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(54) **FORMING ALUMINIDE COATING USING METAL ALLOY GRAVEL**

FORMUNG EINER ALUMINIDBESCHICHTUNG MITHILFE VON METALLLEGIERUNGSKIES  
FORMATION DE REVÊTEMENT EN ALUMINIURE AU MOYEN DE GRAVIER D'ALLIAGE MÉTALLIQUE

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**Description**

## BACKGROUND OF THE INVENTION

## 1. Technical Field

**[0001]** This disclosure relates to forming an aluminide coating on a component.

## 2. Background Information

**[0002]** Various methods are known for forming aluminide coatings on a component. During a pack cementation method, for example, aluminum from an aluminum powder surrounding the component can be heated and diffused into a base material of that component. Such a method, however, may be susceptible to cracking and/or trenching. There is a need in the art therefore for improved methods for forming an aluminide coating on a component.

**[0003]** US 2011/074113 discloses features of the preamble of claim 1.

## SUMMARY OF THE DISCLOSURE

**[0004]** According to the present disclosure, a method is provided for coating a component as claimed in claim 1.

**[0005]** The aluminum source may be chrome aluminum and/or cobalt aluminum.

**[0006]** Activator material may be disposed with the metal alloy gravel.

**[0007]** The activator material may be configured as or otherwise include halide material.

**[0008]** The method may include a further step of heat treating the aluminide coating to provide a heat treated diffusion coating.

**[0009]** The aluminide coating may be a green state coating. In addition or alternatively, the heat treated diffusion coating may be a three-zone aluminide coating.

**[0010]** The component may be laid on top of the metal alloy gravel.

**[0011]** The component may be partially submersed in the metal alloy gravel.

**[0012]** The component may be completely submersed in the metal alloy gravel.

**[0013]** The method may include a step of masking a portion of the component such that the masked portion of the component is not coated with the aluminide coating.

**[0014]** The component may be configured from or otherwise include a nickel alloy.

**[0015]** The component may be configured as a part of a gas turbine engine.

**[0016]** The component may be configured as an airfoil.

**[0017]** The foregoing features and the operation of the invention will become more apparent in light of the following description and the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0018]**

5 FIG. 1 is a block diagram illustration of a system for coating a component.

FIG. 2 is a flow diagram of a method for coating a component using a system.

10 FIG. 3 is a block diagram of a component disposed partially in material used in coating that component.

FIG. 4 is a block diagram of a component disposed on material used in coating that component.

15 FIG. 5 is a block diagram of a component disposed completely within material used in coating that component.

FIG. 6 is a sectional block diagram of a coated component.

FIG. 7 is a sectional block diagram of a portion of another coated component.

20 FIG. 8 is a block diagram of a masked component prior to being coating.

FIG. 9 is a block diagram of the masked component during the coating.

25 FIG. 10 is a block diagram of the component after the coating and unmasked.

FIG. 11 is a side cutaway illustration of a gas turbine engine.

## DETAILED DESCRIPTION OF THE INVENTION

30 **[0019]** FIG. 1 is a block diagram illustration of a system 20 for coating a component 22. FIG. 2 is a flow diagram of a method 200 for coating a component (e.g., 22) using a system such as, for example, the system 20 of FIG. 1.

35 **[0020]** The component 22 may be configured for an item of rotational equipment such as a gas turbine engine. This gas turbine engine may be configured in an aircraft propulsion system. Alternatively, the gas turbine engine may be configured in an auxiliary power unit for the aircraft. The methods and apparatuses of the present disclosure, however, are not limited to such aircraft applications. In other embodiments, for example, the gas turbine engine may be configured as an industrial gas turbine engine in a power generation system. In still other embodiments, the item of rotational equipment may alternatively be configured as a wind turbine, a water turbine or any other item of rotational equipment which includes a component with a coating as described below.

40 **[0021]** For ease of description, the component 22 is described below as a component of a gas turbine engine. The component 22, for example, may be configured as or include an airfoil as described below. Examples of such a component include, but are not limited to, a fan blade, a compressor blade, a turbine blade, a guide vane, a compressor vane, a turbine vane and a propeller. The component 22 of the present disclosure, however, is not limited to the foregoing exemplary component configurations, or to rotational equipment applications.

**[0022]** The component 22 has a metal component body 24; e.g., base material. This component body 24 provides the component 22 with its structure and general geometry; e.g., shape and dimensions. The component body 24 is constructed from metal, which is the base material. Examples of suitable metals include, but are not limited to, nickel (Ni), titanium (Ti) or an alloy of one or more of the foregoing materials. Examples of a component body metal alloy include, but are not limited to, airfoil and various hot section turbine components. The component body 24 of the present disclosure, however, is not limited to the foregoing exemplary component body materials.

