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(54) **Erosion barrier for thermal barrier coatings**

Erosionssperre für Wärmedämmschichten

Barrière contre l'érosion pour revêtements de barrière thermique

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Description

[0001] The present invention relates to an erosion barrier for thermal barrier coatings and to processes for forming the erosion barrier.

[0002] Many turbine engine components are provided with a thermal barrier coating to protect the underlying substrate. High velocity particles in the gas path of an engine cause considerable erosion damage to the thermal barrier coating. The erosion of the thermal barrier coating leads to premature failure of the coated turbine engine part. Thus, it is highly desirable to form a hard exterior shell strongly bonded to the thermal barrier coating. For example, EP 0783043 discloses a thermal barrier coating having an erosion-resistant composition dispersed within or overlaying a ceramic layer, and EP 1788122 discloses a process for forming a protective deposit over a ceramic thermal barrier layer.

[0003] The present invention provides a process for forming an erosion barrier for protecting a thermal barrier coating on a workpiece as claimed in claim 1. Thus, in the present invention, a hard exterior shell is formed that is strongly bonded to the thermal barrier coating.

[0004] The erosion barrier may be formed from aluminum oxide, silicon carbide, silicon nitride, and molybdenum disilicide.

[0005] Other details of the erosion barrier for thermal barrier coatings of the present invention, as well as other objects and advantages attendant thereto, are set forth in the following detailed description and the accompanying drawings wherein like reference numerals depict like elements.

FIG. 1 is a schematic representation of an apparatus for forming an erosion barrier on a workpiece having a thermal barrier coating; and

FIG. 2 is a schematic representation of a workpiece having a thermal barrier coating and an erosion barrier.

[0006] The present invention involves forming a hard shell exterior coating which acts as an erosion barrier on a thermal barrier coating applied to a substrate such as a turbine engine component. The exterior coating erosion barrier is formed by electrophoretic deposition.

[0007] With regard to the electrophoretic deposition, as shown in FIG. 1, the workpiece 50, such as a turbine engine component or part, forming the substrate is immersed in a suspension 10 and electrically connected to one terminal of a voltage source 12. A second electrode 14, which may be formed from any suitable electrically conductive material known in the art, is electrically connected to a second terminal of the voltage source 12.

[0008] Prior to immersion in the suspension, a thermal barrier coating 52, such as a zirconia based thermal barrier coating, is applied to the turbine engine component 50. The thermal barrier coating 52 may be applied to the turbine engine component using any suitable technique

known in the art.

[0009] The suspension 10 consists of very fine ceramic particles ranging in size from about 0.02 microns to 0.2 microns in sol form. Preferably, the ceramic particles have a size in the range of from about 0.02 to 0.05 microns. The ceramic particles may be suspended in a solvent such as water, alcohols including, but not limited to, ethanol or methanol, and water-alcohol mixtures. One can use organic solvents, such as trichloroethane, however, such use may be prohibited by health and environmental issues.

[0010] In the simplest embodiment, an aluminum oxide (alumina) sol is put in suspension in water, alcohol, or mixtures thereof, and stabilized by the addition of sufficient acid to keep the pH of the solution below 4.25. This results in a positive charge on the alumina particles, such that they repel each other, avoiding agglomeration and sedimentation of the particles out of solution. Candidates for acids to be added to the solution include, but is not limited to, nitric acid, hydrochloric acid, acetic acid, and stearic acid. Reducing the pH of the solution as low as 2.0 is possible, but low pHs could result in acid attack of any exposed metal on the parts or components to be coated in the suspension. The preferred pH for alumina sol suspensions in water and/or alcohol is from 3.0 to 4.5. The part or component 50 to be coated may be strongly biased with a negative DC voltage to accelerate the suspended particles in the suspension toward the thermal barrier coated surface of the part or component 50. Typical negative biasing voltages range from about 50 to 2000V, preferably from about 900 to 1100V. Higher voltages lead to higher deposition rates, but are potentially hazardous by increasing the system's potential energy to a level that can compromise workplace safety.

