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(54) Title: COATINGS FOR STERILIZATION WITH UV LIGHT

(57) Abrégé/Abstract:
Coating compositions that may be used in combination with UV light for sterilization include a polyurethane component and nanoparticles having an average particle size of from about 30 nm to about 400 nm. The nanoparticles absorb light having a wavelength of from about 100 nm to about 290 nm, and are present in an amount of less than about 25 weight percent of total solids in the coating composition.

ABSTRACT

Coating compositions that may be used in combination with UV light for sterilization include a polyurethane component and nanoparticles having an average particle size of from about **30** nm to about **400** nm. The nanoparticles absorb light having a wavelength of from about **100** nm to about **290** nm, and are present in an amount of less than about **25** weight percent of total solids in the coating composition.

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COATINGS FOR STERILIZATION WITH UV LIGHT

BACKGROUND

1. Technical Field

The present disclosure relates to coatings and methods for disinfection of aircraft lavatories and other surfaces, and more particularly, to coatings that may be used in combination with ultraviolet (UV) light for disinfection.

2. Related Art

Current galley and lavatory cleaning is generally conducted by an airline cleaning company on a frequent basis, and typically during aircraft turn-around times. During these cleaning procedures, chemical disinfection is used to clean exposed surfaces, such as countertops, sinks, trolley doors, and floors. The interior of compartments may also be cleaned on a regular basis, such as ovens, chillers, storage containers, and so forth.

However, this process is time consuming, and there is a resulting need for improved techniques of cleaning and disinfecting aircraft.

SUMMARY

In accordance with examples of the present disclosure, various coating compositions and methods are provided for sterilization. Advantageously, the coating compositions allow sterilization of various surfaces using UV-C light while remaining transparent. The coating compositions protect the surfaces from UV-C light, but allow the UV-C light to kill or inactivate microorganisms on the surfaces.

In one aspect of the present disclosure, the coating composition includes a polyurethane component, and nanoparticles having an average particle size of from about

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30 nm to about **400** nm. The nanoparticles absorb light having a wavelength of from about **100** nm to about **290** nm (*i.e.*, UV-C light) and are present in an amount of less than about **25** weight percent of total solids in the coating composition. In several examples, the polyurethane component includes a crosslinked aliphatic polyurethane.

In certain examples, the nanoparticles include chemically inert and nonflammable particles. Suitable nanoparticles include, but are not limited to, metal oxides (*e.g.*, titanium dioxide, tin oxide, silicon dioxide, or zinc oxide), polytetrafluoroethylenes (PTFE), or polyamides.

In various examples, the coating composition further includes a UV light blocking agent. Any suitable UV blocking agent may be used. In exemplary examples, a phenolic antioxidant is included in the coating composition.

Methods of applying a coating composition to an article include providing the coating composition described above and applying the coating composition to an external surface of the article.

In a second aspect of the present disclosure, an article includes a substrate having an external surface, and a coating composition on the external surface. The coating composition includes a crosslinked aliphatic polyurethane, and nanoparticles having an average particle size of from about **30** nm to about **400** nm. The nanoparticles absorb light having a wavelength of from about **100** nm to about **290** nm, and are present in an amount of less than about **25** weight percent of total solids in the coating composition.

In various examples, the substrate includes a metal or a plastic. In several examples, the nanoparticles include one or more of titanium oxide, zinc oxide, tin oxide, silicon oxide, a polytetrafluoroethylene (PTFE), or a polyamide.

In some examples, a method of sterilizing a surface includes exposing the external surface of the article to light having a wavelength of about **200** nm to about **240** nm. In

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certain examples, the coating composition is transparent on the external surface after exposure to light having a wavelength of about **200** nm to about **240** nm.

In a further aspect, a method includes providing a coating composition and applying the coating composition to a surface to be sterilized. The coating composition includes a crosslinked aliphatic polyurethane, and nanoparticles having an average particle size of from about **30** nm to about **400** nm. The nanoparticles absorb light having a wavelength of from about **100** nm to about **290** nm, and are present in an amount of less than about **25** weight percent of total solids in the transparent coating composition.