**[0023]** In step 202, source material 26 is provided for coating the component 22 and, more particularly, its body 24. The source material 26, for example, may be disposed in an open container 27 to provide a bed of the source material 26 as shown in FIG. 1. This source material 26 includes metal alloy gravel. The source material 26 may also include activator material, which may be homogeneously or heterogeneously mixed with some or all of the metal alloy gravel.

**[0024]** The metal alloy gravel includes a loose aggregation of small particles of metal alloy material. This metal alloy gravel is different from a quantity of metal alloy dust or powder. The metal alloy gravel of the present invention has an average particle size of at least about 0.125 inches (3.18 mm).

**[0025]** The particle size may be a measure of a particle's diameter where that particle is generally spherical. The particle size may alternatively be a measure of a particle's length, width or height where that particle is non-spherical; e.g., globular cluster, cubic, ellipsoidal, etc. In such a case, the average particle size of that particle may be the average of the particle's length, width and height. In turn, the average particle size of the metal alloy gravel may be calculated as an average of the particle sizes of the particles in the metal alloy gravel.

**[0026]** The metal alloy material is a metal alloy which includes aluminum. The metal alloy material, for example, may be an alloy of cobalt (Co) and aluminum such as, for example, CoAl. In another example, the metal alloy material may be an alloy of chrome (Cr) and aluminum such as, for example, CrAl. The present disclosure, however, is not limited to the foregoing exemplary alloys.

**[0027]** The activator material is selected to promote diffusion of the aluminum from the metal alloy gravel into the component 22 and its body 24 to form an aluminide coating 28 (see FIG. 6). An example of such an activation material is a halide material; e.g., chloride halide. The present disclosure, however, is not limited to the foregoing exemplary halide or activator material.

**[0028]** In step 204, the component 22 is disposed with the source material 26. The component 22, for example, may be partially submersed (e.g., covered) within the bed of the source material 26 as shown in FIGS. 1 and 3. In this manner, the component 22 projects into the bed of the source material 26 such as that the source material

26 contacts multiple exterior surfaces 30-32 of the component body 24. Alternatively, the component 22 may be laid on top of the bed of the source material 26 as shown in FIG. 4. In this manner, only the bottom surface 30 of the component body 24 contacts the source material 26. Still alternatively, the component 22 may be completely submersed within (e.g., covered and surrounded by) the source material 26 as shown in FIG. 5. In this manner, the source material 26 contacts all exterior surfaces (e.g., 30-33) of the component body 24 of FIG. 5.

**[0029]** In step 206, the aluminide coating 28 is formed on the component 22 (see FIG. 6). In particular, an environment within a heating vessel 34 (e.g., oven) and, as a result, at least an outer peripheral portion of the component 22 as well as the source material 26 is heated to an elevated temperature using a heater 36 (see FIG. 1). At this elevated temperature, the aluminum from the metal alloy gravel diffuses into material in an outer peripheral region of the component body 24 and thereby forms the aluminide coating 28 (see FIG. 6).

**[0030]** The elevated temperature may be selected such that the aluminide coating 28 is generally (or more of) an inward diffusion coating rather than an outward diffusion coating. The term "inward diffusion coating" may describe a coating formed by diffusing material into a base material; i.e., the material being coated. Generally speaking, such an inward diffusion coating does not substantially change the exterior dimensions of the original base material. In contrast, the term "outward diffusion coating" may describe a coating formed by the diffusion of a base material outward into surrounding material; i.e., coating material. Generally speaking, such an outward diffusion coating increases the exterior dimensions of the original base material.

**[0031]** To form an inward diffusion coating, the elevated temperature is selected to be between fourteen-hundred degrees Fahrenheit (1400°F or 760°C) and sixteen-hundred degrees Fahrenheit (1600°F or 871°C).

**[0032]** Upon completion of the coating step 206, an exterior of the component body 24 of FIG. 6 is completely (partially in FIG. 10) coated with the aluminide coating 28; e.g., an inward diffusion aluminide coating. This aluminide coating 28 may be referred to as a green state coating. Herein, the term "green state coating" may describe a coating with a relatively high weight percentage and a relatively high atomic percentage of aluminum. The aluminide coating 28, for example, may have a weight percentage of aluminum of about forty percent (40%) to about sixty percent (60%). The aluminide coating 28 may have an atomic percentage of aluminum of about sixty percent (60%) to about seventy percent (70%). Such a green state coating may be relatively brittle. The aluminide coating 28 formed in the coating step 206, however, is not limited to the foregoing exemplary weight and atomic percentages of aluminum.

**[0033]** In step 208, the coated component 22 and, more particularly, the aluminide coating 28 is heat treated to provide a heat treated aluminide coating 28' (see FIG.