[0011] In addition to alumina sol in suspension, other hard ceramic materials that would be suitable include silicon nitride sol, silicon carbide sol, and molybdenum disilicide sol. The suitable pH range required to produce a stable suspension varies with the composition of the fine ceramic particles in the suspension. This is due to surface chemistry variations which lead to different build-ups of charge on the surfaces of the particles as a function of the pH of the suspension. At low pH, surfaces are positively charged, and at high pH, surfaces are negatively charged. Thus, there exists a pH level that corresponds to zero surface charge on the particles, which is known as the isoelectric point or pH_{Iep}. Alumina has a pH_{Iep} of 4.5, while silicon nitride has a pH_{Iep} of 9.0, silicon nitride has a pH_{Iep} of 5.4, and molybdenum disilicide has a pH_{Iep} of 2.2.

[0012] Since the present invention may be used to form hard shell materials deposited on zirconia based thermal barrier coatings, it may also be advantageous to operate in a pH range that results in negative charge on the zirconia based coatings. This can be done by operating above the pH_{Iep} of zirconia which is 4.0. With regard to alumina particles in a suspension, the biasing of the zirconia coating would supply plenty of negative charge to

the zirconia surface, thereby extending the useable pH lower limit downwards to 3.0.

[0013] As discussed above, strong acids do tend to attack the metals forming the substrate of the part or component as well as metallic coatings. For this reason, silicon nitride may have an advantage over the other coatings since its pH_{iep} is high at 9.0. This system has the additional advantage of being able to be deposited at neutral pH, which has health and safety advantages.

[0014] The pH level at which the electrophoretic deposition is carried out may be raised by modifying the surface chemistry of the sols prior to putting them into suspension. For example, nitriding alumina sols, or aluminizing molybdenum disilicide sols may raise the operating pH level, minimizing damage to parts or components 50.

[0015] While the foregoing has discussed the addition of an acid to control the pH, one could also add a base to the suspension to maintain the pH equal to or greater than 7.0. Typical bases to add include ammonium hydroxide and aluminum hydroxide. The thermal stability of alumina, as well as its excellent hardness, makes it the preferred material for the erosion barrier coating.

[0016] Hardness of the hard shell materials at room temperature are:

Alumina: Vickers hardness, approx. 2650 kgf/mm² (26.0 GPa);

Silicon nitride: Vickers hardness, approx. 1900 kgf/mm² (18.6 GPa);

Silicon carbide: Vickers hardness, approx. 2750 kgf/mm² (27.0 GPa); and

Molybdenum disilicide: Vickers hardness, approx. 1300 kgf/mm² (12.8 GPa).

The suspension may be maintained at a temperature in the range of from about room temperature (68°F) to 120°F (20°C to 49°C), with room temperature being preferred for cost minimization.

[0017] The concentration of sols in the suspensions may range from about 0.001 wt% to 5.0 wt% solids. Preferably, the concentration of sols in the suspensions may be from about 0.005 to 0.05 wt% solids.

[0018] After the part or component 50 is removed from the suspension after the erosion barrier coating has been deposited, it may be dried using any suitable drying technique known in the art. Drying may be carried out at a temperature in the range of from about room temperature to 650°F (20°C to 343°C). Drying times at room temperature may range from about 1.0 to 20 hours, preferably from about 3.0 to 10 hours. At drying temperatures in the range of 250°F to 650°F (121°C to 343°C), the drying times may be reduced from about 0.5 to 5.0 hours with a preferred drying time range of from about 1.0 to 2.0 hours.

[0019] After drying, the coated part or component may be subjected to a sintering operation to form strong bonds within the deposited erosion barrier coating and between the erosion barrier coating and the thermal barrier coat-

ing. Also, sintering reduces porosity in the erosion barrier coating which drives the hardness values toward the bulk hardness values discussed hereinbefore. Sintering may be carried out using any suitable technique known in the art. Sintering times may range from about 3.0 to 4.0 hours at a temperature in the range of from about 1950°F to 2000°F (1066°C to 1093°C).

[0020] If desired, one or more dispersants such as polymethyl methacrylate alcohol and ammonium stearate could be added to the suspension to avoid agglomeration and settling of particles. The dispersant(s) may be present in a concentration from 0.01 to 1.0 wt%, preferably from 0.4 to 0.8 wt%.

[0021] If desired, polyvinyl alcohol can be added as a binder to the suspension to increase the strength of the hard shell prior to sintering if necessary. The polyvinyl alcohol may be added in an amount from 0.1 to 3.0 wt%, preferably from 1.0 to 2.0 wt%. The goal of the polyvinyl alcohol binder addition is to coat each particle of sol in the suspension with a monolayer of binder.

