US 20160152840A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2016/0152840 A1**

(43) **Pub. Date: Jun. 2, 2016**

Smith et al.

(54) **HYDROPHOBIC COATING FOR COATED ARTICLE**

(71) Applicant: **United Technologies Corporation**, Hartford, CT (US)

(72) Inventors: **Richard L. Smith**, South Windsor, CT (US); **Joshua A. Sheffel**, Manchester, CT (US)

(21) Appl. No.: **15/016,380**

(22) Filed: **Feb. 5, 2016**

Related U.S. Application Data

(63) Continuation of application No. 12/874,677, filed on Sep. 2, 2010, now Pat. No. 9,260,629.

Publication Classification

(51) **Int. Cl.**

C09D 5/16	(2006.01)
C09D 183/04	(2006.01)
C08L 83/04	(2006.01)
C08K 3/04	(2006.01)
C08K 3/08	(2006.01)
C08K 3/22	(2006.01)

(52) **U.S. Cl.**

CPC ***C09D 5/1675*** (2013.01); ***C08K 3/08*** (2013.01); ***C08K 3/22*** (2013.01); ***C08L 83/04*** (2013.01); ***C08K 3/04*** (2013.01); ***C09D 183/04*** (2013.01)

(57) **ABSTRACT**

An article includes a superhydrophobic body that has a matrix and non-silica (SiO_2) particles dispersed through the matrix. The matrix includes at least one of silicone or polysiloxane. The non-silica (SiO_2) particles include at least one of oxide particles, non-oxide ceramic particles, metal particles, polymer particles, carbon particles, metal hydroxide particles, or oxide-hydroxide particles.