7). In particular, the environment within the heating vessel 34 of FIG. 1 (or another heating vessel or system) and, as a result, the aluminide coating 28 is heated to another elevated temperature. At this elevated temperature, the relatively brittle green state coating may be transformed into a less brittle diffused state coating. Herein, the term "diffused state coating" may describe a coating with a relatively low weight percentage and a relatively low atomic percentage of aluminum. The heat treated aluminide coating 28', for example, may have a weight percentage of aluminum of about twenty-five percent (25%) to about thirty-two percent (32%). The heat treated aluminide coating 28' may have an atomic percentage of aluminum of about forty percent (40%) to about fifty percent (50%). The heat treated aluminide coating 28' formed in the heat treating step 208, however, is not limited to the foregoing exemplary weight and atomic percentages of aluminum.

**[0034]** The heat treated aluminide coating 28' may be a three-zone aluminide coating as shown in FIG. 7. Such a three-zone aluminide coating may include a diffusion zone 38, an intermediate zone 40 and an additive zone 42. The diffusion zone 38 is between the base material of the component body 24 and the intermediate zone 40. This zone 38 includes a relatively low atomic percentage of aluminum which has diffused into the base material of the component body 24. The intermediate zone 40 is between the diffusion zone 38 and the additive zone 42. This zone 40 includes a higher atomic percentage of aluminum than the diffusion zone 38, in which aluminum is also diffused to a lesser degree into the base material of the component body 24. The additive zone 42 is the outermost zone and includes the highest atomic percentage of aluminum, where the base material of the component body 24 may have diffused outward to form an additive portion.

**[0035]** In some embodiments, one or more portions of the component body 24 may be masked to prevent coating those portions with the aluminide coating 28, 28' described above. For example, referring to FIG. 8, a mask 44 (e.g., masking putty) may be applied to an exterior surface of the component body 24. The masked off component 22 may then undergo the coating step 206 as shown in FIG. 9. After this coating step 206, the mask 44 may be removed from the now coated component body 24 to reveal an uncoated (e.g., bare) surface 46 of the component body 24 as shown in FIG. 10 where the mask was removed.

**[0036]** As described above, the component 22 of the present disclosure may be configured with various different types and configurations of rotational equipment, or other devices. FIG. 11 illustrates one such type and configuration of the rotational equipment - a geared turbofan gas turbine engine 70. This turbine engine 70 includes various types and configurations of rotor blade airfoils as described below as well as stator vane airfoils, where the component 22 can be configured as anyone of the foregoing airfoils, or other structures not mentioned herein.

**[0037]** Referring still to FIG. 11, the turbine engine 70 extends along an axial centerline 76 between an upstream airflow inlet 78 and a downstream airflow exhaust 80. The turbine engine 70 includes a fan section 82, a compressor section 83, a combustor section 84 and a turbine section 85. The compressor section 83 includes a low pressure compressor (LPC) section 83A and a high pressure compressor (HPC) section 83B. The turbine section 85 includes a high pressure turbine (HPT) section 85A and a low pressure turbine (LPT) section 85B.

**[0038]** The engine sections 82-85 are arranged sequentially along the centerline 76 within an engine housing 86. This housing 86 includes an inner case 88 (e.g., a core case) and an outer case 90 (e.g., a fan case). The inner case 88 may house one or more of the engine sections 83-85; e.g., an engine core. The outer case 90 may house at least the fan section 82.

**[0039]** Each of the engine sections 82, 83A, 83B, 85A and 85B includes a respective rotor 92-96. Each of these rotors 92-96 includes a plurality of rotor blades with airfoils arranged circumferentially around and connected to one or more respective rotor disks. The rotor blades, for example, may be formed integral with or mechanically fastened, welded, brazed, adhered and/or otherwise attached to the respective rotor disk(s).

**[0040]** The fan rotor 92 is connected to a gear train 98, for example, through a fan shaft 100. The gear train 98 and the LPC rotor 93 are connected to and driven by the LPT rotor 96 through a low speed shaft 101. The HPC rotor 94 is connected to and driven by the HPT rotor 95 through a high speed shaft 102. The shafts 100-102 are rotatably supported by a plurality of bearings 104. Each of these bearings 104 is connected to the engine housing 86 by at least one stationary structure such as, for example, an annular support strut.

**[0041]** During operation, air enters the turbine engine 70 through the airflow inlet 78. This air is directed through the fan section 82 and into a core gas path 106 and a bypass gas path 108. The core gas path 106 flows sequentially through the engine sections 83-85. The bypass gas path 108 flows away from the fan section 82 through a bypass duct, which circumscribes and bypasses the engine core. The air within the core gas path 106 may be referred to as "core air". The air within the bypass gas path 108 may be referred to as "bypass air".