In some examples, the nanoparticles include one or more of titanium oxide, zinc oxide, tin oxide, silicon oxide, a polytetrafluoroethylene (PTFE), or a polyamide. In other examples, the coating composition further includes a UV light blocking agent.

In several examples, the method also includes exposing the surface to light having a wavelength of about **200** nm to about **240** nm. In some examples, the surface is exposed to light having a wavelength of about **220** nm in intermittent bursts.

In various examples, applying the coating composition includes spray applying. In certain examples, the surface to be sterilized includes one or more of a surface on and around a toilet inside a lavatory, a surface inside and around a sink inside a lavatory, a floor of a lavatory, a surface of a door handle, or a surface of a drawer handle or cabinet knob.

. A better understanding of the methods and formulations for iron-tungsten coating of the present disclosure, as well as an appreciation of the above and additional advantages thereof, will be afforded to those of skill in the art by a consideration of the following detailed description of one or more examples thereof. In this description, reference is made to the various views of the appended sheets of drawings, which are briefly described below, and within which, like reference numerals are used to identify like ones of the elements illustrated therein.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a lavatory on an aircraft in accordance with an example of the present disclosure.

FIG. **2** illustrates an example process for sterilizing the surface of an article in accordance with an example of the present disclosure.

DETAILED DESCRIPTION

In aircraft lavatories, the toilets, countertops, cabinet doors, sinks and floors are cleaned by the cleaning company during aircraft turn-around and/or at the end of scheduled flight service. Aircraft lavatories provide an environment that is often considered unclean by passengers due to the possible presence of microbiological contamination. There may also be a perceived increased risk for transmissible disease from use of a lavatory, which are used by hundreds of users. Since various pathogens can live for weeks on hard surfaces, various viruses or bacterial infection may spread. Additionally, air traveler immune systems are constantly under assault from disruptions to circadian rhythms, stress, foreign environments, and so forth, which can escalate their vulnerability to various pathogens. As the pathogenic landscape continues to morph daily, it is desirable that decontamination of lavatories be addressed.

UV-C light is germidical. It deactivates the DNA of bacteria, viruses, and other pathogens. UV-C light causes damage to the nucleic acid of microorganisms by forming covalent bonds between certain adjacent bases in the DNA. Their formation prevents the DNA from replication. When the microorganism tries to replicate, it dies.

UV-C light, however, has undesirable effects on plastics, paints, and coatings. Conventional coatings degrade or darken after repeated exposure to UV-C light, and

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more robust coatings, such as those used in hospitals, are opaque. Countertops and surfaces in the lavatory, are patterned to resemble granite or marble, and aircraft passengers do not want these patterns to be hidden with an opaque coating.

Accordingly, transparent coatings that can be sterilized with UV-C light without degradation or discoloration are described in the present disclosure.

The present disclosure describes coating compositions and methods that can be used to sterilize or disinfect surfaces, for example aircraft lavatory surfaces. The coating compositions include a base material and nanoparticles that do not interact with visible light so that the coating compositions do not appear hazy or colored when applied to different substrates such as metal or plastic. Different substrates that include the coating composition may be exposed to UV-C light and disinfected without degradation or discoloration. As used herein, UV-C light refers to ultraviolet C light having wavelengths of about **100** nm to about **290** nm.

In several examples, the base material of the coating compositions includes a polyurethane component, such as a crosslinked aliphatic polyurethane. Examples of exterior grade polyurethane coatings include PPG's Desothane® HS CA**8000** Polyurethane Topcoat, AkzoNobel's Eclipse Semi-Gloss High Solids Decorative Topcoat, or Sherwin-Williams' Skyscapes® Clearcoat Topcoats.

