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THERMAL BARRIER COATING UTILIZING
A DISPERSION STRENGTHENED METALLIC BOND COAT

BACKGROUND OF THE INVENTION

The present invention relates to improved overlay or bond coatings applied to materials used in the hot sections of modern gas turbine engines.

Thermal barrier coatings on a substrate alloy usually include a thermally insulating ceramic layer deposited over a metallic bond coat. Traditionally, thermal barrier coatings use yttria partially stabilized zirconia on a bond coat such as MCrAlY delivered by a low pressure plasma spray, air plasma, or physical vapor deposition method. A typical thermal barrier coating for a rotating airfoil application consists of the metallic bond coat over a single crystal casting of a nickel based alloy. On the bond coat, the thermally insulating layer is deposited typically by electron beam physical vapor deposition. The ceramic adheres to the bond coat through the formation of a thin, thermally grown oxide scale of aluminum oxide. During engine operation, the thermally grown oxide grows. Attendant with the growth of the oxide scale are increased thermally grown oxide residual stresses and bond coat creep.

Thus, there is needed an overlay bond coat which has improved strength, particularly creep strength, and which would lead to improved thermal barrier coating life.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a bond coating which has improved strength properties.



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It is a further object of the present invention to provide a method for forming an improved overlay bond coating having improved strength properties.

The foregoing objects are attained by the overlay coatings and the deposition method of the present invention.

In accordance with the present invention, an improved overlay coating is provided. The overlay coating comprises a deposited layer of MCrAlY material containing discrete nitride particles therein. The overlay coatings of the present invention may also include dispersed oxide particles as well as dispersed nitride particles.

A method for forming an overlay coating on a substrate material, such as a component used in a hot section of a gas turbine engine, broadly comprises depositing a MCrAlY coating on a substrate material and forming a plurality of discrete nitride particles in the coating. The nitride particles are preferably formed using a controlled introduction of nitrogen during the deposition step. After the overlay or bond coating with the dispersion particles have been formed, a thermal barrier coating may be formed over the overlay or bond coating.

Other details of the thermal barrier coating through the application of dispersion strengthened metallic bond, as well as other objects and advantages attendant thereto, are set forth in the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a photomicrograph of the cross section of a thermal barrier coated blade having a bond coat with a fine dispersion of aluminum nitride;

FIG. 1B is a photomicrograph of the cross section of a thermal barrier coated blade having a bond coat without a fine dispersion of aluminum nitride; and

FIG. 2 is a graph showing a thermal barrier coating spall life in cycles.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The present invention is directed to providing an improved overlay or bond coating of the MCrAlY type family of overlay coatings which is particularly useful when applied to components, such as blades and vanes, used in the hot section (turbine and combustor sections) of modern gas turbine engines. The overlay or bond coatings of the present invention have improved strength properties, particularly creep strength, through the incorporation of a dispersion of particles in the overlay or bond coatings. The particles may be nitride particles or a combination of nitride and oxide particles.

In accordance with the present invention, an overlay or bond coating having a desirable set of strength properties is formed by providing a substrate material, depositing a layer of MCrAlY type coating material on the substrate material, and forming a plurality of discrete nitride particles in the coating. The coatings of the present invention may be applied to any substrate alloy used to form components used in the hot section (turbine and combustor sections) of a modern gas turbine engine, such as single crystal nickel- or cobalt-based alloys. The overlay coating material to be deposited may be comprised of any suitable MCrAlY coating where M is selected from the group consisting of nickel, cobalt, iron, and mixtures thereof. A particularly useful MCrAlY type coating to be deposited on the

substrate material used for a gas turbine engine component is a NiCoCrAlY coating. An illustrative NiCoCrAlY coating which may be applied has a composition comprising from 20 to 24 wt% cobalt, from 15 to 19 wt% chromium, from 10 to 15 wt% aluminum, from 0.1 to 0.4 wt% hafnium, from 0.4 to 1.25 wt% yttrium, and the balance nickel.

The MCrAlY coating may be deposited using either a physical vapor deposition process or a low pressure plasma spray process. When a physical vapor deposition process such as cathodic arc is used, the process is carried out in a chamber containing the substrate material and the materials to be deposited at a temperature greater than ambient (68°F), preferably 300 degrees Fahrenheit to 1000 degrees Fahrenheit, for a time greater than 2 minutes, preferably in the range of 30 minutes to 60 minutes, at a pressure greater than 0.005 Torr, preferably from 0.01 to 0.02 Torr. The process may be carried out in an argon containing atmosphere such as a pure argon atmosphere or an argon and helium atmosphere. When a low pressure plasma spray process is used, the substrate and the materials used to form the coating are again placed in a chamber and the process is carried out at a temperature preferably in the range of 1600 to 1900 degrees Fahrenheit for a time on the order of 5 minutes at a pressure typically in the range of 30 to 40 Torr vacuum.