**[0042]** The core air is compressed by the compressor rotors 93 and 94 and directed into a combustion chamber 110 of a combustor in the combustor section 84. Fuel is injected into the combustion chamber 110 and mixed with the compressed core air to provide a fuel-air mixture. This fuel air mixture is ignited and combustion products thereof flow through and sequentially cause the turbine rotors 95 and 96 to rotate. The rotation of the turbine rotors 95 and 96 respectively drive rotation of the compressor rotors 94 and 93 and, thus, compression of the air received from a core airflow inlet. The rotation of the turbine rotor 96 also drives rotation of the fan rotor 92, which propels bypass air through and out of the bypass

gas path 108. The propulsion of the bypass air may account for a majority of thrust generated by the turbine engine 70, e.g., more than seventy-five percent (75%) of engine thrust. The turbine engine 70 of the present disclosure, however, is not limited to the foregoing exemplary thrust ratio.

**[0043]** The component 22 may be included in various aircraft and industrial turbine engines other than the one described above as well as in other types of rotational equipment and non-rotating equipment. The component 22 may be included in a geared turbine engine where a gear train connects one or more shafts to one or more rotors in a fan section, a compressor section and/or any other engine section. Alternatively, the component 22 may be included in a turbine engine configured without a gear train. The component 22 may be included in a geared or non-geared turbine engine configured with a single spool, with two spools (e.g., see FIG. 11), or with more than two spools. The turbine engine may be configured as a turbofan engine, a turbojet engine, a propfan engine, a pusher fan engine or any other type of turbine engine. The present invention, however, is not limited to any particular types or configurations of turbine engines or rotational equipment.

**[0044]** Accordingly, the present invention is not to be restricted except in light of the attached claims.

#### Claims

1. A method for coating a component (22), comprising:

disposing the component (22) with metal alloy gravel comprising aluminum;  
 heating the metal alloy gravel adjacent the component (22) to a temperature between 1400 degrees Fahrenheit and 1600 degrees Fahrenheit (760 degrees Celsius and 871 degrees Celsius);  
 and  
 forming an aluminide coating (28) on the component (22), wherein the aluminum from the metal alloy gravel diffuses into the component (22) to form the aluminide coating (28),  
**characterised in that** the metal alloy gravel has an average particle size of at least 0.125 inches (3.18 mm).

2. The method of claim 1, wherein the metal alloy gravel further comprises chrome aluminum and/or cobalt aluminum.
3. The method of any preceding claim, wherein activator material is disposed with the metal alloy gravel.
4. The method of claim 3, where the activator material comprises halide material.
5. The method of any preceding claim, further compris-

ing heat treating the aluminide coating (28) to provide a heat treated diffusion coating.

6. The method of claim 5, wherein the aluminide coating (28) is a green state coating, and the heat treated diffusion coating is a three-zone aluminide coating.
7. The method of any preceding claim, wherein the component (22) is laid on top of the metal alloy gravel.
8. The method of any of claims 1 to 6, wherein the component (22) is partially or completely submersed in the metal alloy gravel.
9. The method of any preceding claim, further comprising masking a portion of the component (22) such that the masked portion of the component (22) is not coated with the aluminide coating (28).
10. The method of any preceding claim, wherein the component (22) comprises a nickel alloy.
11. The method of any preceding claim, wherein the component (22) is configured as a part of a gas turbine engine (70).
12. The method of claim 11, wherein the component (22) is an airfoil.

#### Patentansprüche

1. Verfahren zum Beschichten einer Komponente (22), umfassend:

Anordnen der Komponente (22) mit Metalllegierungskies, der Aluminium umfasst;  
 Erhitzen des Metalllegierungskies, der an die Komponente (22) angrenzt, auf eine Temperatur zwischen 1400 Grad Fahrenheit und 1600 Grad Fahrenheit (760 Grad Celsius und 871 Grad Celsius); und  
 Formen einer Aluminidbeschichtung (28) an der Komponente (22), wobei das Aluminium aus dem Metalllegierungskies in die Komponente (22) eindringt, um die Aluminidbeschichtung (28) zu formen,  
**dadurch gekennzeichnet, dass** der Metalllegierungskies eine durchschnittliche Partikelgröße von mindestens 0,125 Zoll (3,18 mm) aufweist.

2. Verfahren nach Anspruch 1, wobei der Metalllegierungskies ferner Chrom-Aluminium und/oder Cobalt-Aluminium umfasst.
3. Verfahren nach einem der vorgehenden Ansprüche,

wobei Aktivatormaterial mit dem Metalllegierungskies angeordnet ist.