The nanoparticles have an average particle size of from about **30** nm to about **400** nm. Thus, the nanoparticles have a particle size that is generally smaller than the wavelength of visible light (**380**-**740** nm). Because of their size, the nanoparticles do not interact with visible light, and the coating compositions do not appear hazy or colored, but appear clear or transparent.

In addition, the nanoparticles absorb UV-C light and can convert the UV-C light to harmless infrared radiation (*e.g.*, heat). In this way, the UV-C light does not interact with

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(*e.g.*, degrade or destroy) the coating composition or the underlying substrate that the coating composition is applied on.

The concentration of nanoparticles needed to protect the surfaces of the substrate typically depends on the solids content of the coating. In illustrative examples, the nanoparticles are present in an amount of less than about **25** weight percent of total solids in the coating composition. For example, the nanoparticles may be present in an amount of about **5**, **10**, or **20** weight percent of the total solids in the coating composition, which can be sufficient for protecting the surface of the substrate, without interfering with the manufacturing, application of the coating, or the coating's resulting appearance, performance, or lifetime.

Suitable nanoparticles include inorganic particles that are chemically inert and nonflammable. Examples include metal oxide (*e.g.*, titanium dioxide, tin oxide, silicon dioxide, or zinc oxide), a polytetrafluoroethylene (PTFE), or a polyamide (*e.g.*, nylon). Inorganic particles are less soluble in cleaning agents (and are therefore less prone to leaching), can provide some abrasion or scuff resistance to the coating composition, do not result in colored breakdown products compared to organic particles, dissipate energy without degradation into smaller species or particles (no fragmentation), and are commercially available.

The coating compositions may be prepared using conventional methods. For example, a solution of the base material is prepared and then the appropriate amount of the inorganic particles is mixed in the solution to form the coating composition. Generally, the base material includes two parts that are mixed immediately prior to use. The smaller size of the inorganic particles may affect the viscosity of the coating composition, and therefore affect how well the coating composition can be applied or how fast the coating composition dries by evaporation of the solvent. This may require changing some of the solvent used to a slower blend (*i.e.*, a solvent that evaporates more slowly), which can affect the rest of the solvent in the coating composition, and if spray applying, how the spray droplets form, coalesce, and dry. All of these factors can also affect the pot life

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(*i.e.*, the amount of time it takes for an initial mixed viscosity to double). A person having ordinary skill in the art, with guidance from the present disclosure, is able to prepare an appropriate coating composition based on the desired viscosity of the coating composition.

The coating compositions may further include a UV blocking agent. A suitable UV blocking agent includes the IRGANOX® product. IRGANOX® is a trade name for BASF's phenolic antioxidants. These are characterized as having a phenolic group in which the two adjacent positions on the ring are substituted with tert-butyl groups. One example of the IRGANOX® product is the IRGANOX® **1010** product, shown below.

