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(54) **ANODIZED METAL MATRIX COMPOSITE**

ANODISIERTER METALLMATRIX-VERBUNDWERKSTOFF

COMPOSITE DE MATRICE MÉTALLIQUE ANODISÉ

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EP 3 283 673 B1

Description

BACKGROUND

[0001] US2011048958 A1 discloses an anodized aluminum-silicon alloy work piece formed from a cast aluminum-silicon alloy substrate material by applying a friction stir processing treatment to the cast aluminum-silicon alloy substrate material to reduce an average particle size of a plurality of silicon particles contained within the substrate material while increasing a size uniformity of the plurality of silicon particles, and subsequently anodizing the treated cast aluminum-silicon alloy substrate material. The publication of Chunlin He et al.: "Effect of size of reinforcement on thickness of anodized coatings on SiC/Al Matrix composites", MATERIALS LETTERS, ELSEVIER, AMSTERDAM, NL, vol. 62, no. 16, 15 June 2008 (2008-06-15), pages 2441-2443 investigates the effect of size of reinforcements on morphology and thickness of anodic coatings on 3.5 μm and 10 μm SiC particles reinforced 2024A1 metal matrix composites (SiC_p/A1 MMCs) formed in sulfuric acid was investigated with optical microscopy and scanning electron microscopy. The thickness of anodized coating on the MMCs is strongly dependent of size of SiC particles, and it is smaller for the MMC with smaller SiC particles because growth of more pores is affected when the concentration of SiC particles is fixed. The oxide/substrate interface became locally scalloped, and the anodized coatings formed on the MMCs were non-uniform in thickness, especially for the MMC reinforced by bigger particles.

[0002] The present disclosure relates to metal matrix composite articles including a substrate and an anodized layer. The anodized layer includes an aluminum oxide matrix phase and a dispersed phase of reinforcement particles. The ratio of the thickness of the anodized layer to the average particle size (D50) of the reinforcement particles is at least 1.3.

[0003] Anodizing is often used to protect aluminum and aluminum alloy components from corrosion. The anodizing process works by converting the top surface of an aluminum alloy substrate into an amorphous aluminum oxide layer. Anodizing does not add an extra oxide layer to the substrate; rather, the process converts the top surface of aluminum metal into an oxide layer via an electrochemical reaction. The oxide layer typically has a larger volume than the surface aluminum prior to conversion, so the overall dimensions may increase. The anodizing layer effectively seals the top surface of the aluminum substrate and prevents any corrosive elements from reaching and reacting with the aluminum metal.

[0004] For anodizing to work effectively as a corrosion barrier, the anodized layer needs to be both thick enough and free from defects. Defects in the anodized layer, such as cracks or pores that run through the entire thickness of the anodized layer, allow corrosive materials to reach the aluminum metal and, therefore, these defects act as sites for localized corrosion.

[0005] Metal matrix composites typically include reinforcement particles dispersed in a metal matrix. In principle, metal matrix composites can be anodized. However, the anodization process is complicated by the presence of the reinforcement particles. The reinforcement particles are effectively inert to the chemicals in the anodizing bath and thus, during the anodizing process, the particles will become part of the anodized layer as well.

[0006] Anodized layers typically have thicknesses in the range of from about 2 micrometers (μm) to about 25 μm , while conventional reinforcement particles have an average particle size in the range of from about 3 μm to about 40 μm . As a result, it is possible for the reinforcement particles to bridge the anodized layer (i.e. extend entirely through the anodized layer) and act as paths/sites for local corrosion to occur when corrosive materials seep through the anodized layer. The reinforcement particles that bridge the anodized layer can also act as weak points and could provide nucleation sites for the anodized layer to delaminate during any mechanical loading.

[0007] It would be desirable to provide metal matrix composite articles with improved anodized layers.

BRIEF DESCRIPTION

[0008] The present invention relates to composite articles including a substrate and an anodized layer according to claim 1. The anodized layer includes an aluminum or aluminum oxide matrix phase and a dispersed phase of reinforcement particles. The ratio of the thickness of the anodized layer to the average particle size (D50) of the reinforcement particles is at least 1.3. The combination of the thickness of the anodized layer and the average size of the reinforcement particles prevents defects in the anodized layer, such as bridges being formed by the reinforcement particles. In addition, the composite anodized layer will have improved wear resistance compared to conventional anodized layers.

[0009] Disclosed in various embodiments are metal matrix composite articles. The articles include a substrate and an anodized layer. The substrate includes an aluminum or aluminum alloy matrix; and reinforcement particles dispersed in the matrix. The anodized layer includes an aluminum oxide matrix and reinforcement particles dispersed in the aluminum oxide matrix. The ratio of the thickness of the anodized layer to the average particle size (D50) of the reinforcement particles is at least 1.3.

[0010] In more specific embodiments, the ratio of the thickness of the anodized layer to the average particle size (D50) of the reinforcement particles may be at least 1.6, or at least 2, or at least 3.

[0011] The thickness of the anodized layer is from about 1 μm to about 3 μm ; and the average particle size is from about 0.3 μm to about 0.7 μm .

[0012] The reinforcement particles may include at least one ceramic material selected from carbides, oxides, silicides, borides, and nitrides.

[0013] In some embodiments, the reinforcement particles include at least one ceramic material selected from silicon carbide, titanium carbide, boron carbide, silicon nitride, titanium nitride, and zirconium oxide.

[0014] The aluminum alloy may include at least one element selected from chromium, copper, lithium, magnesium, manganese, nickel, and silicon.

[0015] In some embodiments, the aluminum alloy includes from about 91.2 wt% to about 94.7 wt% aluminum, from about 3.8 wt% to about 4.9 wt% copper, from about 1.2 wt% to about 1.8 wt% magnesium, and from about 0.3 wt% to about 0.9 wt% manganese.

[0016] The aluminum alloy may include from about 95.8 wt% to about 98.6 wt% aluminum, from about 0.8 wt% to about 1.2 wt% magnesium, and from about 0.4 wt% to about 0.8 wt% silicon.

[0017] The substrate includes from about 15 vol% to about 50 vol% of the reinforcement particles.

[0018] Also disclosed herein are articles comprising an anodized layer, wherein the anodized layer comprises: an aluminum oxide matrix; and reinforcement particles dispersed in the aluminum oxide matrix; and wherein a ratio of a thickness of the anodized layer to an average particle size (D50) of the reinforcement particles is at least 1.3.

[0019] Disclosed in other embodiments are methods for producing an article according to claim 5. The methods include anodizing a surface of a substrate comprising a metal matrix composite to form an anodized layer on that surface. The metal matrix composite includes reinforcement particles dispersed in an aluminum or aluminum alloy matrix. The ratio of the thickness of the anodized layer to the average particle size (D50) of the reinforcement particles is at least 1.3.

[0020] The anodizing may be performed using typical conditions for un-reinforced aluminum alloys. The anodizing may be performed at a voltage of about 10 volts to about 60 volts, including from about 10 to about 50 volts and from about 10 to about 20 volts. The anodizing may be performed for a time period of about 15 minutes to about 90 minutes. The anodizing may be performed at a bath temperature of about 15°C to about 30°C. Combinations of these process parameters are envisioned.

[0021] These and other non-limiting characteristics of the disclosure are more particularly disclosed below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The following is a brief description of the drawings, which are presented for the purposes of illustrating the exemplary embodiments disclosed herein and not for the purposes of limiting the same.

FIG. 1 is a cross-sectional view of a metal matrix composite article including an anodized layer with relatively large reinforcement particles.

FIG. 2 is a cross-sectional view of a metal matrix composite article including an anodized layer with

relatively small reinforcement particles in accordance with embodiments of the present disclosure.

FIG. 3 is a cross-sectional view of an anodized aluminum article, with an anodized layer having tubular pores extending through the entire anodized layer.

FIG. 4 is a top view of the article of **FIG. 3**.

FIG. 5 is a cross-sectional view of a metal matrix composite article, showing an anodized layer with a reduced number of tubular pores, and such pores being significantly shortened in length as well.

FIG. 6 is a top view of the article of **FIG. 5**.