[0022] Referring now to FIG. 2, the processes of the present invention preferably yield a component or part 50 having a thermal barrier coating (TBC) 52 and a hard shell erosion barrier coating 54 deposited over the thermal barrier coating 52. An infiltrated region 56 may be formed between the coating 54 and the coating 52. The infiltrated region may constitute from 5.0 to 100% of the thickness of the TBC measured down from the surface of the TBC. Preferably, the thickness of the infiltrated region is from 10-20% of the TBC thickness. The component or part 50 may be formed from any suitable metallic material known in the art such as a nickel based superalloy.

[0023] Erosion of TBCs tends to happen on specific areas of turbine engine components. For example, blade tips get eroded, especially on the suction side. Outer buttresses of vanes also get eroded due to centrifugal forces. Most particulates in the turbine gas stream are centrifuged out to the outer diameter of the turbine, where they do most of their damage. Any relatively steep contours on the turbine engine components get eroded, simply because steep contours increase the local pressure on the part surface by compressing the gas stream, which increases the frequency of collisions with both molecules and any particulates in the gas stream--thus increasing erosion. To minimize the weight added by the hard shell coating and to minimize any potential detrimental effects a hard shell coating might have on TBCs on any turbine engine component, such as reduction of strain tolerance, it would be beneficial to put the hard shell coating only on areas with known susceptibility to erosion.

[0024] The placement of a hard shell coating on only a portion of a turbine engine component may be done using a painting process, a dipping process, or an electrophoretic approach. An organic maskant may be applied to all surfaces not intended to be coated.

[0025] The placement of the hard shell coating may be done by applying a UV curable resin, such as a commer-

cially available resin known as PHOTORESIST, on the turbine engine component. Then one could apply a sheet metal mask to the areas onto which the deposition of the hard coating is desired. Thereafter, the resin-coated, masked component may be exposed to UV light for a time period from 1.0 to 10 minutes to cure all exposed resin. After curing, the sheet metal mask is removed. Any uncured resin may be washed off. Then one can proceed to the hard coating process. If photolithography is used, drying may be carried out at a temperature in the range of from 600°F to 900°F (316°C to 482°C) for a time in the range of from 2.0 to 4.0 hours to burn off the cured resin.

[0026] The processes of the present invention may be used to form an erosion barrier coating on a wide variety of parts and components having a thermal barrier coating thereon. The parts or components which may be treated include, but are not limited, any part having an airfoil, any part having a seal, airfoils, seals, and the like. Examples of such parts or components include blades, vanes, stators, mid-turbine frames, combustor panels, combustor cans, combustor bulkhead panels, disk side plates, and fuel nozzle guides.

[0027] Although the present invention has been described with reference to preferred embodiments, it will be understood by those skilled in the art that various changes in form and detail can be made to the particular embodiments described above without departing from the scope of the invention as set forth in the accompanying claims.

Claims

1. A process for forming an erosion barrier for protecting a thermal barrier coating (52) on a workpiece (50), said process comprising the steps of:

forming a suspension (10) of ceramic particles suspended in a solvent; and
depositing particles in said suspension on said thermal barrier coating (52);

characterised in that:

said suspension forming step comprises adding an acid or a base to said suspension (10) so that said suspension has a pH no greater than 9.0;

said depositing step comprises electrophoretically depositing said particles in said suspension (10) on said thermal barrier coating by biasing said workpiece having said thermal barrier coating (52) with a DC voltage sufficient to accelerate suspended particles in said suspension (10) toward a surface of the workpiece (50); and
by drying said particles deposited on said thermal barrier coating (52) so as to form an erosion barrier coating (54) which has a

Vickers hardness in the range of from 1300 to 2750 kgf/mm² (12.8 to 27.0 GPa).