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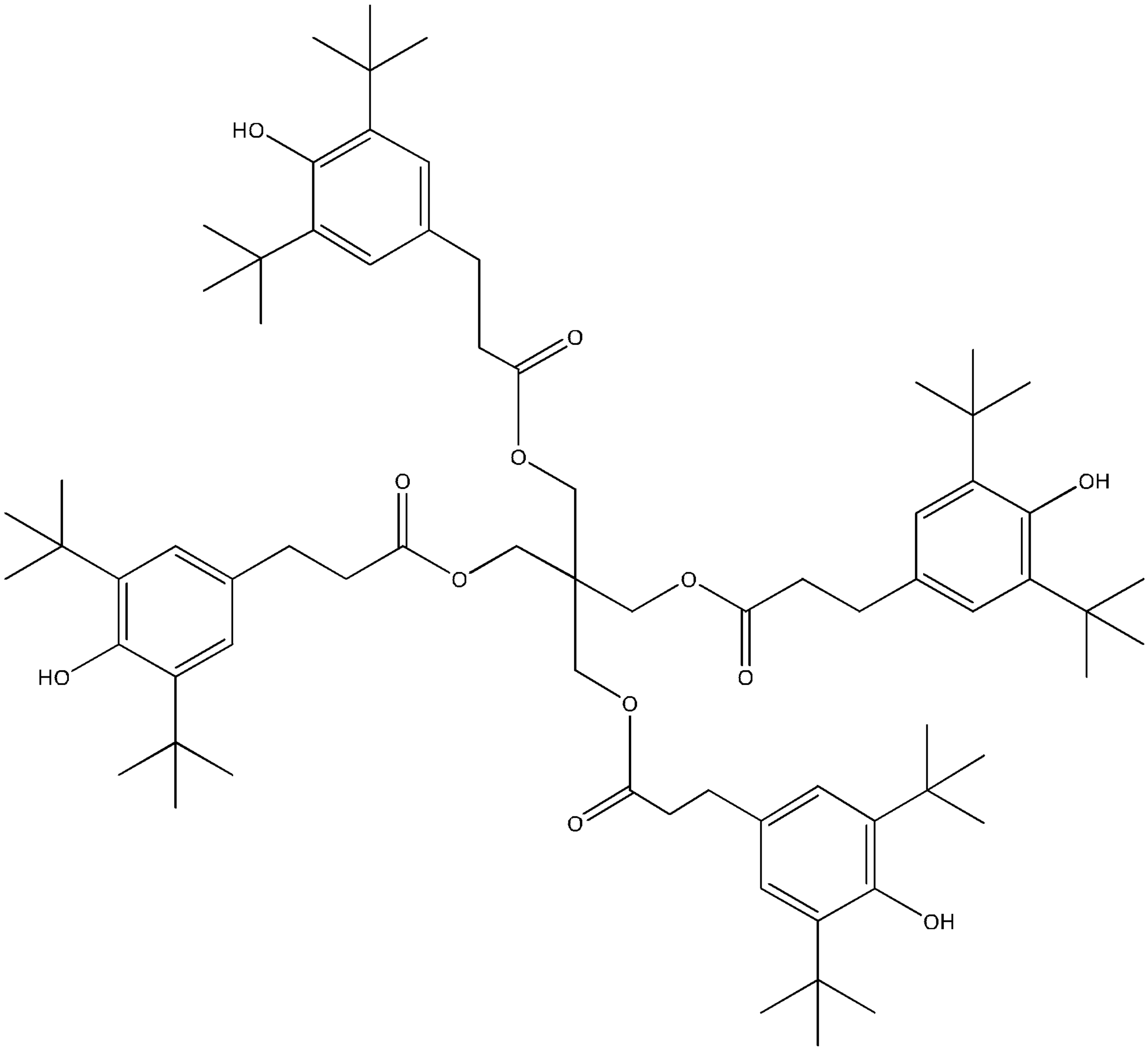

Irganox® 1010

Referring now to the figures and, in particular, with reference to FIG. **1**, an illustration of a lavatory **100** is depicted in accordance with an illustrative example. As depicted, lavatory **100** may be located in a vehicle. The vehicle may take the form of an aerospace vehicle, such as an aircraft, a spacecraft, a space shuttle, a space station, or some other type of aerospace vehicle. In other illustrative examples, the vehicle may take the form of a ground vehicle or a water vehicle, such as a bus, train, submarine, boat, or a ship.

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As shown, the lavatory **100** includes a plurality of surfaces. Such surfaces may include any surfaces inside the lavatory **100** that may need to be disinfected due to the potential for contact with at least one of a person, animal, or object carrying any number of pathogens. Such pathogens can include air-borne pathogens from coughing, spitting, or any type of body fluid that could be released by a person or animal. The plurality of surfaces may include, for example, surfaces **101** on and around a toilet inside lavatory **100**, surfaces **103** inside and around a sink inside lavatory **100**, a floor of lavatory **101**, one or more door handles, one or more drawer handles or cabinet knobs, and any other types of surfaces that can become infected through direct or indirect contact with at least one of a person, animal, or object.