FIG. 7 and **FIG. 8** are optical microscope images at 500X and 1000X magnification, respectively, of an article anodized under a first set of exemplary conditions.

FIG. 9 and **FIG. 10** are optical microscope images at 500X and 1000X magnification, respectively, of an article anodized under a second set of exemplary conditions.

FIG. 11 and **FIG. 12** are optical microscope images at 500X and 1000X magnification, respectively, of an article anodized under a third set of exemplary conditions.

FIG. 13 and **FIG. 14** are optical microscope images at 500X and 1000X magnification, respectively, of an article anodized under a fourth set of exemplary conditions.

DETAILED DESCRIPTION

[0023] A more complete understanding of the components, processes and apparatuses disclosed herein can be obtained by reference to the accompanying drawings. These figures are merely schematic representations based on convenience and the ease of demonstrating the present disclosure, and are, therefore, not intended to indicate relative size and dimensions of the devices or components thereof and/or to define or limit the scope of the exemplary embodiments.

[0024] Although specific terms are used in the following description for the sake of clarity, these terms are intended to refer only to the particular structure of the embodiments selected for illustration in the drawings, and are not intended to define or limit the scope of the disclosure. In the drawings and the following description below, it is to be understood that like numeric designations refer to components of like function.

[0025] The singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise.

[0026] As used in the specification and in the claims, the term "comprising" may include the embodiments "consisting of" and "consisting essentially of." The terms "comprise(s)," "include(s)," "having," "has," "can," "contain(s)," and variants thereof, as used herein, are intended to be open-ended transitional phrases, terms, or words that require the presence of the named components/steps and permit the presence of other compo-

nents/steps. However, such description should be construed as also describing compositions or processes as "consisting of" and "consisting essentially of" the enumerated components/steps, which allows the presence of only the named components/steps, along with any impurities that might result therefrom, and excludes other components/steps.

[0027] Numerical values in the specification and claims of this application should be understood to include numerical values which are the same when reduced to the same number of significant figures and numerical values which differ from the stated value by less than the experimental error of conventional measurement technique of the type described in the present application to determine the value.

[0028] All ranges disclosed herein are inclusive of the recited endpoint and independently combinable (for example, the range of "from 2 to 10" is inclusive of the endpoints, 2 and 10, and all the intermediate values).

[0029] The present disclosure refers to particles having an average particle size. The average particle size is defined as the particle diameter at which a cumulative percentage of 50% (by volume) of the total number of particles are attained. In other words, 50% by volume of the particles have a diameter above the average particle size, and 50% by volume of the particles have a diameter below the average particle size. The size distribution of the particles will be Gaussian, with upper and lower quartiles at 125% and 75% of the stated average particle size, and all particles being less than 150% of the stated average particle size.

[0030] The present disclosure relates to metal matrix composite articles including a substrate and an anodized layer. The anodized layer is formed by anodizing a surface of the substrate. The substrate includes (i) an aluminum or aluminum alloy matrix phase and (ii) a dispersed phase of reinforcement particles. The anodized layer includes (i) an aluminum oxide matrix formed from the underlying aluminum or aluminum alloy substrate and (ii) a dispersed phase of reinforcement particles. The reinforcement particles may have been originally located in the aluminum or aluminum alloy substrate prior to anodizing and may have been transferred to the anodized layer during anodizing. The ratio of the thickness of the anodized layer to the average particle size (D50) of the reinforcement particles is at least 1.3. Such articles can include aerospace or airborne optical parts, space parts, automotive parts, and consumer goods.

[0031] FIG. 1 illustrates a prior art anodized metal matrix composite article 100 including a substrate 110 and an anodized layer 120. The metal matrix composite includes reinforcement particles 130 dispersed in a metal matrix 140. The reinforcement particles 130 are large relative to the thickness of the anodized layer 120. Consequently, reinforcement particle 130a bridges the anodized layer 120, or in other words extends entirely through the anodized layer. This localized defect in the anodized layer 120 leads to poor corrosion resistance

and other properties. In particular, the substrate 110 is more susceptible to corrosion.

[0032] FIG. 2 illustrates an anodized metal matrix composite article 200 in accordance with embodiments of the present disclosure. The article 200 includes a substrate 210 and an anodized layer 220. The metal matrix composite includes reinforcement particles 230 dispersed in a metal matrix 240. The reinforcement particles 230 are small relative to the thickness of the anodized layer 220. Consequently, the reinforcement particles 230 cannot span the entire thickness of the anodized layer 220. Localized defects in the anodized layer 220 are avoided and the corrosion resistance of the substrate 210 is enhanced. The anodized layer 220 comprises aluminum oxide and the reinforcement particles, and generally no aluminum. The substrate 210 is made of aluminum or an aluminum alloy, and contains reinforcement particles, and generally no aluminum oxide.

[0033] The combination of the thickness of the anodized layer and the average size of the reinforcement particles prevents defects such as reinforcement particle bridges through the anodized layer. The formed anodized layer is a composite anodized layer formed from a "normal" anodized layer with hard ceramic particles distributed within the anodized layer. The composite anodized layer exhibits improved wear resistance compared to conventional anodized layers (i.e., anodized layers without reinforcement particles).

[0034] The use of finer reinforcement particles also allows for thinner anodized layers to be produced without having defects present in the anodized layer. This has advantages for tolerance critical components, where thicker anodized layers could cause critical dimensions to go out of specification. For example, a defect-free anodized layer with a thickness of from about 1 μm to about 3 μm could not be achieved with a material that contains 3- μm reinforcement particles because the particles could bridge the anodized layer, thereby creating sites for localized corrosion. However, defect-free anodized layers with a thickness of from about 1 μm to about 3 μm can be used if the reinforcement average particle size is from about 0.3 μm to about 0.7 μm .

[0035] In addition, when normal aluminum (i.e. not containing reinforcement particles) is anodized, the resulting anodized layer has tubular pores that run through the thickness of the anodized layer, i.e. from the substrate to the top of the anodized layer, or through the entirety of the anodized layer. This type of anodized layer with tubular pores is generally referred to as "soft anodizing." The porous anodized layer develops by a nucleation and growth process. FIG. 3 is a cross-sectional view of such a layer, while FIG. 4 is a top view of such a layer. The article 300 has a substrate 310 and an anodized layer 320. Tubular pores 305 run through the anodized layer from a first surface 312 of the substrate to a top or outer surface 322 of the anodized layer. As seen in FIG. 4, these tubular pores can be distributed across the entire outer surface.

[0036] The use of finer reinforcement materials interrupts the growth of tubular pores, producing a dense anodized layer without or with a reduced number of tubular pores. The overall tubular porosity of the anodized layer is reduced. This is illustrated in **FIG. 5** and **FIG. 6**. As seen here, the presence of the reinforcement materials **330** cause the tubular pores **305** to be much shorter, and their occurrence to be much lower as well. They do not extend through the length of the anodized layer. This results in an anodized layer with higher hardness, higher wear resistance, improved electrical insulation, and improved fatigue properties for the final part. The fatigue performance is improved because the tubular pores can act as a crack initiation site for fatigue growth, and reducing eliminating them removes such crack initiation sites. The finer reinforcement particles are more effective than larger particles at preventing the growth of tubular pores because the spacing between particles can be much smaller.

[0037] The finer reinforcement materials also allow high strengths to be achieved in heat treatments that allow low residual stress (high stability) conditions. Finer reinforcements also allow low and medium strength 2xxx and 6xxx alloys to be utilized as the matrix alloy and their strengths can be increased to levels equivalent to or greater than 7xxx aluminum alloys. Good corrosion and stress corrosion performance can be achieved as a result of the lower solute content matrix alloys. This results in strength and modulus increases which are useful for designing lightweight structural components.

[0038] The finer reinforcement materials may also allow enhanced elevated temperature properties and/or strength stability after soaking at medium and high temperatures.

[0039] The composite material includes from about 15 vol% to about 50 vol% of the reinforcement particles, including from about 17 vol% to about 50 vol% and from about 20 vol% to about 25 vol%.