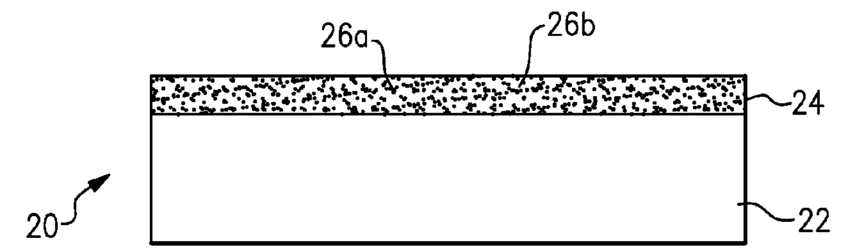

FIG.1

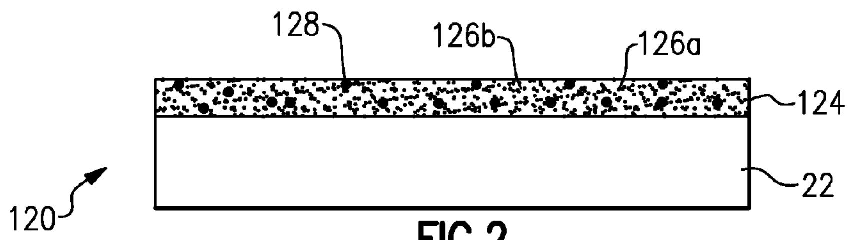

FIG.2

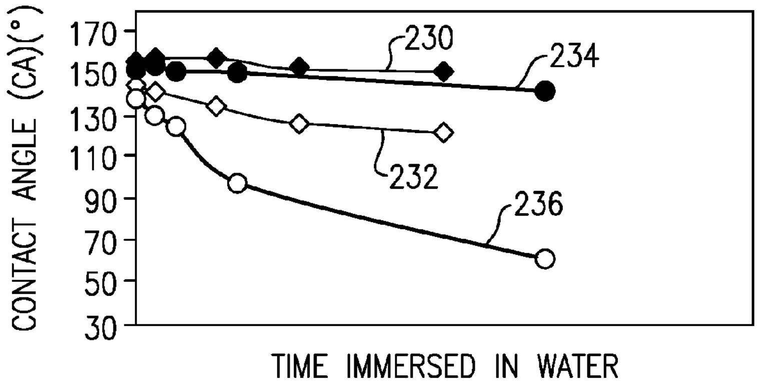

FIG.3

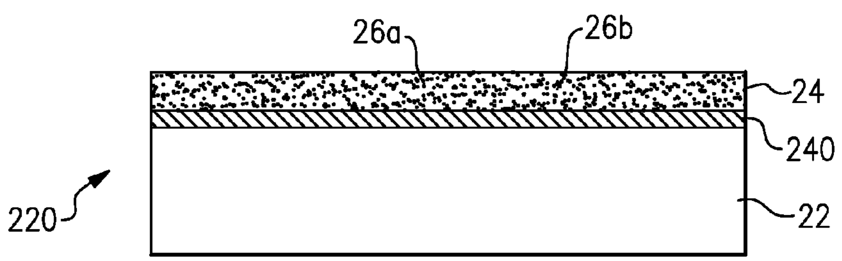

FIG.4

HYDROPHOBIC COATING FOR COATED ARTICLE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present is a continuation to U.S. Provisional patent application Ser. No. 12/874,677, filed Sep. 2, 2010.

BACKGROUND

[0002] This disclosure relates to anti-icing or icephobic coatings for reducing ice and water formation or accumulation on a surface.

[0003] Surfaces of aircraft, power generation (e.g. wind turbines and land-based gas turbines), and architectural components may collect moisture that can freeze and debit the performance of the component. The component may include an anti-icing or icephobic coating to reduce ice accumulation by reducing adhesion between the ice and the coating. In operation of the component, sheer loads from drag, wind, or other forces exceed the adhesive strength and shed the accumulated ice.

SUMMARY

[0004] An article according to an example of the present disclosure includes a superhydrophobic body that has a matrix of at least one of silicone or polysiloxane, and non-silica (SiO2) particles dispersed through the matrix. The non-silica (SiO2) particles include at least one of oxide particles, non-oxide ceramic particles, metal particles, polymer particles, carbon particles, metal hydroxide particles, or oxide-hydroxide particles.

[0005] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles include at least one of the metal particles or the carbon particles.

[0006] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles include at least one of the metal hydroxide particles or the oxide-hydroxide particles.

[0007] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles include the oxide particles.

[0008] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles include at least one of the metal particles or the non-oxide ceramic particles.

[0009] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles include the non-oxide ceramic particles.

[0010] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles include the polymer particles, and the polymer particles are polytetrafluorothylene particles.

[0011] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles include at least two different kinds of particles with respect to composition.

[0012] In a further embodiment of any of the foregoing embodiments, one of the at least two different kinds of particles is microsphere particles.

[0013] In a further embodiment of any of the foregoing embodiments, one of the at least two different kinds of particles is hydrophobic particles and another of the at least two different kinds of particles is water durability particles. The water durability particles increase water durability of the superhydrophobic coating with respect to ability to retain superhydrophobic surface properties over prolonged immersion in liquid water.

[0014] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles include at least two different kinds of particles with respect to size.

[0015] In a further embodiment of any of the foregoing embodiments, the superhydrophobic body has a mass ratio of the two different kinds of particles that is between 0.3 and 2.

[0016] In a further embodiment of any of the foregoing embodiments, the non-silica (SiO2) particles have a surface roughness on the nanometer scale.

[0017] In a further embodiment of any of the foregoing embodiments, the superhydrophobic body consists essentially of the silicone or polysiloxane.

[0018] An article according to an example of the present disclosure includes a substrate and a superhydrophobic coating on the substrate. The superhydrophobic coating includes a matrix of at least one of silicone or polysiloxane and particles dispersed through the matrix. The particles include at least one of non-oxide ceramic particles, metal particles, or carbon particles.

[0019] In a further embodiment of any of the foregoing embodiments, the particles include the metal particles.

[0020] In a further embodiment of any of the foregoing embodiments, the particles include the non-oxide ceramic particles.

[0021] In a further embodiment of any of the foregoing embodiments, the particles include the carbon particles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The various features and advantages of the disclosed examples will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

[0023] FIG. **1** illustrates an example coated article.

[0024] FIG. **2** illustrates another example coated article having at least two different kinds of hydrophobic particles.