To disinfect the surfaces in lavatory **100**, different sources of UV-C light may be used. As shown, a UV-C light source **105** is disposed above the sink area **103**, though it may be mounted to any surface inside the lavatory **100**. In particular, the UV-C light source **105** may be mounted to a location that allows UV-C light emitted by the UV-C light source **105** to encounter the greatest number of surfaces inside the lavatory **100**. Advantageously, the surfaces **101**, **102**, and **103** include the coating composition, which protects the surfaces **101**, **102**, and **103** from damage from UV-C light emitted by the UV-C light source **105**. In an illustrative example, the UV-C light source **105** is selected as emitting a wavelength of about **200** nm to about **240** nm. In illustrative examples, the UV-C light source emits light having a wavelength of about **220** nm.

In most cases, the UV-C light source **105** is configured as an automatic light that is activated when the door to the lavatory **100** is closed and inactivated when the door is open to prevent passenger exposure when entering or leaving the lavatory **100**. In some examples, a passenger may be offered an option to activate the disinfection process prior to entering the lavatory **100**. Once the option is activated, the lavatory door locks automatically, preventing the passenger from entering the lavatory until the disinfection process is complete. The disinfection process is typically of short duration, *e.g.*, a matter of seconds, and may take place in intermittent bursts, *e.g.*, UV-C light is activated for **1-2**

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seconds, deactivated for **5** seconds, and UV-C light is activated again for **3-4** seconds. In case of an intrusion, the disinfection process may be aborted to protect the passenger's eyes from the UV-C light.

Once the surfaces **101**, **102**, and **103** are exposed to UV-C light from UV-C light source **105**, UV-C light begins disinfecting the surfaces **101**, **102**, and **103**. Disinfecting the surfaces **101**, **102**, and **103** includes destroying potential pathogens that may be present on the surfaces **101**, **102**, and **103**. The crucial hydrogen bonds that link the DNA chain of the pathogens together rupture when exposed to UV-C light.

FIG. **2** shows an example process of applying the coating composition to an article. In block **202**, the coating composition is provided. In block **204**, the coating composition is applied to an external surface of the article. Any suitable article having an external surface to be disinfected may include the coating composition. Examples include toilets, sinks, floors, countertops, table tops, cabinet doors, door knobs, faucets, and walls.

The coating composition can be applied by manual application or by spray application. For example, the coating composition may be loaded into a spray gun or other type of spray applicator, and then sprayed onto the surface to be coated.

In block **206**, the coating composition is dried or cured (or otherwise solidified). For example, the coating composition can be dried at room temperature or at an elevated temperature (*e.g.*, **30-40**°C). In other examples, infrared (IR) heating by heat lamps, or use of UV light, which crosslinks various reactive species in the coating composition, may be used.

In block **208**, once the coating composition is dried or cured, the surface may be sterilized with UV-C light having a wavelength of about **200** nm to about **240** nm. Advantageously, the coating composition remains transparent on the external surface of the article even after exposure to light having a wavelength of about **200** nm to about **240**

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nm. The nanoparticles in the coating composition absorb the UV-C light, rather than reflecting the UV-light.

When introducing elements of the embodiments disclosed or exemplary aspects or example(s) thereof, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there can be additional elements other than the listed elements. Although embodiments have been described with respect to specific examples, the details of these examples are not to be construed as limitations. Different aspects, examples and features are defined in detail herein. Each aspect, example or feature so defined can be combined with any other aspect(s), example(s) or feature(s) (preferred, advantageous or otherwise) unless clearly indicated to the contrary. Examples described above illustrate but do not limit. It should also be understood that numerous modifications and variations are possible in accordance with the principles of the present disclosure.

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EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A coating composition, comprising:

a polyurethane component; and

nanoparticles having an average particle size of from about **30** nm to about **400** nm and absorbing light having a wavelength of from about **100** nm to about **290** nm, wherein the nanoparticles are present in an amount of less than about **25** weight percent of total solids in the coating composition.