[0040] In some embodiments, the aluminum alloy includes from about 91.2 wt% to about 94.7 wt% aluminum, from about 3.8 wt% to about 4.9 wt% copper, from about 1.2 wt% to about 1.8 wt% magnesium, and from about 0.3 wt% to about 0.9 wt% manganese.

[0041] In other embodiments, the aluminum alloy includes from about 95.8 wt% to about 98.6 wt% aluminum, from about 0.8 wt% to about 1.2 wt% magnesium, and from about 0.4 wt% to about 0.8 wt% silicon.

[0042] The aluminum alloy may be 2124. The composition of 2124 aluminum alloy is as follows:

Component	Wt%
Aluminum	91.2-94.7
Chromium	Max 0.1
Copper	3.8-4.9
Iron	Max 0.3

(continued)

Component	Wt%
Magnesium	1.2-1.8
Manganese	0.3-0.9
Other, each	Max 0.05
Other, total	Max 0.15
Silicon	Max 0.2
Titanium	Max 0.15
Zinc	Max 0.25

[0043] The reinforcement particles may include at least one material selected from carbides, oxides, silicides, borides, and nitrides. In some embodiments, the material is selected from silicon carbide, titanium carbide, boron carbide, silicon nitride, titanium nitride, and zirconium oxide.

[0044] The metal matrix composite can be made by providing metal particles (e.g., aluminum or aluminum alloy particles) and reinforcement particles (e.g., ceramic particles) to a high energy mixing stage.

[0045] The metal and ceramic powders may be mixed with a high energy technique to distribute the ceramic reinforcement particles into the metal matrix. Suitable techniques for high energy mixing include ball milling, mechanical attritors, teamer mills, rotary mills and other methods to provide high energy mixing to the powder constituents. Mechanical alloying may be completed in an atmosphere to avoid excessive oxidation of powders preferable in an inert atmosphere using nitrogen or argon gas. The processing parameters may be selected to achieve an even distribution of the ceramic particles in the metallic matrix.

[0046] The powder from the high energy mixing stage may be degassed to remove any retained moisture from the powder surface. Degassing may be completed at a temperature in the range of from about 120 to about 500 °C.

[0047] A hot compacting step may also be performed to increase density and produce a billet. The hot compacting may be performed at a temperature in the range of from about 400 °C to about 600 °C, including from about 425 °C to about 550 °C and about 500 °C. Hot compaction may include the use of hot die compaction, hot isostatic pressing and/or hot extrusion. The pressure during the hot compacting may be in the range of from about 30 to about 150 MPa.

[0048] The billet may be subsequently processed into a final article. This processing may include rolling, extrusion, machining, and/or forging. In some embodiments, the billet is rolled, extruded, or forged into an intermediate article. Final machining, (e.g., computer numerical control machining or CNC) may be performed on the intermediate article resulting in a final article.

[0049] The billet or the final article can be used as a substrate and anodized to form an anodized layer on one or more surfaces of the substrate. The substrate is exposed to an anodizing bath, for example using chromic acid, sulphuric acid, phosphoric acid, organic acid, borate or tartrate, as is known in the art. The anodizing may be performed at a voltage of about 10 volts to about 20 volts. The anodizing may be performed for a time period of about 15 minutes to about 90 minutes. The anodizing may be performed at a bath temperature of about 15°C to about 30°C. Combinations of these process parameters are envisioned.

[0050] The following examples are provided to illustrate the compositions, articles, and methods of the present disclosure. The examples are merely illustrative and are not intended to limit the disclosure to the materials, conditions, or process parameters set forth therein.

EXAMPLES (not part of the invention)

[0051] Substrates including a metal matrix composite having 25 vol% of 3- μm (D50) silicon carbide particles dispersed in an aluminum alloy were anodized.

[0052] FIG. 7 and FIG. 8 are optical microscope images of the substrate and anodized layer produced under anodizing conditions of 15 volts in a 20 °C bath temperature for 30 minutes with no dye. The anodized layer had a thickness of from about 2 μm to about 4 μm . Magnification was 500X for FIG. 7 and 1000X for FIG. 8.

[0053] FIG. 9 and FIG. 10 are optical microscope images of the substrate and anodized layer produced under anodizing conditions of 15 volts in a 20 °C bath temperature for 30 minutes with black dye. The anodized layer had a thickness of from about 2 μm to about 4 μm . Magnification was 500X for FIG. 9 and 1000X for FIG. 10.

[0054] FIG. 11 and FIG. 12 are optical microscope images of the substrate and anodized layer produced under anodizing conditions of 15 volts ramping up to 18 volts in a 25 °C bath temperature for 60 minutes with no dye (not within the scope of the claims). The anodized layer had a thickness of from about 8 μm to about 10 μm . Magnification was 500X for FIG. 11 and 1000X for FIG. 12.

[0055] FIG. 13 and FIG. 14 are optical microscope images of the substrate and anodized layer produced under anodizing conditions of 15 volts ramping up to 18 volts in a 25 °C bath temperature for 60 minutes with black dye (not within the scope of the claims). The anodized layer had a thickness of from about 8 μm to about 10 μm . Magnification was 500X for FIG. 13 and 1000X for FIG. 14.

Claims

1. A composite article comprising:

a substrate; and

an anodized layer;
wherein the substrate comprises:

an aluminum or aluminum alloy matrix; and
reinforcement particles dispersed in the matrix;

wherein the anodized layer comprises:

an aluminum oxide matrix; and
reinforcement particles dispersed in the aluminum oxide matrix;

wherein a ratio of a thickness of the anodized layer to an average particle size D50, defined as 50% by volume of the particles have a diameter above the average particle size, and 50% of the particles have a diameter below the average particle size, of the reinforcement particles is at least 1.3;

wherein the substrate comprises from 15 vol% to 50 vol% of the reinforcement particles; and
wherein the average particle size is from 0.3 μm to 0.7 μm , and wherein the thickness of the anodized layer is from 1 μm to 3 μm .

2. The article of claim 1, wherein the ratio is at least 1.6, or wherein the ratio is at least 3.

3. The article of claim 1, wherein the reinforcement particles comprise at least one ceramic material selected from the group consisting of carbides, oxides, silicides, borides, and nitrides, or wherein the reinforcement particles comprise at least one ceramic material selected from the group consisting of silicon carbide, titanium carbide, boron carbide, silicon nitride, titanium nitride, and zirconium oxide.

4. The article of claim 1, wherein the aluminum alloy comprises at least one element selected from the group consisting of chromium, copper, lithium, magnesium, manganese, nickel, and silicon, or wherein the aluminum alloy comprises from 91.2 wt% to 94.7 wt% aluminum, from 3.8 wt% to 4.9 wt% copper, from 1.2 wt% to 1.8 wt% magnesium, and from 0.3 wt% to 0.9 wt% manganese, or wherein the aluminum alloy comprises from 95.8 wt% to 98.6 wt% aluminum, from 0.8 wt% to 1.2 wt% magnesium, and from 0.4 wt% to 0.8 wt% silicon.

5. A method for producing composite article according to claim 1, comprising:

anodizing a surface of a substrate comprising a metal matrix composite to form an anodized layer on the surface;

wherein the metal matrix composite comprises reinforcement particles dispersed in an alumi-

- num or aluminum alloy matrix;
 wherein a ratio of a thickness of the anodized layer to an average particle size D50 of the reinforcement particles is at least 1.3;
 wherein the substrate comprises from 15 vol% to 50 vol% of the reinforcement particles;
 wherein the average particle size is from 0.3 μm to 0.7 μm , and wherein the thickness of the anodized layer is from 1 μm to 3 μm .
6. The method of claim 5, wherein the anodizing is performed at a voltage of 10 volts to 60 volts.
7. The method of claim 5, wherein the anodizing is performed for a time period of 15 minutes to 90 minutes.
8. The method of claim 5, wherein the anodizing is performed at a bath temperature of 15°C to 30°C.
9. The method of claim 5, wherein the ratio is at least 3.