2. The process of claim 1, wherein said suspension forming step comprises forming a suspension using a solvent selected from the group consisting of water, alcohol, and mixtures thereof.
3. The process of claim 1 or 2, wherein said step suspension forming step comprises forming a suspension (10) with ceramic particles selected from the group consisting of aluminum oxide, silicon nitride, silicon carbide, and molybdenum disilicide.
4. The process of any preceding claim, wherein said step suspension forming step comprises forming a suspension using ceramic particles having a particle size in the range of from 0.02 to 0.2 microns.
5. The process of any preceding claim, further comprising maintaining said suspension (10) at a temperature in the range of from room temperature (68°F) to 120°F (20°C to 49°C).
6. The process of any preceding claim, further comprising forming said suspension (10) so that said ceramic particles are present in a concentration of from 0.001 to 5.0 wt%.
7. The process of claim 6, comprising forming said suspension (10) so that said ceramic particles are present in a concentration of from about 0.005 to 0.05 wt%.
8. The process of any preceding claim, wherein said acid adding step comprises adding an acid which maintains the pH of said suspension at one of: (i) below 4.25; and (ii) in the range of from 2.0 to 4.25.
9. The process of claim 8, wherein said acid adding step comprises adding an acid selected from the group consisting of nitric acid, hydrochloric acid, acetic acid, and stearic acid.
10. The process of any of claims 1 to 7, wherein said base adding step comprises adding a base selected from the group of aluminum hydroxide and ammonium hydroxide to raise the pH of said suspension (10).
11. The process of any preceding claim, further comprising adding from 0.01 to 1.0 wt% of a dispersant selected from the group consisting of polymethyl methacrylate alcohol and ammonium stearate to said suspension to avoid agglomeration and settling of said particles.
12. The process of any preceding claim, further compris-

ing adding from 0.1 to 3.0 wt% of a binder to said suspension to increase the strength of a shell formed by said erosion barrier.

13. The process of claim 12, wherein said binder adding step comprises adding from 1.0 to 2.0 wt% of polyvinyl alcohol. 5
14. The process of any preceding claim, wherein said depositing step comprises applying a voltage in the range of from 50 to 2000V to said workpiece (50). 10
15. The process of claim 14, wherein said depositing step comprises applying a voltage in the range of from 900 to 1100V to said workpiece (50). 15
16. The process of any preceding claim, further comprising removing said workpiece (50) with said deposited particles from said suspension and said drying step comprising drying said workpiece at a temperature in the range from room temperature (68°F) to 650°F (20°C to 343°C) for a time in the range of from 0.5 to 20 hours. 20
17. The process of claim 16, wherein said drying step comprises one of: (i) drying said workpiece at room temperature for a time in the range of from 1 to 20 hours; (ii) drying said workpiece at room temperature for a time in the range of 3 to 10 hours; (iii) drying said workpiece at a temperature in the range of 250°F to 650°F (121°C to 343°C) for a time in the range of from 0.5 to 5.0 hours; and (iv) drying said workpiece at a temperature in the range of 250°F to 650°F (121°C to 343°C) for a time in the range of from 1.0 to 2.0 hours. 25
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18. The process of any preceding claim, further comprising sintering said workpiece (50) at a temperature in the range of 1950°F to 2000°F (1066°C to 1093°C) for a time period in the range of from 3.0 to 4.0 hours. 40
19. The process of any preceding claim, wherein said thermal barrier coating (52) comprises a zirconia based thermal barrier coating. 45
20. The process of any preceding claim, wherein an infiltrated region (56) is formed between said thermal barrier coating (52) and said erosion barrier (54). 50
21. The process of any preceding claim, wherein said workpiece (50) comprises a turbine engine component. 55

Patentansprüche

1. Verfahren zum Bilden einer Erosionssperre zum Schützen einer Wärmesperrschicht (52) an einem

Werkstück (50), wobei das Verfahren folgende Schritte umfasst:

Bilden einer Suspension (10) aus Keramikpartikeln, die in einem Lösungsmittel suspendiert werden; und

Abscheiden von Partikeln in der Suspension auf die Wärmesperrschicht (52);

dadurch gekennzeichnet, dass:

der Schritt des Bildens der Suspension das Zusetzen einer Säure oder einer Basis zu der Suspension (10) umfasst, derart, dass die Suspension einen pH-Wert von nicht höher als 9,0 aufweist;

wobei der Schritt des Abscheidens elektrophoretisches Abscheiden der Partikel in der Suspension (10) auf der Wärmesperrschicht durch Vorspannen des Werkstücks mit der Wärmesperrschicht (52) mit einer Gleichspannung umfasst, die ausreicht, um suspendierte Partikel in der Suspension (10) zu einer Oberfläche des Werkstücks (50) hin zu beschleunigen; und

durch Trocknen der Partikel, die auf der Wärmesperrschicht (52) abgeschieden wurden, um eine Erosionssperre (54) zu bilden, die eine Vickers-Härte im Bereich von 1300 bis 2750 kgf/mm² (12,8 bis 27,0 GPa) aufweist.