2. The coating composition of claim **1**, wherein the nanoparticles comprise chemically inert and nonflammable particles.

3. The coating composition of claim **2**, wherein the chemically inert and nonflammable particles comprise one or more of a metal oxide, a polytetrafluoroethylene (PTFE), or a polyamide.

4. The coating composition of claim **3**, wherein the metal oxide comprises one or more of titanium dioxide, tin oxide, silicon dioxide, or zinc oxide.

5. The coating composition of any one of claims **1**-**4**, further comprising an ultraviolet (UV) light blocking agent.

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6. The coating composition of claim **5**, wherein the UV blocking agent comprises a phenolic antioxidant.

7. The coating composition of any one of claims **1**-**6**, wherein the polyurethane component comprises a crosslinked aliphatic polyurethane.

8. A method of applying a coating composition to an article, comprising:

providing the coating composition of any one of claims **1**-**7**; and

applying the coating composition to an external surface of the article.

9. An article comprising:

a substrate having an external surface; and

a coating composition on the external surface, wherein the coating composition comprises:

a crosslinked aliphatic polyurethane; and

nanoparticles having an average particle size of from about **30** nm to about **400** nm and absorbing light having a wavelength of from about **100** nm to about **290** nm, wherein the nanoparticles are present in an amount of less than about **25** weight percent of total solids in the coating composition.

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10. The article of claim **9**, wherein the coating composition is transparent on the external surface after exposure to light having a wavelength of about **200** nm to about **240** nm.

11. The article of claim **9** or **10**, wherein the substrate comprises a metal or a plastic.

12. The article of any one of claims **9**-**11**, wherein the nanoparticles comprise one or more of titanium oxide, zinc oxide, tin oxide, silicon oxide, a polytetrafluoroethylene (PTFE), or a polyamide.

13. A method of sterilizing a surface, comprising exposing the external surface of the article of any one of claims **9**-**12** to light having a wavelength of about **200** nm to about **240** nm.

14. A method, comprising:

providing a coating composition comprising:

a crosslinked aliphatic polyurethane; and

nanoparticles having an average particle size of from about **30** nm to about **400** nm and absorbing light having a wavelength of from about **100** nm to about **290** nm, wherein the nanoparticles are present in an amount of less than about **25** weight percent of total solids in the transparent coating composition; and

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applying the coating composition to a surface to be sterilized.

15. The method of claim **14**, further comprising exposing the surface to light having a wavelength of about **200** nm to about **240** nm.

16. The method of claim **15**, wherein the surface is exposed to light having a wavelength of about **220** nm in intermittent bursts.

17. The method of any one of claims **14**-**16**, wherein the applying comprises spray applying.

18. The method of any one of claims **14**-**17**, wherein the surface comprises one or more of a surface on and around a toilet inside a lavatory, a surface inside and around a sink inside a lavatory, a floor of a lavatory, a surface of a door handle, or a surface of a drawer handle or cabinet knob.

19. The method of any one of claims **14**-**18**, wherein the nanoparticles comprise one or more of titanium oxide, zinc oxide, tin oxide, silicon oxide, a polytetrafluoroethylene (PTFE), or a polyamide.

20. The method of any one of claims **14**-**19**, wherein the coating composition further comprises an ultraviolet (UV) light blocking agent.