Patentansprüche

1. Verbundartikel, umfassend:
- ein Substrat; und
 eine anodisierte Schicht;
 wobei das Substrat das Folgende umfasst:
- eine Aluminium- oder Aluminiumlegierungsmatrix; und
 Verstärkungspartikel, die in der Matrix dispergiert sind;
- wobei die anodisierte Schicht das Folgende umfasst:
- eine Aluminiumoxidmatrix; und
 Verstärkungspartikel, die in der Aluminiumoxidmatrix dispergiert sind;
- wobei ein Verhältnis einer Dicke der anodisierten Schicht zu einer durchschnittlichen Partikelgröße D50 der Verstärkungspartikel mindestens 1,3 beträgt, wobei D50 als 50 Vol.-% der Partikel, die einen Durchmesser oberhalb der durchschnittlichen Partikelgröße aufweisen, und 50 % der Partikel, die einen Durchmesser unterhalb der durchschnittlichen Partikelgröße aufweisen, definiert ist;
 wobei das Substrat 15 Vol.-% bis 50 Vol.-% der Verstärkungspartikel umfasst; und
 wobei die durchschnittliche Partikelgröße 0,3 μm bis 0,7 μm beträgt, und wobei die Dicke der anodisierten Schicht von 1 μm bis 3 μm beträgt.
2. Artikel nach Anspruch 1, wobei das Verhältnis min-

destens 1,6 beträgt, oder wobei das Verhältnis mindestens 3 beträgt.

3. Artikel nach Anspruch 1, wobei die Verstärkungspartikel mindestens ein keramisches Material umfassen, das aus der Gruppe ausgewählt ist, bestehend aus Carbiden, Oxiden, Siliciden, Boriden und Nitriden, oder wobei die Verstärkungspartikel mindestens ein keramisches Material umfassen, das aus der Gruppe ausgewählt ist, bestehend aus Siliziumcarbid, Titancarbid, Borcarbid, Siliziumnitrid, Titanitrid und Zirkonoxid.
4. Artikel nach Anspruch 1, wobei die Aluminiumlegierung mindestens ein Element umfasst, ausgewählt aus der Gruppe, bestehend aus Chrom, Kupfer, Lithium, Magnesium, Mangan, Nickel und Silizium, oder wobei die Aluminiumlegierung 91,2 Gew.-% bis 94,7 Gew.-% Aluminium, 3,8 Gew.-% bis 4,9 Gew.-% Kupfer, 1,2 Gew.-% bis 1,8 Gew.-% Magnesium und 0,3 Gew.-% bis 0,9 Gew.-% Mangan umfasst, oder wobei die Aluminiumlegierung 95,8 Gew.-% bis 98,6 Gew.-% Aluminium, 0,8 Gew.-% bis 1,2 Gew.-% Magnesium und 0,4 Gew.-% bis 0,8 Gew.-% Silizium umfasst.
5. Verfahren zur Herstellung eines Verbundartikels nach Anspruch 1, umfassend:
- Anodisieren von einer Oberfläche eines Substrats, umfassend einen Metallmatrixverbundstoff, um eine anodisierte Schicht auf der Oberfläche zu bilden;
 wobei der Metallmatrixverbundstoff Verstärkungspartikel umfasst, die in einer Aluminium- oder Aluminiumlegierungsmatrix dispergiert sind;
 wobei ein Verhältnis einer Dicke der anodisierten Schicht zu einer durchschnittlichen Partikelgröße D50 der Verstärkungspartikel mindestens 1,3 beträgt;
 wobei das Substrat 15 Vol.-% bis 50 Vol.-% der Verstärkungspartikel umfasst;
 wobei die durchschnittliche Partikelgröße 0,3 μm bis 0,7 μm beträgt, und wobei die Dicke der anodisierten Schicht 1 μm bis 3 μm beträgt.
6. Verfahren nach Anspruch 5, wobei das Anodisieren bei einer Spannung von 10 Volt bis 60 Volt durchgeführt wird.
7. Verfahren nach Anspruch 5, wobei das Anodisieren für einen Zeitraum von 15 Minuten bis 90 Minuten durchgeführt wird.
8. Verfahren nach Anspruch 5, wobei das Anodisieren bei einer Badtemperatur von 15 °C bis 30 °C durchgeführt wird.

9. Verfahren nach Anspruch 5, wobei das Verhältnis mindestens 3 beträgt.

Revendications

1. Article composite comprenant :

un substrat ; et
une couche anodisée ;
dans lequel le substrat comprend :

une matrice en aluminium ou en alliage d'aluminium ; et
des particules de renforcement dispersées dans la matrice ;

dans lequel la couche anodisée comprend :

une matrice en oxyde d'aluminium ; et
des particules de renforcement dispersées dans la matrice en oxyde d'aluminium ;
dans lequel le rapport de l'épaisseur de la couche anodisée à la granulométrie moyenne D50, définie par 50 % en volume des particules ayant un diamètre supérieur à la granulométrie moyenne, et 50 % des particules ayant un diamètre inférieur à la granulométrie moyenne, des particules de renforcement, est d'au moins 1,3 ;
dans lequel le substrat comprend de 15 % en volume à 50 % en volume des particules de renforcement ; et
dans lequel la granulométrie moyenne est de 0,3 μm à 0,7 μm , et dans lequel l'épaisseur de la couche anodisée est de 1 μm à 3 μm .

2. Article selon la revendication 1, dans lequel le rapport est d'au moins 1,6, ou dans lequel le rapport est d'au moins 3.

3. Article selon la revendication 1, dans lequel les particules de renforcement comprennent au moins un matériau céramique choisi dans le groupe constitué par les carbures, les oxydes, les siliciures, les borures et les nitrures, ou dans lequel les particules de renforcement comprennent au moins un matériau céramique choisi dans le groupe constitué par le carbure de silicium, le carbure de titane, le carbure de bore, le nitrure de silicium, le nitrure de titane, et l'oxyde de zirconium.

4. Article selon la revendication 1, dans lequel l'alliage d'aluminium comprend au moins un élément choisi dans le groupe constitué par le chrome, le cuivre, le lithium, le magnésium, le manganèse, le nickel et le silicium, ou dans lequel l'alliage d'aluminium com-

prend de 91,2 % en poids à 94,7 % en poids d'aluminium, de 3,8 % en poids à 4,9 % en poids de cuivre, de 1,2 % en poids à 1,8 % en poids de magnésium, et de 0,3 % en poids à 0,9 % en poids de manganèse, ou dans lequel l'alliage d'aluminium comprend de 95,8 % en poids à 98,6 % en poids, de 0,8 % en poids à 1,2 % en poids de magnésium, et de 0,4 % en poids à 0,8 % en poids de silicium.

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5. Procédé pour produire un article composite selon la revendication 1, comprenant :

l'anodisation d'une surface d'un substrat comprenant un composite de matrice métallique pour former une couche anodisée sur la surface ;
dans lequel le composite de matrice métallique comprend des particules de renforcement dispersées dans une matrice en aluminium ou en alliage d'aluminium ;
dans lequel le rapport de l'épaisseur de la couche anodisée à la granulométrie moyenne D50 des particules de renforcement est d'au moins 1,3 ;
dans lequel le substrat comprend de 15 % en volume à 50 % en volume des particules de renforcement ;
dans lequel la granulométrie moyenne est de 0,3 μm à 0,7 μm , et dans lequel l'épaisseur de la couche anodisée est de 1 μm à 3 μm .

6. Procédé selon la revendication 5, dans lequel l'anodisation est effectuée sous une tension de 10 volts à 60 volts.

7. Procédé selon la revendication 5, dans lequel l'anodisation est effectuée pendant une période de temps de 15 minutes à 90 minutes.

