano-particles **108** may be dispersed over the reflector so that they cover a small fraction of the reflector surface. The small amount of UV absorbed by the nano-particles **108** results in a photo catalytic process forming free radicals such as OH and O_2^-. Normal kinetic processes detach the free radicals formed on the surface of the nano-particles **108** and carry the free radicals over the adjacent surface of the reflective paint layer **106**. These free radicals oxidize organic compounds on the surface of the reflective paint layer **106** converting the free radicals into gaseous H_2O and CO_2 that float away, rendering the surfaces clean and highly reflective.

[0035] As will be apparent to a person skilled in the art, other scattering materials, e.g., aluminum oxide, may be used in making the reflective paint layer **106**.

[0036] Furthermore, embodiments of the present invention may be realized without the reflective paint layer **106**. With an appropriate form of adhesion, such as a thin, UV transparent glue, a coat of the nano-particles **108** may be applied directly to a UV reflective surface, such as aluminum. Such a form of adhesion would

necessarily allow the surface to remain suitably UV reflective while not significantly hindering the reactions catalyzed by the nano-particles **108**.

[0037] Other modifications will be apparent to those skilled in the art and, therefore, the invention is defined in the claims.

We claim:

1. A coating for a UV reflective substrate, comprising:

a plurality of nano-particles of a photo-catalytic material on said substrate, where said photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with UV light in the presence of oxygen.

2. The coating of claim 1 wherein said plurality of nano-particles are partially embedded in said substrate.

3. The coating of claim 1 wherein said nano-particles cover a sufficiently small percentage of said substrate so as to not materially affect UV reflectance.

4. A method of applying a self-cleaning UV reflective coating to a substrate, said method comprising:

spraying said substrate with a plurality of nano-particles of a photo-catalytic material, where said photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with UV light in the presence of oxygen.

5. An ultra-violet light reflective coating for a substrate comprising:

a layer of ultra-violet light reflective paint; and

a plurality of nano-particles of a photo-catalytic material on said layer, where said photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with ultra-violet light in the presence of water.

6. The coating of claim 5 wherein said plurality of nano-particles are partially embedded in said substrate.

7. The coating of claim 5 wherein said plurality of nano-particles cover about one percent of a surface area of said layer of reflective paint.

8. The coating of claim 7 wherein said photo-catalytic material is TiO_2.

9. The coating of claim 8 wherein said layer has a thickness of 100 to 400 μm.

10. The coating of claim 9 wherein said reflective paint comprises barium sulfate crystals and a colloidal silica solution.

11. The coating of claim 10 wherein said reflective paint comprises about 85 percent-by-weight barium sulfate 300 nm crystals and about 15 percent-by-weight of 40 percent colloidal silica solution.

12. The coating of claim 5 further comprising a primer layer between said reflective paint and said substrate, said layer protecting said substrate from direct oxidization by free radicals.

13. The coating of claim 12 where said substrate is aluminum and said primer layer is a 40 percent-by-weight solution of 25 nm colloidal silica solution.

14. The coating of claim 13 wherein said primer layer has a thickness of 25 to 100 nm.

15. The coating of claim 12 where said substrate is galvanized steel and said primer layer is a 40 percent-by-weight solution of 25 nm colloidal silica solution.

16. The coating of claim 12 where said substrate is plastic and said primer layer is a mixture of 25 nm silica solution combined with aluminum powder.

17. The coating of claim 16 wherein said plastic is polyethylene.

18. A method of applying a self-cleaning UV reflective coating to a substrate, said method comprising:

coating said substrate with a reflective paint; and

before said reflective paint dries, spraying said reflective paint with nano-particles of a photo-catalytic material, where said photo-catalytic material is a

semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with ultra-violet light in the presence of water.

19. The method of claim 18 further comprising, before said coating, applying a protective film over said substrate.

20. The method of claim 18 wherein said photo-catalytic material is TiO_2.

21. The method of claim 20 further comprising:

forming a solution of TiO_2 with water; and

aerosolizing said solution of TiO_2 with water for said spraying.

22. The method of claim 21 where said solution of TiO_2 with water further comprises a suspension agent.

23. The method of claim 22 where said suspension agent is colloidal silica.

24. The method of claim 23 wherein said solution of TiO_2 with water has about one percent-by-weight of TiO_2.

25. The method of claim 18 where a rate of said spraying is controlled so that coverage of said TiO_2 over said reflective paint is less than about one percent.

26. The method of claim 18 further comprising air drying said coating at about 50°C for about 30 minutes.

27. The method of claim 26 further comprising baking said coating at between about 50°C and about 350°C for at least one hour.