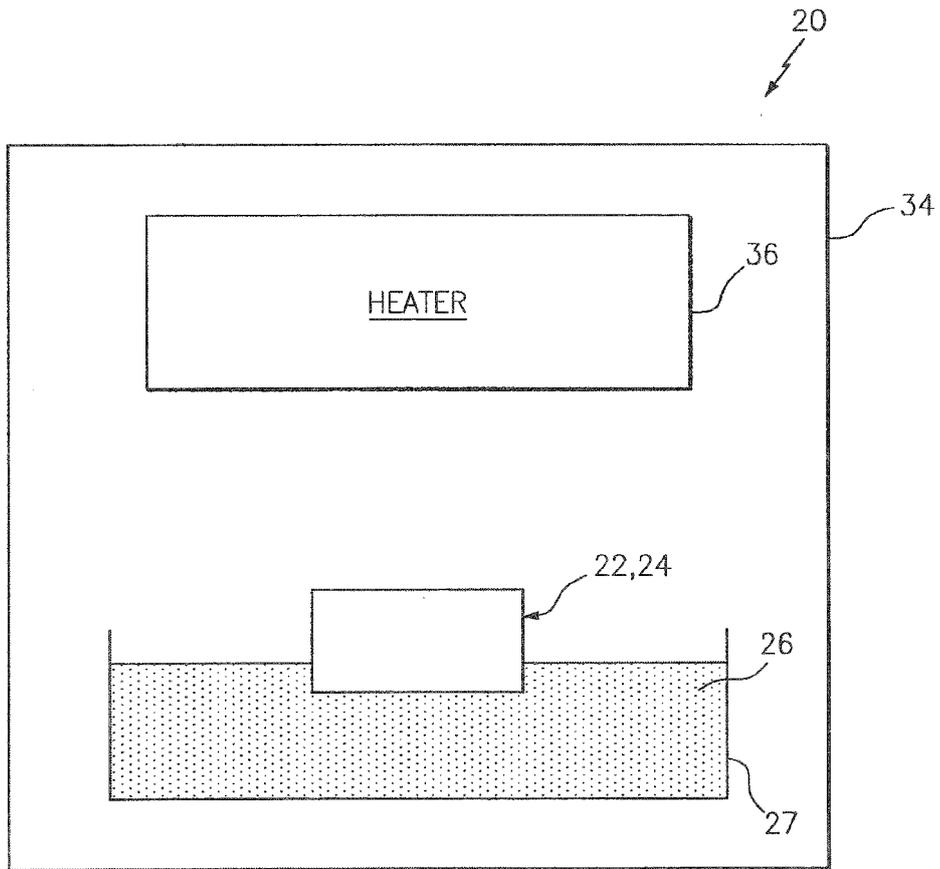
4. Verfahren nach Anspruch 3, wobei das Aktivatormaterial Halogenidmaterial umfasst. 5
5. Verfahren nach einem der vorgehenden Ansprüche, ferner umfassend Wärmebehandeln der Aluminidbeschichtung (28), um eine wärmebehandelte Diffusionsbeschichtung bereitzustellen. 10
6. Verfahren nach Anspruch 5, wobei die Aluminidbeschichtung (28) eine Beschichtung im Grünzustand ist und die wärmebehandelte Diffusionsbeschichtung eine Dreizonen-Aluminidbeschichtung ist. 15
7. Verfahren nach einem der vorgehenden Ansprüche, wobei die Komponente (22) oben auf den Metalllegierungskies gelegt wird. 20
8. Verfahren nach einem der Ansprüche 1 bis 6, wobei die Komponente (22) teilweise oder vollständig in den Metalllegierungskies eingetaucht ist.
9. Verfahren nach einem der vorgehenden Ansprüche, ferner umfassend Maskieren eines Abschnitts der Komponente (22), sodass der maskierte Abschnitt der Komponente (22) nicht mit der Aluminidbeschichtung (28) beschichtet wird. 25
10. Verfahren nach einem der vorgehenden Ansprüche, wobei die Komponente (22) eine Nickellegierung umfasst. 30
11. Verfahren nach einem der vorgehenden Ansprüche, wobei die Komponente (22) als ein Teil eines Gasturbinenriebwerks (70) konfiguriert ist. 35
12. Verfahren nach Anspruch 11, wobei die Komponente (22) ein Schaufelprofil ist. 40