8. Procédé selon la revendication 5, dans lequel l'anodisation est effectuée à une température de bain de 15°C à 30°C.

9. Procédé selon la revendication 5, dans lequel le rapport est d'au moins 3.

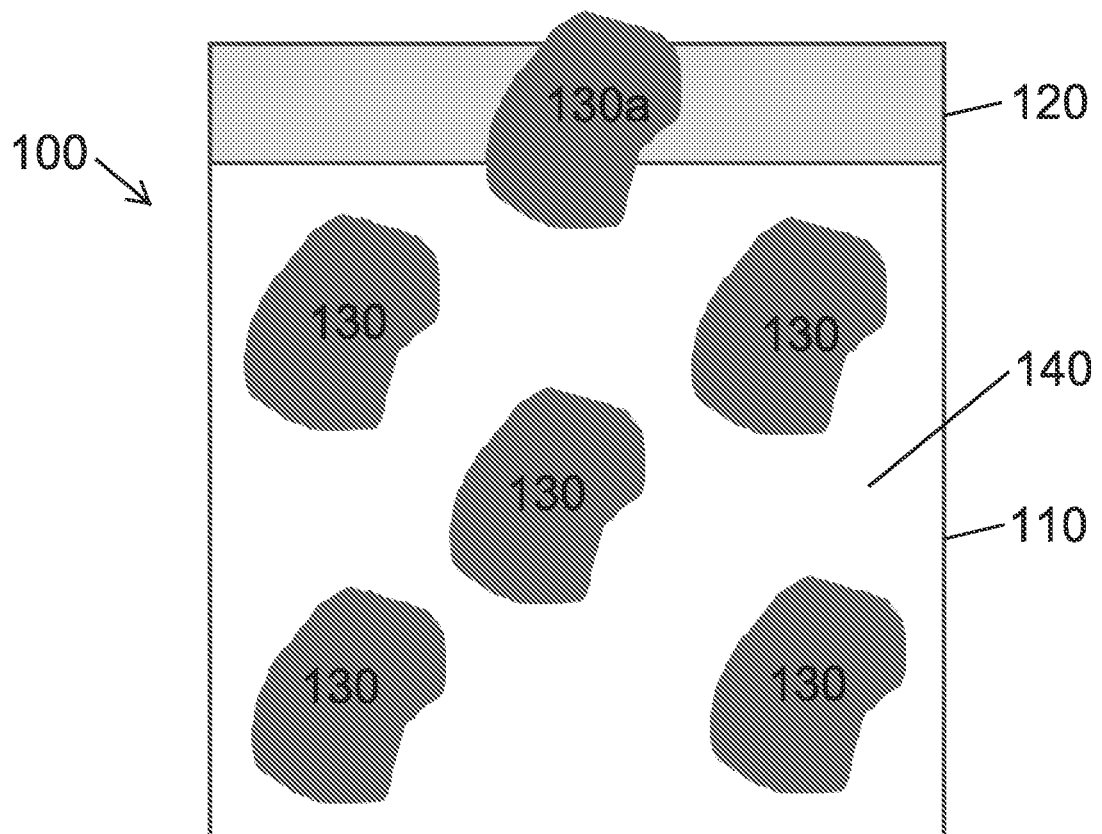