2. Verfahren nach Anspruch 1, wobei der Schritt des Bildens der Suspension das Bilden einer Suspension mithilfe eines Lösungsmittels umfasst, das ausgewählt wird aus der Gruppe bestehend aus Wasser, Alkohol und Gemischen davon.
3. Verfahren nach Anspruch 1 oder 2, wobei der Schritt des Bildens der Suspension das Bilden einer Suspension (10) mit Keramikpartikeln umfasst, die ausgewählt werden aus der Gruppe bestehend aus Aluminiumoxid, Siliziumnitrid, Siliziumkarbid und Molybdändisilizid.
4. Verfahren nach einem der vorangehenden Ansprüche, wobei der Schritt des Bildens der Suspension das Bilden einer Suspension mit Keramikpartikeln umfasst, die eine Partikelgröße im Bereich von 0,02 bis 0,2 Mikrometern aufweisen.
5. Verfahren nach einem der vorangehenden Ansprüche, ferner umfassend Halten der Suspension (10) auf einer Temperatur im Bereich von Raumtemperatur (68 °F) bis 120 °F (20 °C bis 49 °C).
6. Verfahren nach einem der vorangehenden Ansprüche, ferner umfassend Bilden der Suspension (10) derart, dass die Keramikpartikel in einer Konzentra-

tion von 0,001 bis 5,0 Gew.-% vorliegen.

7. Verfahren nach Anspruch 6, umfassend Bilden der Suspension (10) derart, dass die Keramikpartikel in einer Konzentration von 0,005 bis 0,05 Gew.-% vorliegen. 5
8. Verfahren nach einem der vorangehenden Ansprüche, wobei der Schritt des Zusetzens das Zusetzen einer Säure umfasst, die den pH-Wert der Suspension bei einem von: (i) unter 4,25; und (ii) im Bereich von 2,0 bis 4,25 hält. 10
9. Verfahren nach Anspruch 8, wobei der Schritt des Zusetzens einer Säure umfasst, die ausgewählt wird aus der Gruppe bestehend aus Salpetersäure, Salzsäure, Essigsäure und Stearinsäure. 15
10. Verfahren nach einem der Ansprüche 1 bis 7, wobei der Schritt des Zusetzens einer Basis das Zusetzen einer Basis umfasst, die ausgewählt wird aus der Gruppe bestehend aus Aluminiumhydroxid und Ammoniumhydroxid, um den pH-Wert der Suspension (10) zu erhöhen. 20
11. Verfahren nach einem der vorangehenden Ansprüche, ferner umfassend Zusetzen von 0,01 bis 1,0 Gew.-% eines Dispersionsmittels, ausgewählt aus der Gruppe bestehend aus Polymethylmethacrylalkohol und Ammoniumstearat zu der Suspension, um ein Agglomerieren und ein Absetzen der Partikel zu vermeiden. 25
12. Verfahren nach einem der vorangehenden Ansprüche, ferner umfassend Zusetzen von 0,1 bis 3,0 Gew.-% eines Bindemittels zu der Suspension, um die Festigkeit eines Mantels zu erhöhen, der durch die Erosionssperre gebildet wird. 30
13. Verfahren nach Anspruch 12, wobei der Schritt des Zusetzens des Bindemittels das Zusetzen von 1,0 bis 2,0 Gew.-% Polyvinylalkohol umfasst. 35
14. Verfahren nach einem der vorangehenden Ansprüche, wobei der Schritt des Abscheidens das Anlegen einer Spannung im Bereich von 50 bis 2000 V an das Werkstück (50) umfasst. 40
15. Verfahren nach Anspruch 14, wobei der Schritt des Abscheidens das Anlegen einer Spannung im Bereich von 900 bis 1100 V an das Werkstück (50) umfasst. 45
16. Verfahren nach einem der vorangehenden Ansprüche, ferner umfassend Entfernen des Werkstücks (50) mit den abgeschiedenen Partikeln aus der Suspension, wobei der Schritt des Trocknens das Trocknen des Werkstücks bei einer Temperatur im Be-

reich von Raumtemperatur (68 °F) bis 650 °F (20 °F bis 343 °C) für eine Dauer im Bereich von 0,5 bis 20 Stunden umfasst.