#### Revendications

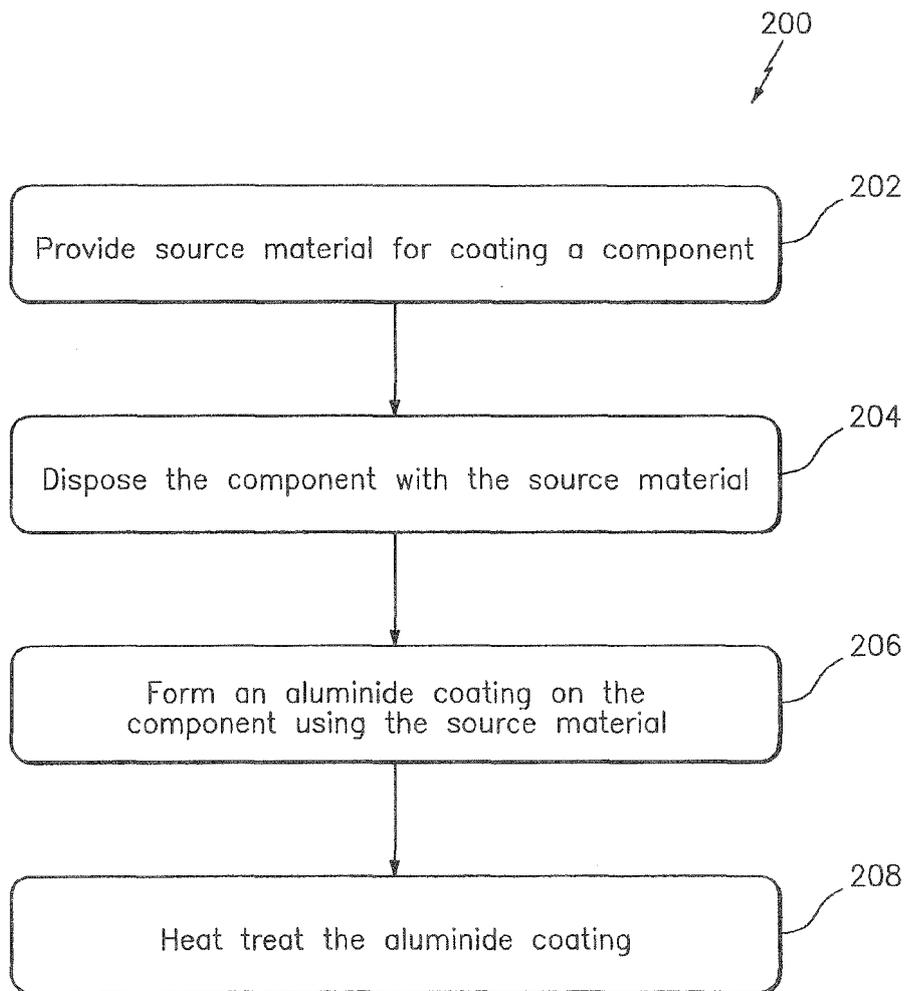
1. Procédé de revêtement d'un composant (22), comprenant : 45
  - la disposition du composant (22) avec un gravier d'alliage métallique comprenant de l'aluminium ; 50
  - le chauffage du gravier d'alliage métallique adjacent au composant (22) à une température comprise entre 1 400 degrés Fahrenheit et 1 600 degrés Fahrenheit (760 degrés Celsius et 871 degrés Celsius) ; et
  - la formation d'un revêtement en aluminiure (28) sur le composant (22), dans lequel l'aluminium provenant du gravier d'alliage métallique se dif-

fuse dans le composant (22) pour former le revêtement en aluminiure (28), **caractérisé en ce que** le gravier d'alliage métallique a une taille moyenne de particule d'au moins 0,125 pouce (3,18 mm).

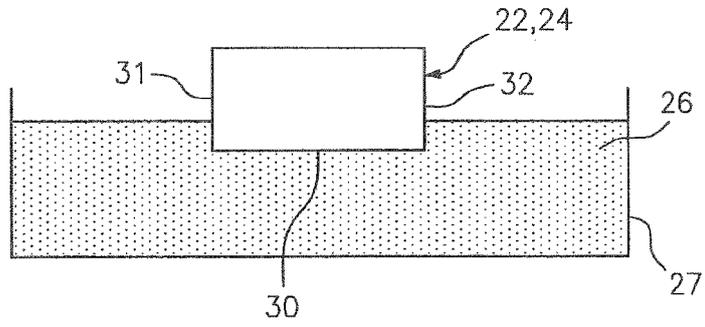
2. Procédé selon la revendication 1, dans lequel le gravier d'alliage métallique comprend en outre de l'aluminium chrome et/ou de l'aluminium cobalt.
3. Procédé selon une quelconque revendication précédente, dans lequel le matériau activateur est disposé avec le gravier d'alliage métallique.
4. Procédé selon la revendication 3, dans lequel le matériau activateur comprend un matériau à base d'halogénure.
5. Procédé selon une quelconque revendication précédente, comprenant en outre le traitement thermique du revêtement en aluminiure (28) pour fournir un revêtement de diffusion traité thermiquement.
6. Procédé selon la revendication 5, dans lequel le revêtement en aluminiure (28) est un revêtement à l'état vert, et le revêtement de diffusion traité thermiquement est un revêtement en aluminiure à trois zones.
7. Procédé selon une quelconque revendication précédente, dans lequel le composant (22) est posé au-dessus du gravier d'alliage métallique.
8. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel le composant (22) est partiellement ou complètement immergé dans le gravier d'alliage métallique.
9. Procédé selon une quelconque revendication précédente, comprenant en outre le masquage d'une partie du composant (22) de sorte que la partie masquée du composant (22) n'est pas revêtue du revêtement en aluminiure (28).
10. Procédé selon une quelconque revendication précédente, dans lequel le composant (22) comprend un alliage de nickel.
11. Procédé selon une quelconque revendication précédente, dans lequel le composant (22) est configuré en tant que partie d'un moteur à turbine à gaz (70).
12. Procédé selon la revendication 11, dans lequel le composant (22) est un profil aérodynamique.