FIG. 1

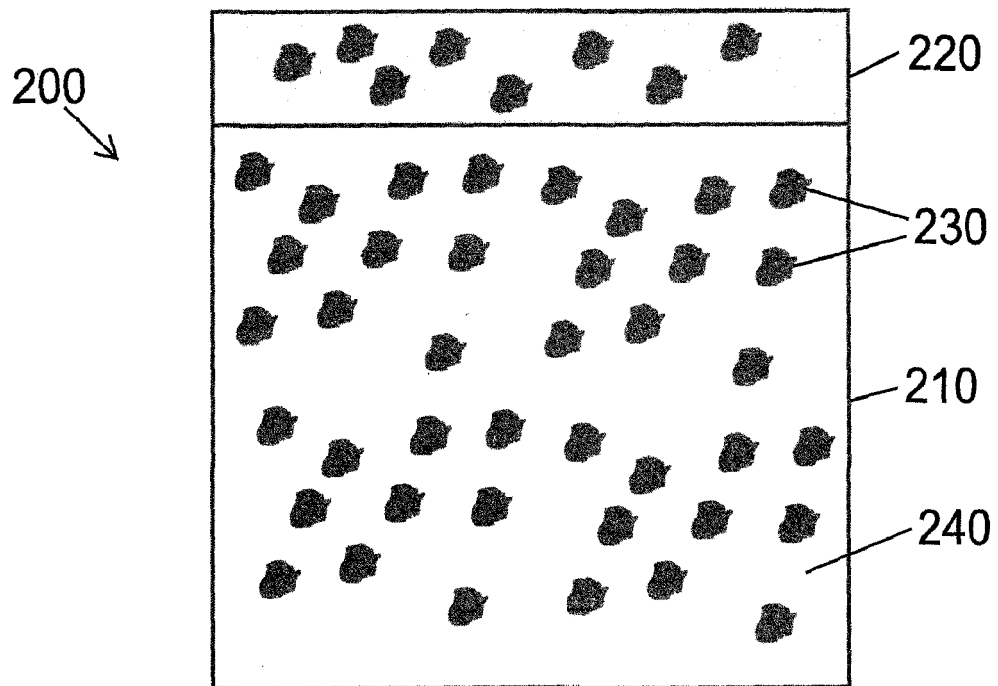


FIG. 2

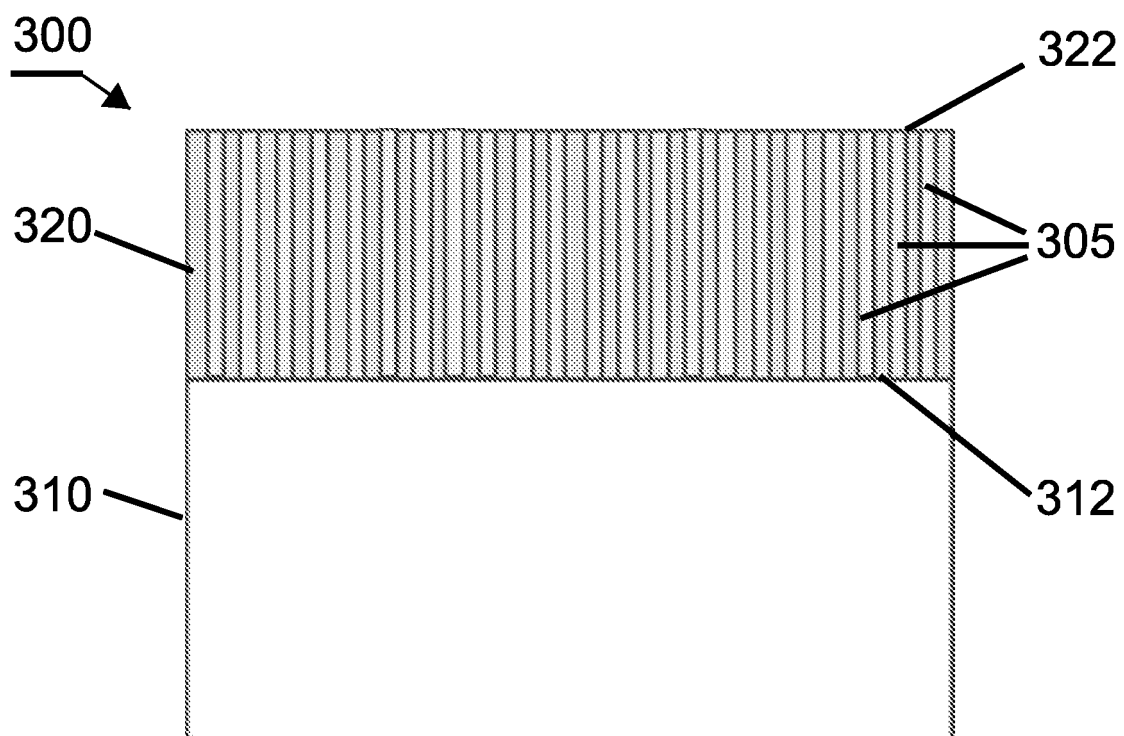


FIG. 3

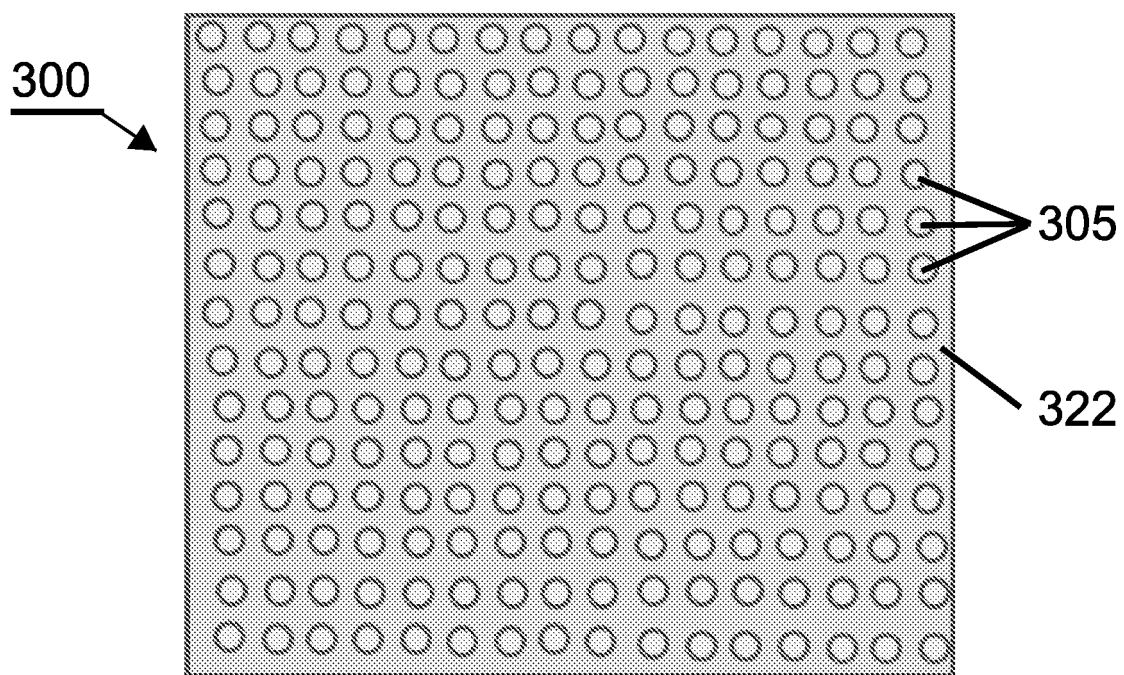


FIG. 4

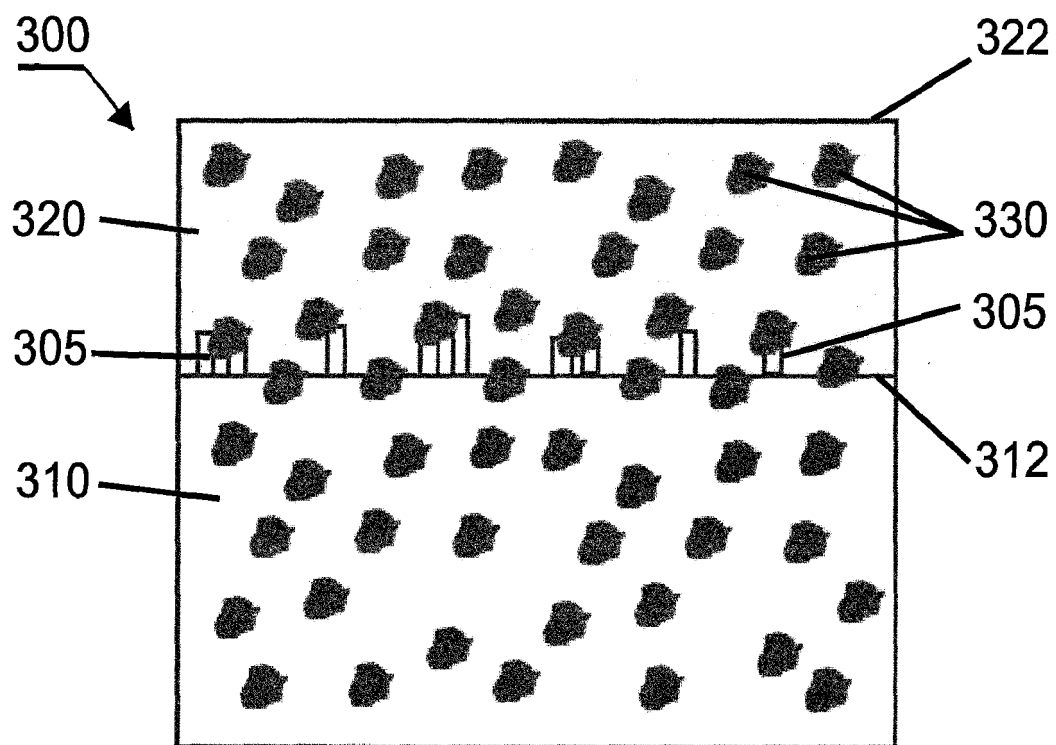


FIG. 5



FIG. 6