17. Verfahren nach Anspruch 16, wobei der Schritt des Trocknens eins der Folgenden umfasst: (i) Trocknen des Werkstücks bei Raumtemperatur für eine Dauer im Bereich von 1 bis 20 Stunden; (ii) Trocknen des Werkstücks bei Raumtemperatur für eine Dauer im Bereich von 3 bis 10 Stunden; (iii) Trocknen des Werkstücks bei einer Temperatur im Bereich von 250 °F bis 650 °F (121 °C bis 343 °C) für eine Dauer im Bereich von 0,5 bis 5,0 Stunden; und (iv) Trocknen des Werkstücks bei einer Temperatur im Bereich von 250 °F bis 650 °F (121 °C bis 343 °C) für eine Dauer im Bereich von 1,0 bis 2,0 Stunden. 50
18. Verfahren nach einem der vorangehenden Ansprüche, ferner umfassend Sintern des Werkstücks (50) bei einer Temperatur im Bereich von 1950 °F bis 2000 °F (1066 °C bis 1093 °C) für eine Dauer im Bereich von 3,0 bis 4,0 Stunden. 55
19. Verfahren nach einem der vorangehenden Ansprüche, wobei die Wärmesperrschicht (52) eine auf Zirkonium basierte Wärmesperrschicht umfasst. 60
20. Verfahren nach einem der vorangehenden Ansprüche, wobei eine infiltrierte Region (56) zwischen der Wärmesperrschicht (52) und der Erosionssperrschicht (54) gebildet wird. 65
21. Verfahren nach einem der vorangehenden Ansprüche, wobei das Werkstück (50) ein Bauteil eines Turbinenriebwerks umfasst. 70

Revendications

1. Procédé de formation d'une barrière contre l'érosion servant à protéger un revêtement formant une barrière thermique (52) sur une pièce à usiner (50), ledit procédé comprenant les étapes suivantes :

formation d'une suspension (10) de particules céramiques en suspension dans un solvant ; et dépôt de particules dans ladite suspension sur ledit revêtement formant une barrière thermique (52) ;

caractérisé en ce que :

ladite étape de formation de suspension comprend l'ajout d'un acide ou d'une base à ladite suspension (10) de sorte que ladite suspension a un pH inférieur à 9,0 ;
ladite étape de dépôt comprend le dépôt par électrophorèse desdites particules dans ladite suspension (10) sur ledit revêtement

- formant une barrière thermique par polarisation de ladite pièce à usiner comportant ledit revêtement formant une barrière thermique (52) avec une tension continue suffisante à accélérer les particules en suspension dans ladite suspension (10) vers une surface de la pièce à usiner (50) ; et par séchage desdites particules déposées sur ledit revêtement formant une barrière thermique (52) de manière à former un revêtement formant une barrière contre l'érosion (54) qui a une dureté Vickers comprise entre 1 300 et 2 750 kgf/mm² (12,8 à 27,0 GPa).
2. Procédé selon la revendication 1, dans lequel ladite étape de formation de suspension comprend la formation d'une suspension à l'aide d'un solvant choisi dans l'ensemble constitué d'eau, d'alcool et de leurs mélanges.
 3. Procédé selon la revendication 1 ou 2, dans lequel ladite étape de formation de suspension comprend la formation d'une suspension (10) avec des particules céramiques choisies dans l'ensemble constitué d'oxyde d'aluminium, de nitrure de silicium, de carbure de silicium et de disiliciure de molybdène.
 4. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite étape de formation de suspension comprend la formation d'une suspension utilisant des particules céramiques dont la taille de particule est comprise entre 0,02 et 0,2 µm.
 5. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre le maintien de ladite suspension (10) à une température comprise entre la température ambiante (68 °F) et 120 °F (20 °C à 49 °C).
 6. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre la formation de ladite suspension (10) de sorte que lesdites particules céramiques soient présentes en une concentration comprise entre 0,001 et 5,0 % en poids.
 7. Procédé selon la revendication 6, comprenant la formation de ladite suspension (10) de sorte que lesdites particules céramiques soient présentes en une concentration comprise entre 0,005 et 0,05 % en poids.
 8. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite étape d'ajout d'acide comprend l'ajout d'un acide qui maintient le pH de ladite suspension soit (i) au-dessous de 4,25 ; soit (ii) dans l'intervalle allant de 2,0 à 4,25.
 9. Procédé selon la revendication 8, dans lequel ladite étape d'ajout d'acide comprend l'ajout d'un acide choisi dans l'ensemble constitué de l'acide nitrique, de l'acide chlorhydrique, de l'acide acétique et de l'acide stéarique.
 10. Procédé selon l'une quelconque des revendications 1 à 7, dans lequel ladite étape d'ajout de base comprend l'ajout d'une base choisie dans l'ensemble constitué d'hydroxyde d'aluminium et d'hydroxyde d'ammonium pour élever le pH de ladite suspension (10).
 11. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre l'ajout de 0,01 à 1,0 % en poids d'un dispersant choisi dans l'ensemble constitué d'alcool de polyméthacrylate de méthyle et de stéarate d'ammonium à ladite suspension pour éviter l'agglomération et la décantation desdites particules.
 12. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre l'ajout de 0,1 à 3,0 % en poids d'un liant à ladite suspension pour accroître la force d'une coque formée par ladite barrière contre l'érosion.
 13. Procédé selon la revendication 12, dans lequel ladite étape d'ajout de liant comprend l'ajout de 1,0 à 2,0 % en poids de polyalcool vinylique.
 14. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite étape de dépôt comprend l'application d'une tension comprise entre 50 et 2 000 V à ladite pièce à usiner (50).
 15. Procédé selon la revendication 14, dans lequel ladite étape de dépôt comprend l'application d'une tension comprise entre 900 et 1 100 V à ladite pièce à usiner (50).
 16. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre l'élimination de ladite pièce à usiner (50) par lesdites particules déposées de ladite suspension et où ladite étape de séchage comprend le séchage de ladite pièce à usiner à une température comprise entre la température ambiante (68 °F) et 650 °F (20 °C à 343 °C) pendant une durée comprise entre 0,5 et 20 h.
 17. Procédé selon la revendication 16, dans lequel ladite étape de séchage comprend soit : (i) le séchage de ladite pièce à usiner à température ambiante pendant une durée comprise entre 1 et 20 h ; (ii) le séchage de ladite pièce à usiner à température ambiante pendant une durée comprise entre 3 et 10 h ; (iii) le séchage de ladite pièce à usiner à une température comprise entre 250 °F et 650 °F (121 °C à