In order to strengthen the MCrAlY coating, a plurality of discrete nitride particles are incorporated into the coating. The nitride particles are preferably formed by introducing nitrogen into the chamber. For a chamber having a volume of 350 liters, nitrogen may be introduced at a flow rate greater than 2 microns per hour, preferably 5.0 to 100 microns per hour. The nitride particles formed in this manner during the coating

operation are present in a volume fraction from greater than 0.1 to 15.0%, preferably from greater than 0.5 to 15.0%, and have a size in the range of from 0.1 to 10.0 microns, preferably from 0.3 to 0.5 microns. The nitride particles are typically uniformly dispersed throughout the coating but can be tailored to have gradient or other application specific microstructure.

If desired, the MCrAlY coating may be strengthened by incorporating oxide particles as well as nitride particles into the coating. The combination of nitride and oxide particles may be formed by introducing a gas containing oxygen and nitrogen, such as air, from the chamber. When nitride and oxide particles are formed, they are typically uniformly dispersed throughout the coating, but can be tailored to have a gradient or other application specific microstructure. The nitride and oxide particles each typically have a size in the range of from 0.1 to 10.0 microns, preferably from 0.3 to 0.5 microns. The nitride and oxide particles are present in a volume fraction from greater than 0.1 to 15.0%, preferably from greater than 0.5 to 15.0%.

Once the overlay coat has been deposited, the coating may be surface finished or peened to smooth the overlay bond coating. The overlay bond coating is more than 90% dense as deposited. Any suitable means known in the art may be used to perform the surface finishing or peening step. Prior to surface finishing or peening, the coating with the dispersed nitride particles or the dispersed nitride and oxide particles may be subjected to a heat treatment at a temperature of 1900 degrees Fahrenheit to 2100 degrees Fahrenheit for a time in the range of 1 to 4 hours.

After the overlay coating is formed, a ceramic thermal barrier coating may be deposited over the overlay coating. The ceramic thermal barrier coating may be any suitable thermal barrier coating known in the art and may be deposited using any suitable technique known in the art.

It should be noted that the dispersions of the present invention could be achieved through mechanical or chemical means as well as the techniques described above.

The following example was performed to demonstrate the invention described herein. Several first stage high pressure turbine blades were coated with a traditional bond coat as well as a dispersion strengthened bond coat formed using a cathodic arc process. The turbine blades were formed from a nickel based alloy having a composition containing 5.0 wt% chromium, 10 wt% cobalt, 5.65 wt% aluminum, 1.9 wt% molybdenum, 5.9 wt% tungsten, 0.10 wt% hafnium, 8.7 wt% tantalum, and 3.0 wt% rhenium, and the balance nickel. A coating was applied having a composition containing 15 - 19 wt% Cr, 20 - 24 wt% Co, 11.8 - 13.2 wt% Al, 0.1 - 0.4 wt% Hf, 0.4 - 0.8 wt% Y, and 0.2 - 0.6 wt% Si. The coating process was carried out in a chamber at a temperature below 1000 degrees Fahrenheit for 65 minutes at a pressure of 0.01 to 0.02 Torr. During the bond coat process, air was introduced at a rate greater than 2.0 microns per hour for a chamber having a volume of 350 liters. After the process for forming the coating with the dispersed nitride particles was completed, the blades were surface finished and a ceramic thermally insulating layer was formed over the bond coating. This layer was deposited by Electron Beam Physical Vapor Deposition. The coating was a 7 wt% yttria partially stabilized zirconia coating.

The microstructure of the coated blades with the dispersion strengthened bond coat produced by the method described above is shown in FIG. 1A and may be compared with a baseline without the dispersion in the bond coat shown in FIG. 1B. Analysis of the composition of the bond coat shows that the dispersions are predominantly aluminum nitride. Hardness measurements indicated that indeed strengthening has occurred. The coated blades were subjected to cyclic burner rig testing to simulate engine exposure. The results of the cyclic burner rig testing (6 minutes in flame, 3 minutes forced air cool) done with maximum metal temperature of 2100 degrees Fahrenheit show that the thermal barrier coating with the dispersion bond coating has a spall life improvement of about 3.6X over that without the dispersion. See Figure 2 where bar 10 shows the spall life of the thermal barrier coating with the non-dispersion bond coating and where bar 12 shows the spall life of the thermal barrier coating with the dispersion bond coating of the present invention.

It is apparent that there has been provided in accordance with the present invention a thermal barrier coating through the application of a dispersion strengthened metallic bond which fully satisfies the objects, means, and advantages set forth hereinbefore. While the present invention has been described in the context of specific embodiments thereof, other alternatives, modifications, and variations will become apparent to those skilled in the art having read the foregoing description. Accordingly, it is intended to embrace those alternatives, modifications, and variations that fall within the broad scope of the appended claims.