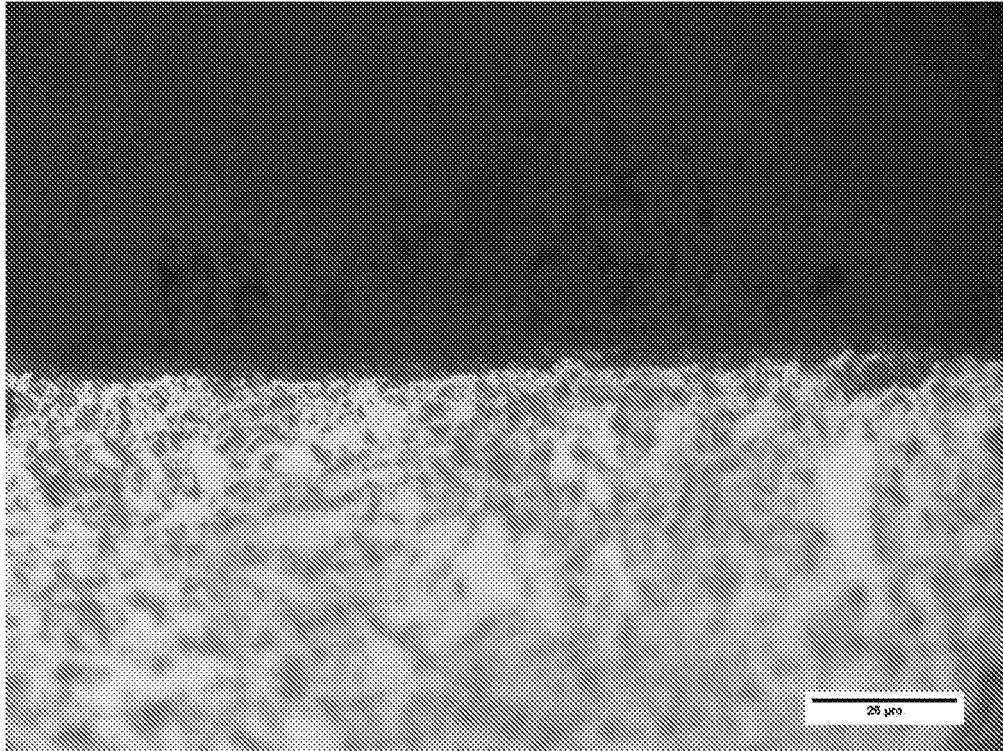


FIG. 7

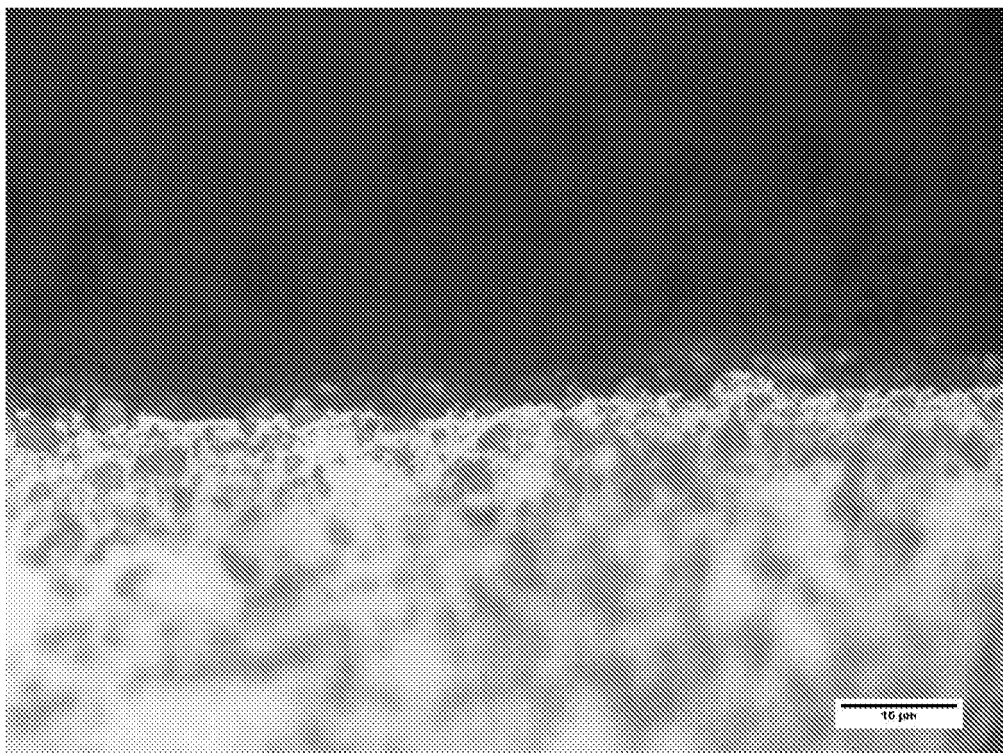


FIG. 8

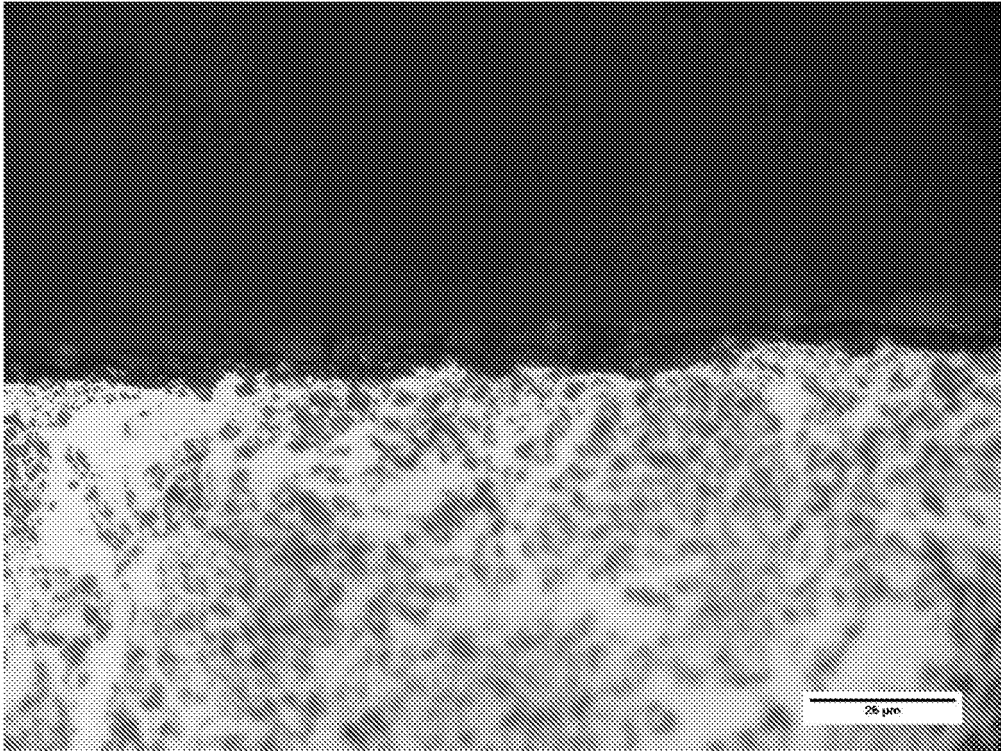


FIG. 9

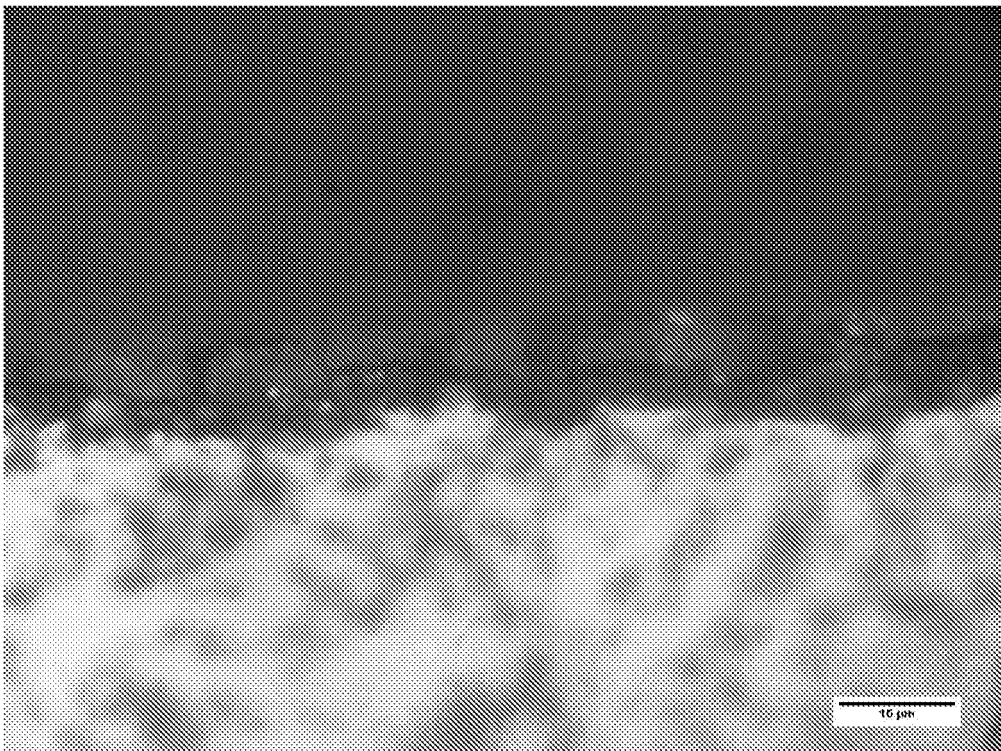


FIG. 10

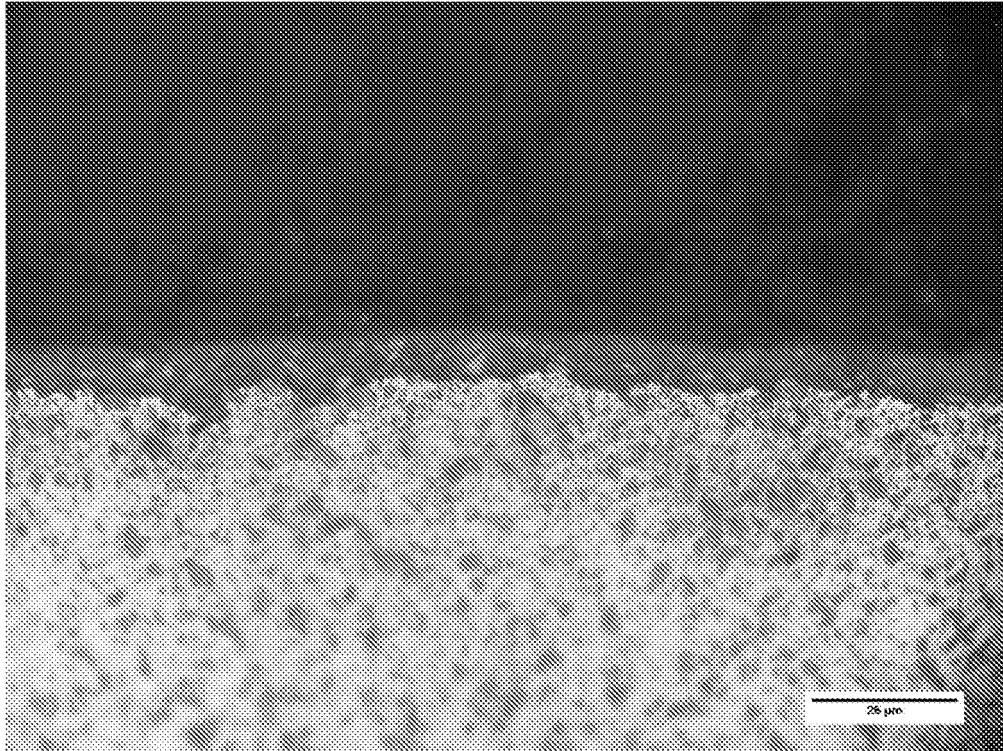


FIG. 11