343 °C) pendant une durée comprise entre 0,5 et 5,0 h ; et (iv) le séchage de ladite pièce à usiner à une température comprise entre 250 °F et 650 °F (121 °C à 343 °C) pendant une durée comprise entre 1,0 et 2,0 h.

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18. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre le frittage de ladite pièce à usiner (50) à une température comprise entre 1 950 °F et 2 000 °F (1 066 °C à 1 093 °C) pendant une durée comprise entre 3,0 et 4,0 h. 10
19. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit revêtement formant une barrière thermique (52) comprend un revêtement formant une barrière thermique à base de zircon. 15
20. Procédé selon l'une quelconque des revendications précédentes, dans lequel une région infiltrée (56) est formée entre ledit revêtement formant une barrière thermique (52) et ladite barrière contre l'érosion (54). 20
21. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite pièce à usiner (50) comprend un composant de moteur de turbine. 25

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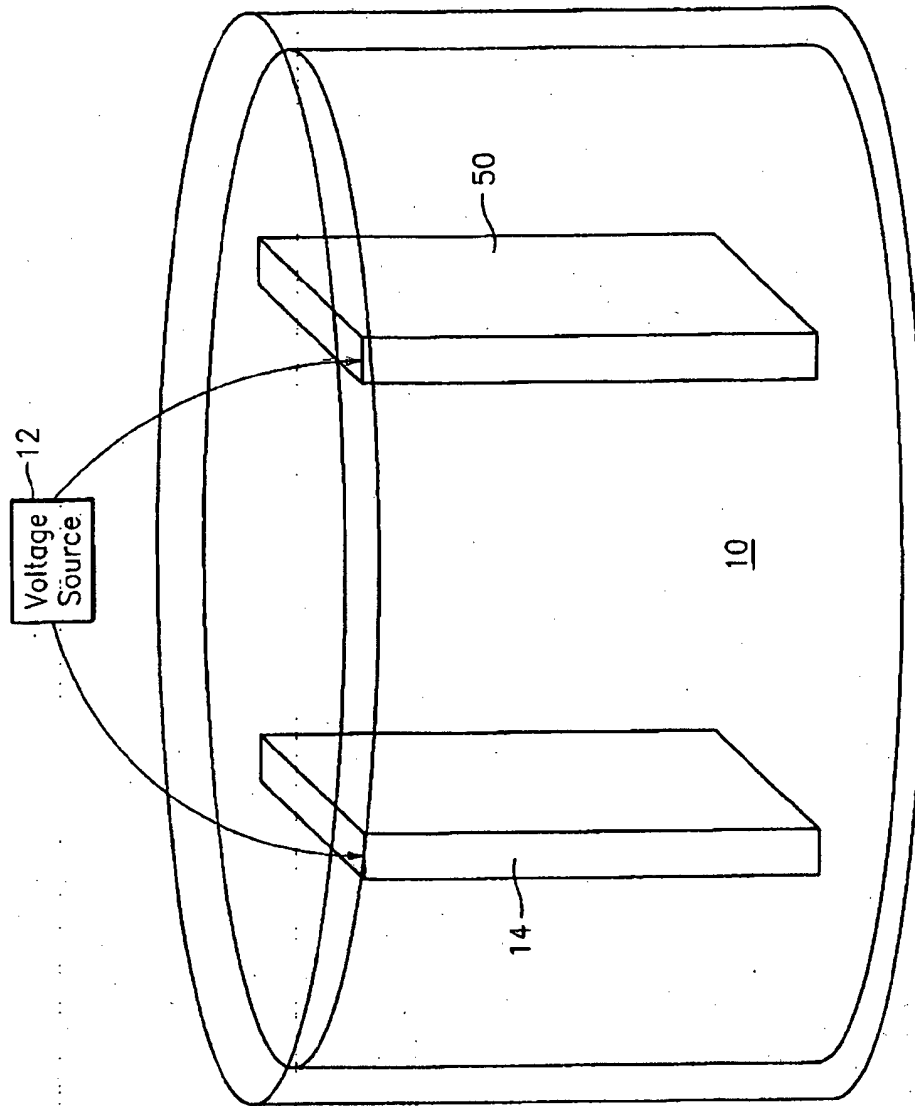


FIG. 1

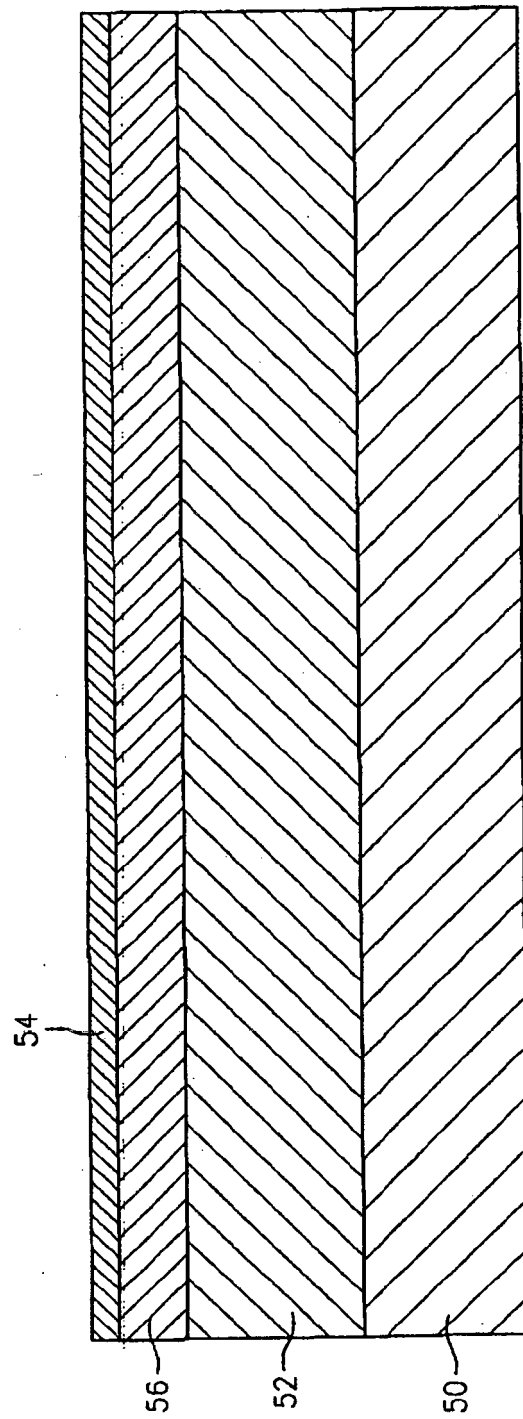


FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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