WHAT IS CLAIMED IS:

1. An overlay coating to be applied to a substrate material comprising a deposited MCrAlY overlay coating containing a plurality of discrete nitride particles.
2. An overlay coating according to claim 1, wherein said nitride particles comprise aluminum nitride particles.
3. An overlay coating according to claim 1, wherein said nitride particles are present in a volume fraction in an amount in the range of greater than 0.1% to 15.0%, preferably greater than 0.5% to 15.0%.
4. An overlay coating according to claim 1, wherein said nitride particles have a size in the range of 0.1 microns to 10.0 microns, preferably in the range of 0.3 microns to 0.5 microns.
5. An overlay coating according to claim 1, wherein said coating further contains a plurality of dispersed oxide particles.
6. An overlay coating according to claim 5, wherein said dispersed oxide particles comprise aluminum oxide particles.
7. An overlay coating according to claim 6, wherein said dispersed nitride and oxide particles are present in a volume fraction in the range of from greater than 0.1% to 15.0%,

preferably in a volume fraction in the range of from greater than 0.5% to 15.0%.

8. An overlay coating according to claim 1, wherein said deposited MCrAlY coating comprises a NiCoCrAlY coating.

9. A method for depositing a dispersion strengthened metallic overlay coating on a substrate material comprising:

depositing a MCrAlY coating onto said substrate material;
and

forming discrete nitride particles dispersed in said coating.

10. A method according to claim 9, wherein said nitride particle forming step comprises introducing nitrogen during said depositing step.

11. A method according to claim 10, wherein said gas introducing step comprises introducing nitrogen at a flow rate greater than 2.0 microns per hour, preferably at a flow rate in the range of 5.0 microns per hour to 100 microns per hour.

12. A method according to claim 9, further comprising forming oxide particles as well as said nitride particles.

13. A method according to claim 12, wherein said nitride particle and oxide particle forming steps comprises introducing

nitrogen and oxygen from a chamber where said forming steps occur.

14. A method according to claim 13, wherein said gas introduction step comprises introducing air from said chamber.

15. A method according to claim 9, wherein said depositing step comprises depositing said MCrAlY coating using a cathodic arc process carried out at a temperature greater than ambient temperature for a time greater than 2 minutes and a pressure greater than 0.005 Torr in an argon containing atmosphere.

16. A method according to claim 15, wherein said temperature is in the range of 300 degrees Fahrenheit to 1000 degrees Fahrenheit for a time in the range of 30 to 60 minutes at a pressure in the range of 0.01 to 0.02 Torr.

17. A method according to claim 9, wherein said depositing step comprises depositing said MCrAlY coating using a low pressure plasma spray method carried out at a temperature in the range of 1600 to 1900 degrees Fahrenheit for a time on the order of 5 minutes at a pressure of 30 to 40 Torr.

18. A method according to claim 9, further comprising surface finishing said coating to smooth the coating and subjecting the coating to a heat treatment at a temperature in the range of 1900 degrees Fahrenheit to 2100 degrees Fahrenheit for a time in the period of 1 to 4 hours prior to said surface finishing step.

19. An article comprising:

a substrate material; and

a MCrAlY coating deposited on said substrate material, said coating having dispersed nitride particles therein.

20. An article according to claim 19, wherein said nitride particles are present in a volume fraction in an amount in the range of greater than 0.1% to 15.0%, preferably in a volume fraction in an amount in the range of greater than 0.5% to 15.0%.

21. An article according to claim 19, wherein said nitride particles have a size in the range of 0.1 microns to 10.0 microns, preferably in the range of 0.3 microns to 10.0 microns.

22. An article according to claim 19, wherein said coating includes dispersed oxide particles in addition to said nitride particles.

23. An article according to claim 22, wherein said nitride and oxide particles are present in a volume fraction in the range of 0.1% to 15.0%, preferably in a volume fraction in the range of from greater than 0.5% to 15.0%.

24. An article according to claim 19, wherein said MCrAlY coating comprises a NiCoCrAlY coating and said substrate material comprises a material selected from the group consisting of nickel-based alloys and cobalt-based alloys.

25. An article according to claim 19, further comprising a thermal barrier coating deposited over said MCrAlY coating.

26. An article according to claim 19, wherein said article comprises a component for a gas turbine engine.

27. A method for forming an article comprising:

providing a substrate material;

depositing a MCrAlY coating onto said substrate material;
and

forming discrete nitride particles dispersed in said coating.

28. A method according to claim 27, further comprising forming a thermal barrier coating over said MCrAlY coating with said dispersed nitride particles.

29. A method according to claim 27, wherein said nitride particle forming step also comprises forming oxide particles in said coating in addition to said nitride particles.