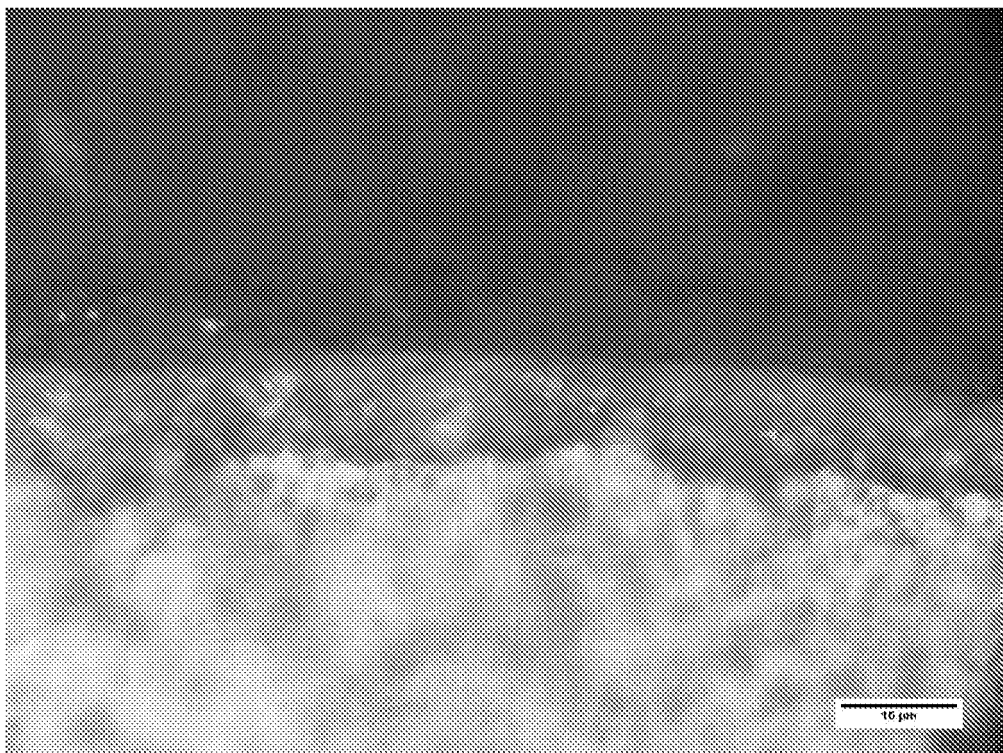


FIG. 12

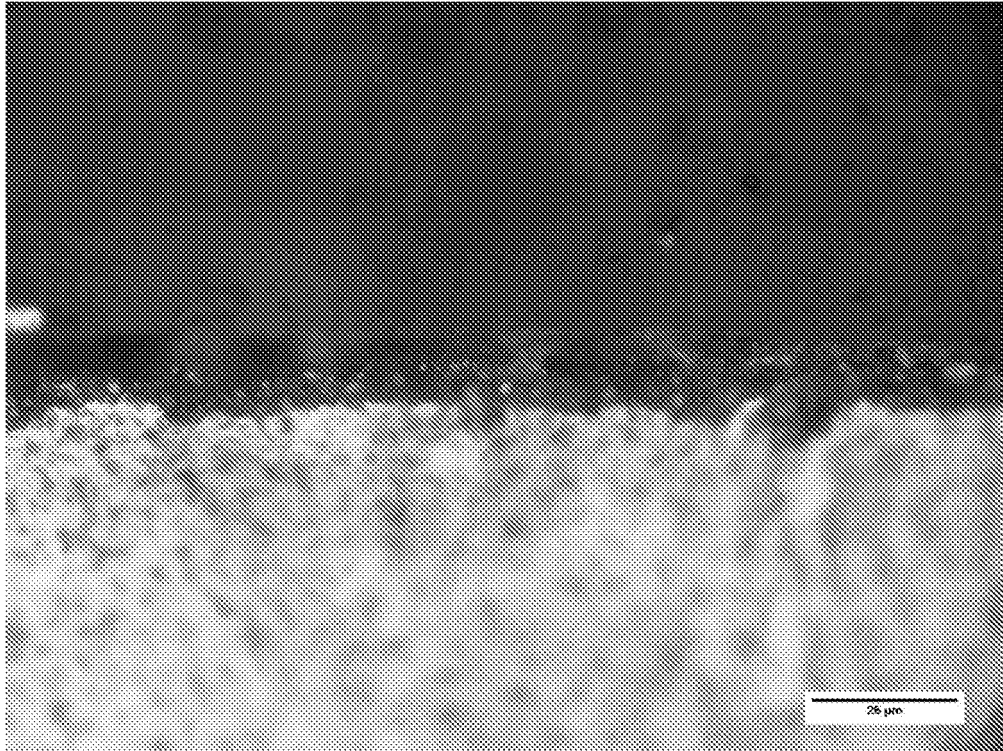


FIG. 13

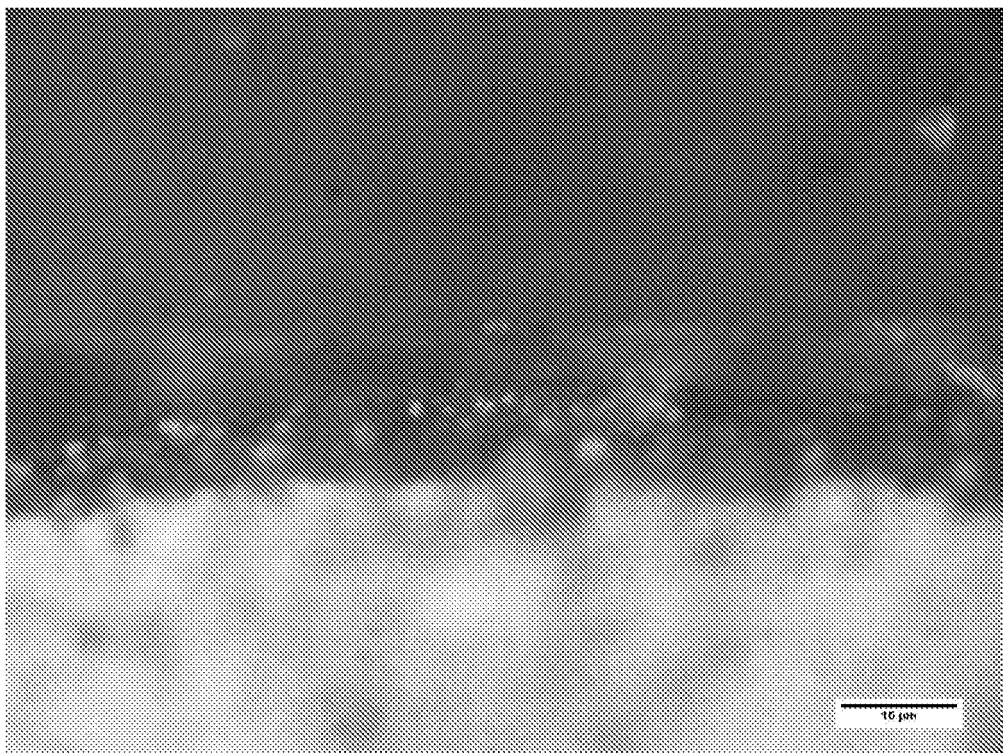


FIG. 14

REFERENCES CITED IN THE DESCRIPTION

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