[0025] FIG. **3** illustrates a graph of water (deionized) contact angle versus time immersed in water.

[0026] FIG. **4** illustrates another example coated article having a primer layer between a superhydrophobic coating and a substrate.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0027] FIG. **1** illustrates selected portions of an example coated article **20** having anti-icing or icephobic properties. It is to be understood that the coated article **20** may be any type of component that would benefit from anti-icing. For instance, the coated article **20** may be an aircraft component, aerospace component, heat exchanger component, wind turbine component or any other component where there is a desire to reduce or eliminate ice formation.

[0028] The coated article **20** generally includes a substrate **22** and a superhydrophobic coating **24** on the substrate **22**. The term "superhydrophobic" and variations thereof refers to an advancing water contact angle that is greater than 140° and a receding water contact angle that is within 20% of the advancing water contact angle. In the illustrated embodiment, the superhydrophobic coating **24** is located on the surface of the substrate **22** exposed to the surrounding environment to protect the substrate **22** from ice formation. The substrate **22** may comprise any material to which the superhydrophobic coating **24** may adhere, including metal alloys (e.g. alloys based on the metals aluminum, titanium, nickel, cobalt, iron, etc.), polymers, polymer blends, ceramics, glasses, and/or composites and combinations thereof. In comparison to icephobic coatings that address anti-icing via reducing ice adhesion strength, the superhydrophobic coatings of the present disclosure are designed to shed water and thereby avoid ice formation. The superhydrophobic coating **24** may be considered to be an anti-icing or icephobic coating and may reduce or inhibit ice accumulation on the substrate by retarding or preventing the nucleation or formation of ice. The superhydrophobic coating **24** is designed to be compatible with or stable to intermittent or extended exposures at elevated temperatures (up to ~550° F.), such as might be encountered in certain aerospace components. The superhydrophobic coating **24** is further designed to be simple to apply. In the simplest embodiment the superhydrophobic coating **24** is applied to the substrate **22** as a single layer in one deposition step (e.g. a single spray coating, flow coating, dip coating, etc. application), although certain attributes may also be attained through a multi-step or multi-layer application process.

[0029] The superhydrophobic coating **24** is a composite of a silicone polymer **26***a* (e.g., matrix) and hydrophobic particles **26***b* (e.g., filler particles). The silicone polymer **26***a* may contain additives or processing aids, such as anti-foaming agents, pigments, dyes, stabilizers, and the like known to those practiced in the art. The silicone polymer may be a silicone, fluorosilicone, polysiloxane, room temperature vulcanized silicone, or other type of silicone composition or combination thereof. The particles **26***b* are inherently hydrophobic or surface-functionalized with a hydrophobic agent that renders the particle surfaces hydrophobic and contribute to the superhydrophobic properties of the coating **24**.

[0030] The particles **26***b* may be nanosized particles. In one example, the particles **26***b* are monodisperse nanosized silica, such as fumed amorphous silica (SiO2). Alternatively, the particles **26***b* may include combinations of different sized particles. Other suitable nanosized particles may include crystalline and amorphous oxides, non-oxide ceramics, metals and metal alloys, polymers and polymer blends, carbons, and metal hydroxides and oxide-hydroxides (such as natural and synthetic clays, mica, and diatomaceous earth). If the particles **26***b* are not inherently hydrophobic their surfaces may be rendered hydrophobic by surface functionalizing with an appropriate hydrophobic agent. The hydrophobic agent may be any type of agent that suitably bonds to the surfaces of the particles **26***b* and renders the particles hydrophobic. For example, the hydrophobic agent may be a functionalized silane coupling agent, polydimethylsiloxane, hexamethyldisilazane, octylsilane, dimethyldichlorosilane, or a combination thereof.