28. The method of claim 18 further comprising, before said applying, pre-cleaning said substrate.

29. The method of claim 28 wherein said substrate is aluminum and said pre-cleaning comprises:

applying a phosphoric acid based cleaner; and

rinsing with distilled water.

30. The method of claim 28 wherein said substrate is aluminum and said pre-cleaning comprises spraying said substrate with CO_2 liquid.

31. The method of claim 28 wherein said substrate is galvanized steel and said pre-cleaning comprises degreasing said substrate with an organic solvent.

32. The method of claim 28 wherein said substrate is plastic and said pre-cleaning comprises spraying said substrate with isoproponal.

33. A ultra-violet irradiating device comprising:

a source of ultra-violet light;

a substrate having an ultra-violet light reflective surface; and

a plurality of nano-particles of a photo-catalytic material on said surface of said substrate, where said photo-catalytic material is a semiconductor material that leads to production of oxygen and hydroxyl free radicals when illuminated with ultra-violet light in the presence of oxygen.

34. The device of claim 32 wherein said source emits ultra-violet light at about 254 nanometers and a size of said nano-particles is about 25 nanometers.

35. A solution for use in coating a UV reflective surface comprising about one percent-by-weight of titanium oxide particles.

36. The solution of claim 35 further comprising a suspension agent.

37. The solution of claim 36 wherein said suspension agent is colloidal silica.

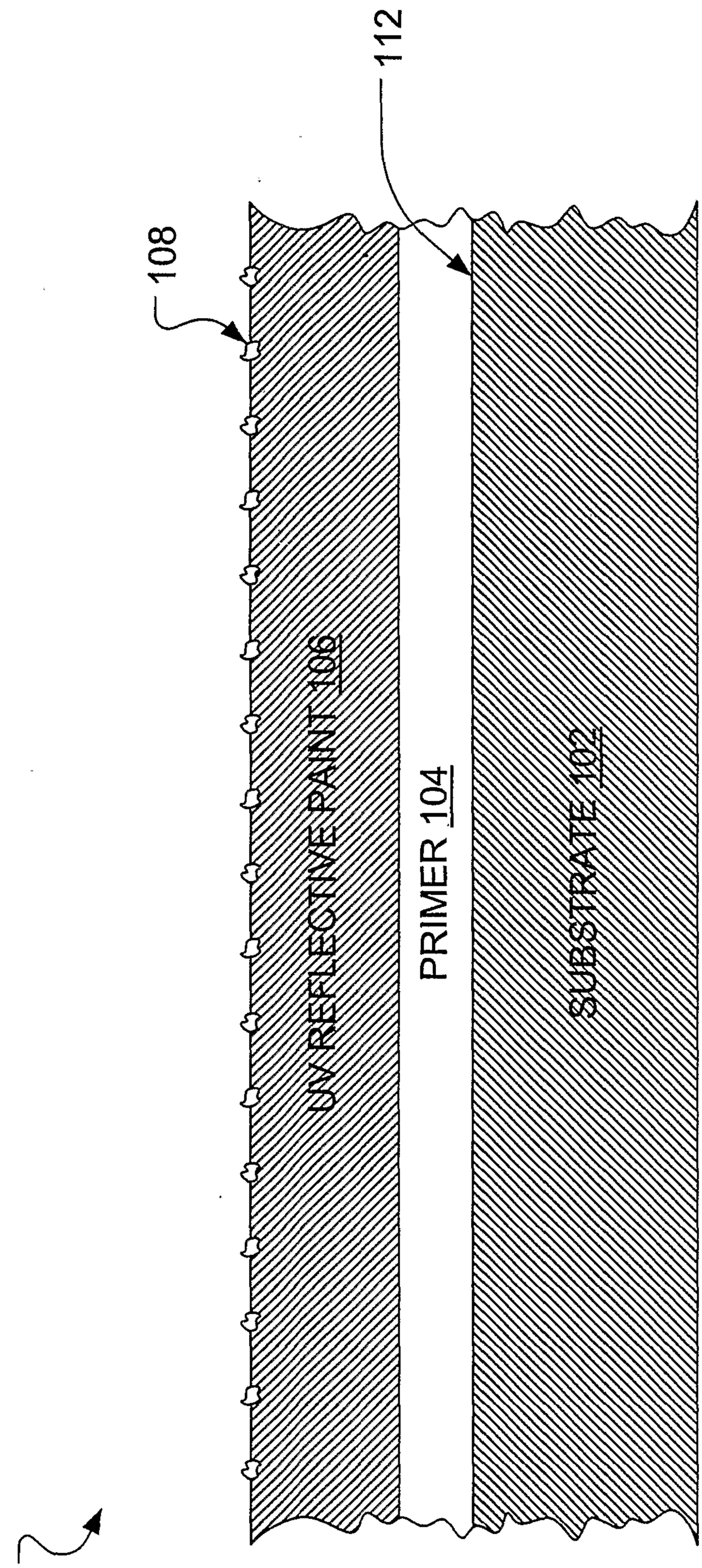

112
108
UV REFLECTIVE PAINT 106
PRIMER 104
SUBSTRATE 102
100

FIG. 1

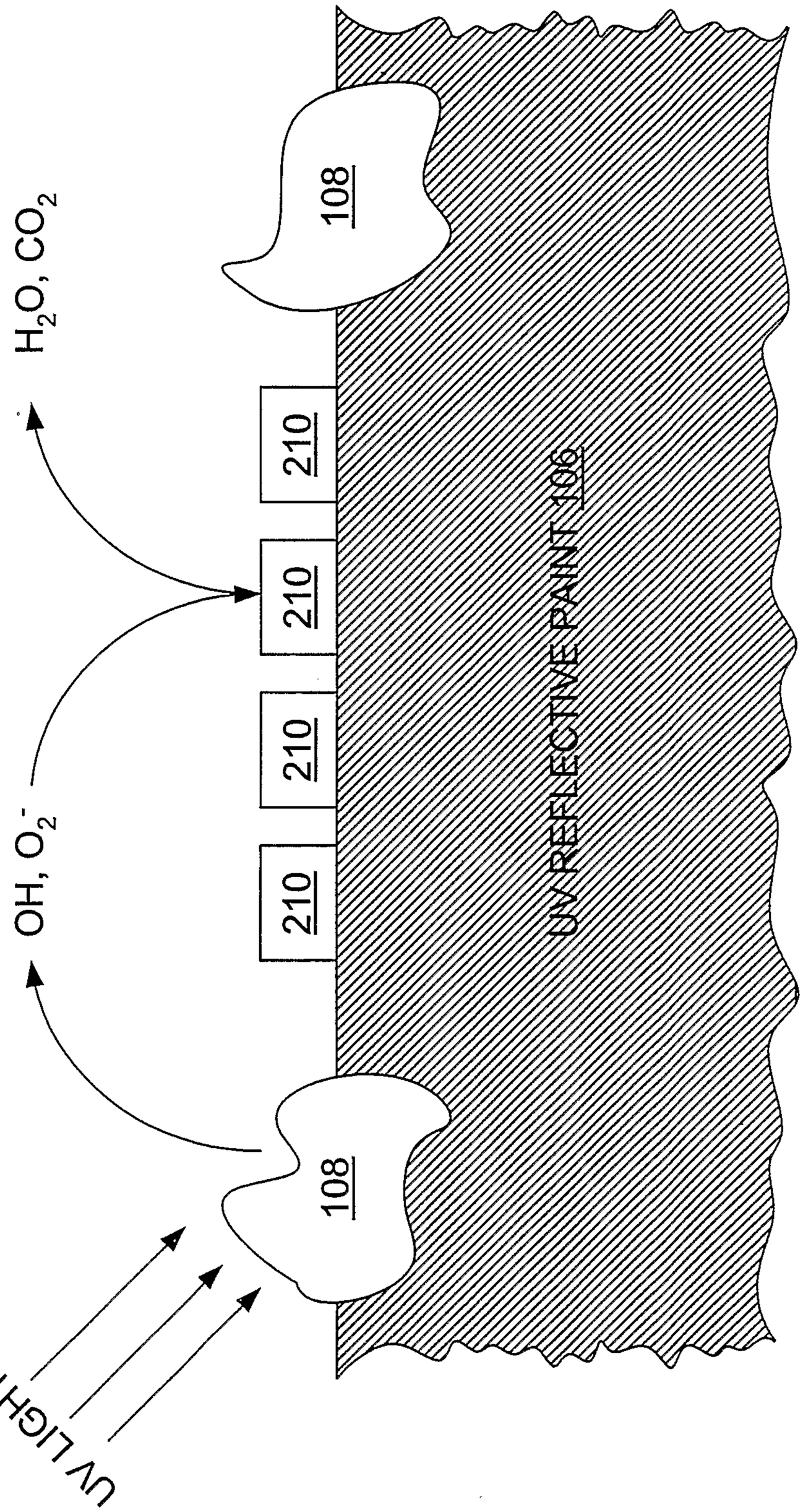

H_2O, CO_2
108
210
210
210
210
UV REFLECTIVE PAINT
OH, O_2^-
108
UV LIGHT

FIG. 2