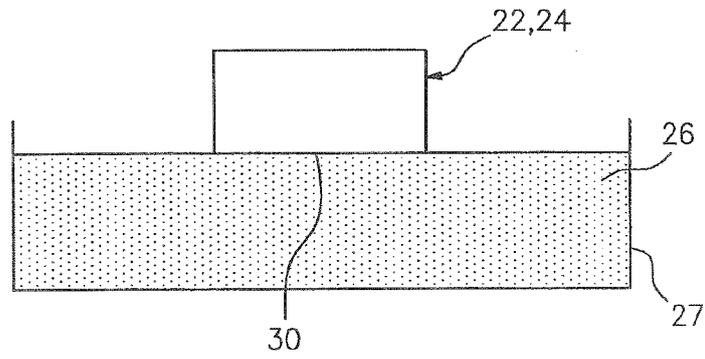
*FIG. 1*



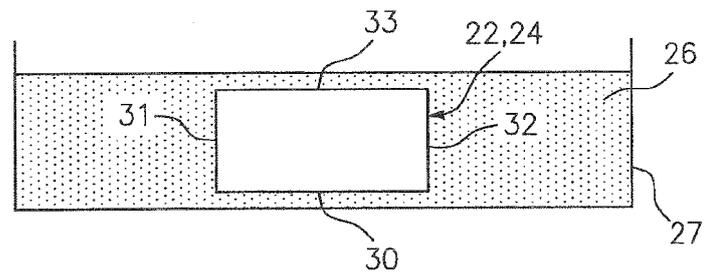
*FIG. 2*



*FIG. 3*



*FIG. 4*



*FIG. 5*

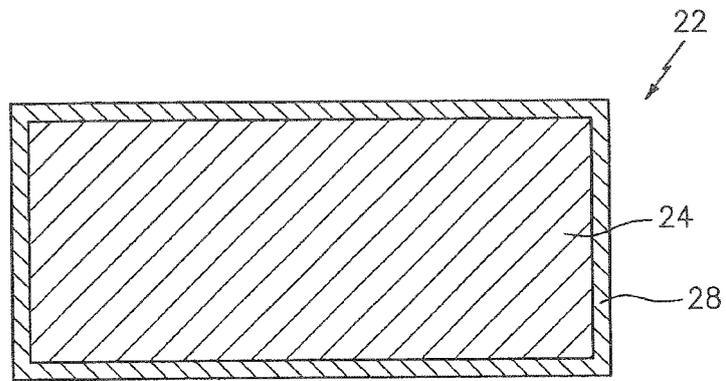


FIG. 6

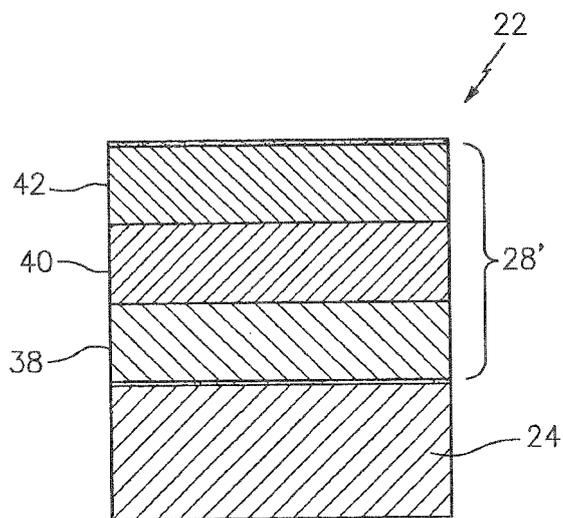


FIG. 7

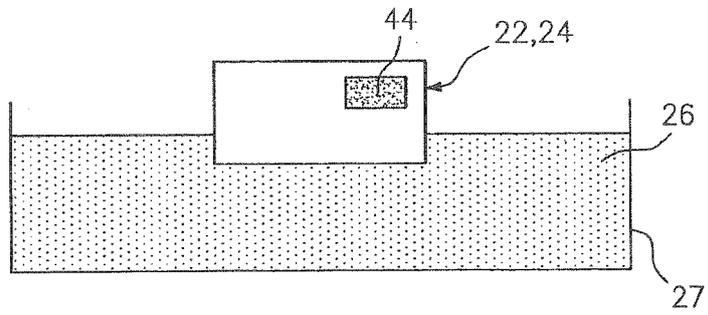