[0031] The composition of the superhydrophobic coating **24** may be characterized by a mass ratio of the silicone polymer **26***a* to the hydrophobic particles **26***b*. In one example, the mass ratio is between 0.5 and 3, and in some examples 0.5-1.5. In a further example, the superhydrophobic coating **24** may include only the silicone polymer **26***a* and the particles **26***b*. The use of nanosized hydrophobic particles **26***b* in combination with the silicone polymer **26***a* may render the coating **24** superhydrophobic. That is, the superhydrophobic coating **24** exhibits an advancing water contact angle that is greater than 140° and a receding water contact angle that is within 20% of the advancing water contact angle (i.e., a contact angle hysteresis that is less than 20%). A user may determine the advancing and receding water contact angles with known equipment and testing techniques, such as the Wilhelmy plate method or using a contact angle goniometer.

[0032] FIG. **2** illustrates another example coated article **120**. In this disclosure, like reference numerals designate like elements where appropriate, and reference numerals with the addition of one-hundred or multiples thereof designate modified elements that are understood to incorporate the same features and benefits of the corresponding original elements. In this case, the coated article **120** includes a superhydrophobic coating **124** on the substrate **22**. The superhydrophobic coating **124** includes a silicone polymer **126***a* and particles **126***b*, as described with regard to FIG. **1**. Additionally, the superhydrophobic coating **124** includes particles **128**. That is, the superhydrophobic coating **124** includes at least two different kinds of hydrophobic particles, the particles **126***b* and the particles **128**. The particles **126***b* and the particles **128** may differ in composition, size, morphology, or other characteristic.

[0033] In the illustrated example, the particles **126***b* may be nanosized hydrophobic particles, as described above, and the particles **128** may be microsized particles. The microsized particles **128** may be polymeric, such as silicone or polytetrafluoroethylene particles, and have a surface roughness on the nanometer scale (0.1-500 nanometers). The particles **128** cooperate with the particles **126***b* and the silicone polymer **126***a* to contribute to the superhydrophobic properties of the coating **124**. In this regard, the particles **128** reduce the need to use high amounts of the particles **126***b*. Thus, the superhydrophobic coating **124** can include generally less of the particles **126***b* in comparison to a coating that does not include the particles **128** and maintain approximately the same or better hydrophobicity performance.

[0034] In one example, the superhydrophobic coating **124** includes a mass ratio of the silicone polymer **126***a* to the particles **126***b* that is 0.5-10 and a mass ratio of the microsized particles **128** to nanosized particles **126***b* that is 0-10, such as 0.1-10. In a more particular example, the mass ratio of silicone polymer **126***a* to particles **126***b* is 4-6 and the mass ratio of particles **128** to particles **126***b* is 0.3-2. Using surface functionalized nanosized silica particles as the particles **126***b* and microsized silicone particles as the particles **128** renders the coating **124** to be superhydrophobic.

[0035] The microsized particles may have a size of 1-100 micrometers, and in some examples 5-25 micrometers. The nanosized silica particles may have a size of 1-200 nanometers, and in some examples 1-50 nanometers. The microsized particles 128 may be regarded as a "roughening agent" to the silicone polymer **126***a* to enhance the surface roughness of the superhydrophobic coating **124** and enhance hydrophobicity.

[0036] Alternatively, the microsized particles **128** may be a ceramic, metallic, polymeric, or composite material having hydrophobic properties and a surface roughness on the nanometer scale (0.1-500 nanometers). Particles **128** may be inherently hydrophobic or surface-functionalized with a hydrophobic agent. Further, microsized particles that are not hydrophobic may also be suitable in certain coating formulations, if the microsized particles are sufficiently coated or wetted by the silicone matrix of the coating.

[0037] Utilizing at least two different kinds of particles in the superhydrophobic coating **124** also enhances the water durability of the superhydrophobic coating **124**. Herein, water durability is defined as the ability of the superhydrophobic coating **124** to retain superhydrophobic surface properties (i.e. advancing contact angle >140° with less than 20% contact angle hysteresis) over prolonged immersion in liquid water.