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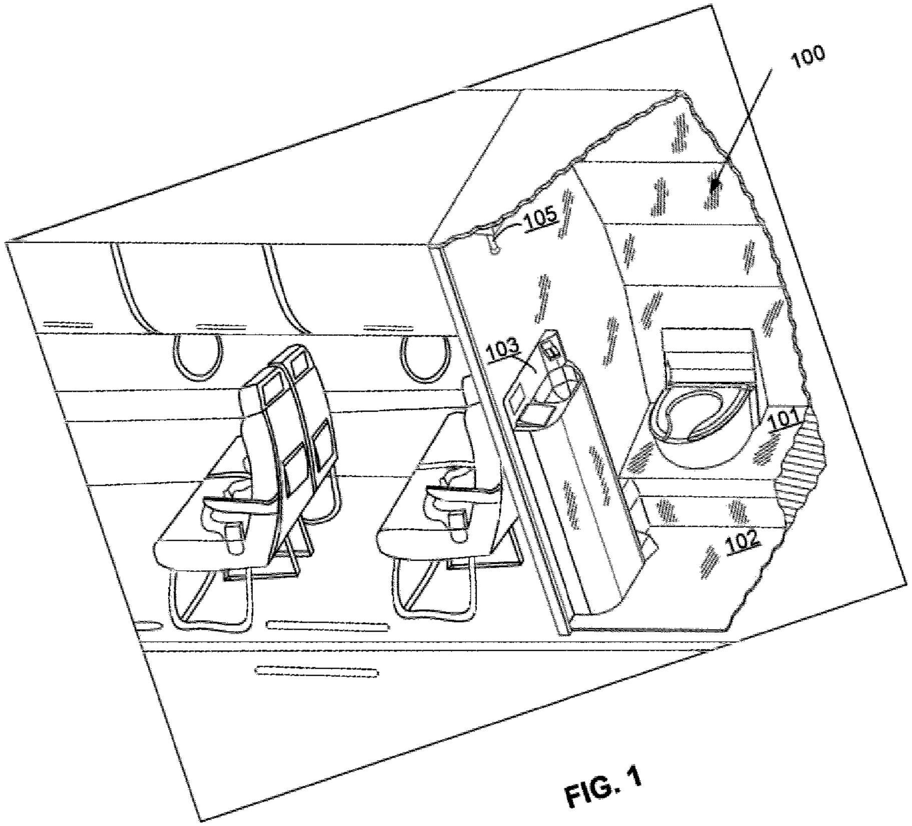

FIG. 1

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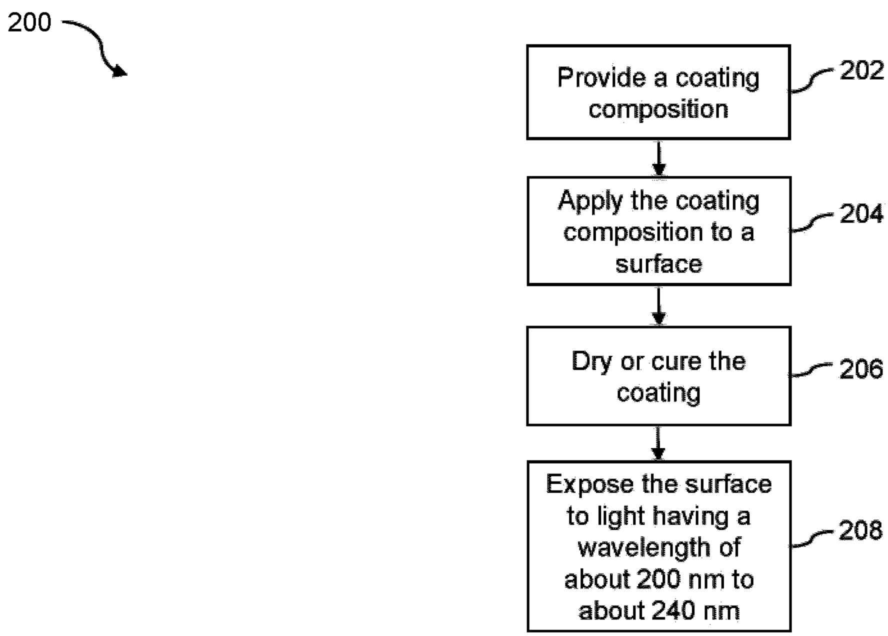

FIG. 2

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