FIG. 8

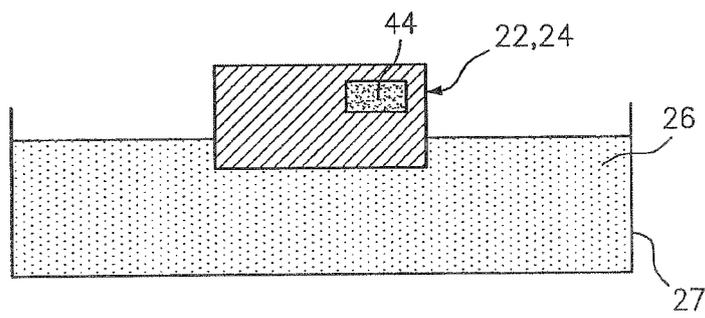


FIG. 9

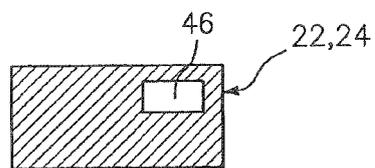


FIG. 10

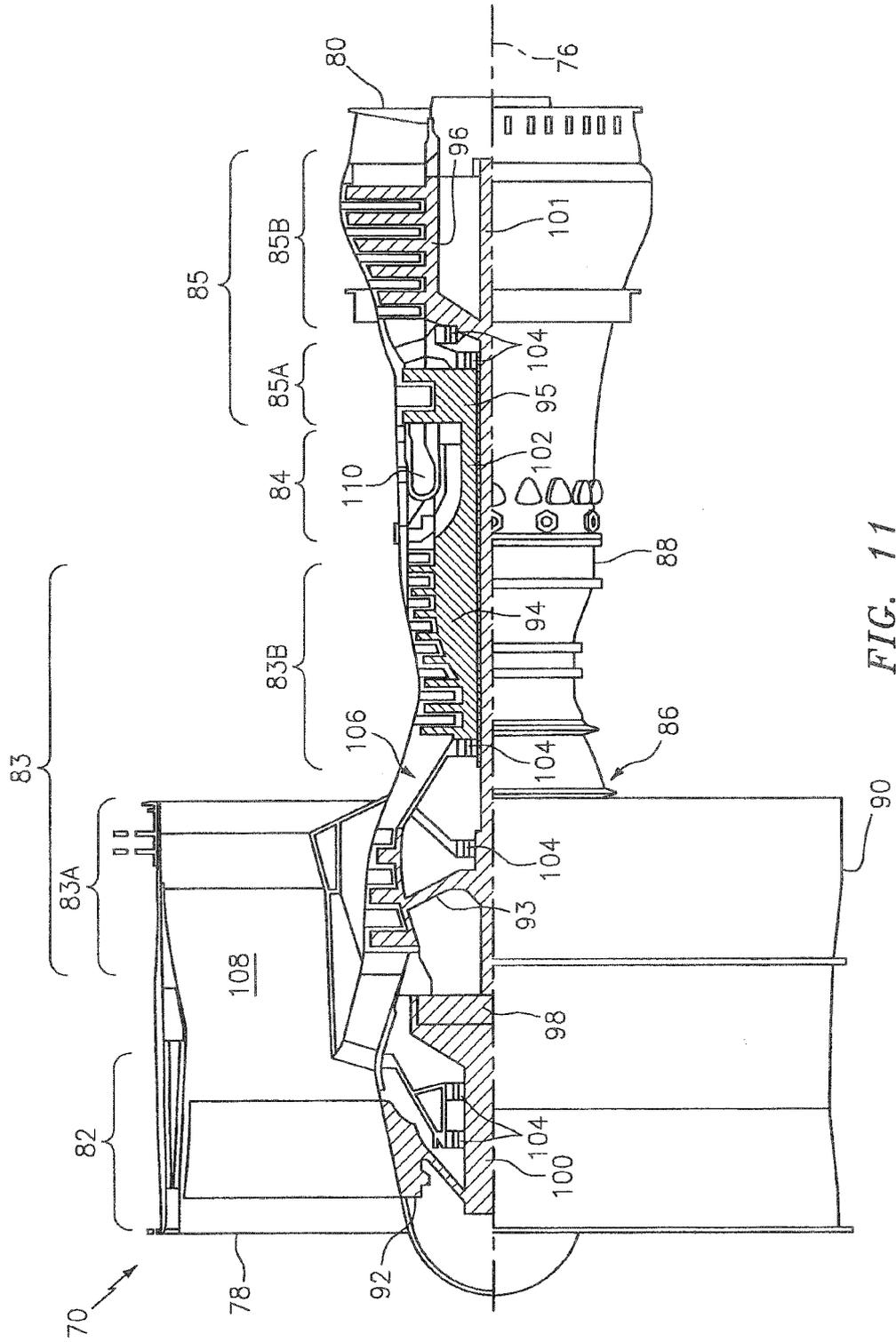


FIG. 11

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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