[0038] FIG. **3** illustrates a graph of water contact angle versus time immersed in water. Sample 1 and sample 2 were prepared by depositing coatings of different compositions on substrates using a known dip coating technique and a suspension of silicone polymer (NUSIL R-2180) and nanosized silica particles (ALFA-AESAR), as described above, in methyl ethyl ketone. Sample 1 additionally included microsized silicone particles (TOSPEARL 1110A polydimethylsiloxane microspheres) as described above. The microsized silicone microspheres had an average size of approximately 11 micrometers and a relatively smooth surface morphology having a roughness on the nanometer scale. Samples 1 and 2 were aged by immersing the coated substrates in deionized water at ambient temperature.

[0039] The graph line **230** represents a plot of the advancing water contact angle of sample 1 as a function of time immersed, and the graph line **232** represents a plot of the receding water contact angle of sample number 1. Graph line **234** represents a plot of the advancing water contact angle of sample number 2 as a function of time immersed, and graph line **236** represents a plot of the receding water contact angle of sample number 2. The receding contact angle **236** of sample 2 declined substantially as a function of time immersed in the water. The receding contact angle **232** of sample 1 did not exhibit such a decline and suggests that the particles **128**, such as the microsized silicone particles in sample 1, enhance water durability of superhydrophobic coatings.

[0040] FIG. **4** illustrates another example coated article **220** that is similar to the coated article **20** of FIG. **1** but includes a primer layer **240** between the superhydrophobic coating **24** and the substrate **22**. For instance, the primer layer **240** may be a metal-organic material that is adapted to bond to the superhydrophobic coating **24** and the material of the substrate **22**.

[0041] Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

[0042] The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

What is claimed is:

1. An article comprising:

a superhydrophobic body including,

a matrix of at least one of silicone or polysiloxane, and non-silica (SiO2) particles dispersed through the matrix, wherein the non-silica (SiO2) particles include at least one of oxide particles, non-oxide ceramic particles, metal particles, polymer particles, carbon particles, metal hydroxide particles, or oxide-hydroxide particles.

2. The article as recited in claim **1**, wherein the non-silica (SiO2) particles include at least one of the metal particles or the carbon particles.

3. The article as recited in claim **1**, wherein the non-silica (SiO2) particles include at least one of the metal hydroxide particles or the oxide-hydroxide particles.

4. The article as recited in claim **1**, wherein the non-silica (SiO2) particles include the oxide particles.

5. The article as recited in claim **1**, wherein the non-silica (SiO2) particles include at least one of the metal particles or the non-oxide ceramic particles.

6. The article as recited in claim **1**, wherein the non-silica (SiO2) particles include the non-oxide ceramic particles.

7. The article as recited in claim **1**, wherein the non-silica (SiO2) particles include the polymer particles, and the polymer particles are polytetrafluorothylene particles.

8. The article as recited in claim **1**, wherein the non-silica (SiO2) particles include at least two different kinds of particles with respect to composition.

9. The article as recited in claim **8**, wherein one of the at least two different kinds of particles is microsphere particles.

10. The article as recited in claim **8**, wherein one of the at least two different kinds of particles is hydrophobic particles and another of the at least two different kinds of particles is water durability particles, the water durability particles increasing water durability of the superhydrophobic coating with respect to ability to retain superhydrophobic surface properties over prolonged immersion in liquid water.

11. The article as recited in claim **1**, wherein the non-silica (SiO2) particles include at least two different kinds of particles with respect to size.

12. The article as recited in claim **11**, wherein the superhydrophobic body has a mass ratio of the two different kinds of particles that is between 0.3 and 2.

13. The article as recited in claim **1**, wherein the non-silica (SiO2) particles have a surface roughness on the nanometer scale.

14. The article as recited in claim **1**, wherein the superhydrophobic body consists essentially of the silicone or polysiloxane.

15. An article comprising:

a substrate; and

a superhydrophobic coating on the substrate, the superhydrophobic coating including,

a matrix of at least one of silicone or polysiloxane, and

particles dispersed through the matrix, wherein the particles include at least one of non-oxide ceramic particles, metal particles, or carbon particles.

16. The article as recited in claim **15**, wherein the particles include the metal particles.

17. The article as recited in claim **15**, wherein the particles include the non-oxide ceramic particles.

18. The article as recited in claim **15**, wherein the particles include the carbon particles.

* * * * *