

ELECTRON BEAM PHYSICAL VAPOR DEPOSITION APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to co-pending United States patent application Serial No. [Attorney Docket No. 13DV-13041], the contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

5 This invention generally relates to an electron beam physical vapor deposition coating apparatus. More particularly, this invention is directed to a movable platform system that enables chambers of such a coating apparatus to be repositioned while causing minimal
10 interference with the operation of the apparatus.

BACKGROUND OF THE INVENTION

Thermal barrier coatings (TBC) have found wide use for thermally insulating the exterior surfaces of high-temperature gas turbine components in order to minimize the service temperatures of such components.
15 Various ceramic materials have been employed as the TBC, particularly zirconia (ZrO_2) stabilized by yttria (Y_2O_3), magnesia (MgO) or other oxides. These particular materials are widely employed in the art because they can be readily deposited by plasma spray and vapor deposition
20 techniques. An example of the latter is electron beam physical vapor deposition (EBPVD), which produces a thermal barrier coating having a columnar grain structure that is able to expand with its underlying substrate without causing damaging stresses that lead to
25 spallation, and therefore exhibits enhanced strain

tolerance.

5 The process of depositing ceramic coatings (e.g., TBC) by EBPVD using a coating apparatus scaled for production generally entails initially loading the components to be coated into a loading chamber. The pressure within the loading chamber is typically lowered to 10^{-2} mbar or less prior to transferring the components to a preheat chamber, where the components are heated to typically 800°C or more in order to promote adhesion of the coating on the component. From the preheat chamber, 10 the components are transferred to a heated coating chamber maintained at a low pressure, typically about 0.005 mbar. The component is supported in proximity to an ingot of the ceramic coating material to be deposited, 15 and an electron beam is projected onto the ingot so as to melt the surface of the ingot and produce a vapor that deposits onto the component, forming an adhesive ceramic layer.

20 Advanced EBPVD apparatuses used for production are often configured to enable coated components to be removed from the coating chamber and replaced with preheated uncoated components without shutting down the apparatus, so that a continuous operation is achieved. The continuous operation of the apparatus during this 25 time can be termed a "campaign," with greater numbers of components successfully coated during the campaign corresponding to greater processing and economic efficiencies.

30 In view of the above, there is considerable motivation to increase the number of components that can be coated within a single campaign, reduce the amount of time required to introduce and remove components from the coating chamber, and reduce the amount of time required to perform maintenance on the apparatus between

campaigns. However, difficulties can arise in view of the complex equipment necessary to move extremely hot components through the loading, preheat and coating chambers, as well as the difficulty of maintaining such equipment of an advanced EBPVD apparatus.

BRIEF SUMMARY OF THE INVENTION

The present invention provides an electron beam physical vapor deposition (EBPVD) apparatus for producing a coating (e.g., a ceramic thermal barrier coating) on an article.

According to a first aspect of this invention, the EBPVD apparatus comprises a coating chamber operable at an elevated temperature and a subatmospheric pressure; support means for supporting an article in the coating chamber; a preheat chamber adjacent and aligned with the coating chamber, the preheat chamber being operable to preheat the article supported by the support means within the preheat chamber prior to the support means introducing the article into the coating chamber; a loading chamber adjacent and aligned with the preheat chamber, the loading chamber having an access through which the article is loaded onto the support means prior to the support means sequentially introducing the article into the preheat and coating chambers; and a movable platform on which the loading chamber is supported, the movable platform being movable relative to the preheat chamber so as to bring the loading chamber into and out of alignment with the preheat chamber, the movable platform having an elevational profile of not more than 2.5 cm.

According to a second aspect of this invention, the EBPVD apparatus comprises a coating

chamber operable at an elevated temperature and a subatmospheric pressure; an electron beam gun for projecting an electron beam into the coating chamber; first support means for supporting a first article in the coating chamber; a preheat chamber mounted to a surface so as to be adjacent and aligned with the coating chamber, the preheat chamber being operable to preheat the first article supported by the first support means within the preheat chamber prior to the first support means introducing the first article into the coating chamber; a first loading chamber adjacent and aligned with the preheat chamber and opposite the coating chamber, the first loading chamber having an access through which the first article is loaded onto the first support means prior to the first support means sequentially introducing the first article into the preheat and coating chambers; second support means for supporting a second article in the preheat and coating chamber; a second loading chamber adjacent to the first loading chamber, the second loading chamber having an access through which the second article is loaded onto the second support means; a movable platform with an upper surface not more than 2.5 cm above the surface, the first and second loading chambers being supported by the movable platform so that movement thereof causes the first and second loading chambers to be brought into and out of alignment with the preheat chamber; and bearings supporting the movable platform above the surface.

The platform system has a low elevational profile, so as to reduce any risk to the operators of the EBPVD apparatus during repositioning of the loading chamber.

Other objects and advantages of this invention

will be better appreciated from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 and 2 are schematic top and front views, respectively, of an electron beam physical vapor deposition apparatus equipped with a movable platform system in accordance with this invention.

DETAILED DESCRIPTION OF THE INVENTION

An EBPVD apparatus 10 in accordance with this invention is generally depicted in Figures 1 and 2. With

the apparatus 10, a ceramic thermal barrier coating can be deposited on a metal component intended for operation within a thermally hostile environment. Notable examples of such components include the high and low pressure turbine nozzles and blades, shrouds, combustor liners and augmentor hardware of gas turbine engines.

For purposes of illustrating the invention, the EBPVD apparatus 10 is shown in Figures 1 and 2 as including a coating chamber 12, a pair of preheat chambers 14, and two pairs of loading chambers 16 and 18, so that the apparatus 10 has a symmetrical configuration. The front loading chambers 16 are shown as being aligned with their preheat chambers 14, with parts 20 originally loaded on a rake 22 within the lefthand loading chamber 16 having been transferred to the lefthand preheat chamber 14 and, as depicted in Figure 1, into the coating chamber 12. With the symmetrical configuration of the apparatus 10, while the parts 20 loaded through the front lefthand loading chamber 16 are being coated within the coating chamber 12, a second batch of parts in the front righthand loading chamber 16 can be preheated in the righthand preheat chamber 14, a third batch of parts can be loaded into the rear lefthand loading chamber 18, and a fourth batch of parts can be unloaded from the rear righthand loading chamber 18. Consequently, four process stages can occur simultaneously with the preferred EBPVD apparatus 10 of this invention.

Within the coating chamber 12, a ceramic coating is deposited on the parts 20 by melting and evaporating ingots 26 of the desired ceramic material with electron beams produced by electron beam (EB) guns 30. Intense heating of the ingots 26 by the electron beams causes the surface of each ingot 26 to melt, forming molten ceramic pools from which molecules of the ceramic material evaporate, travel upwardly, and then

deposit on the surfaces of the parts 20, producing the desired ceramic coating whose thickness will depend on the duration of the coating process.

5 The subatmospheric pressure required within the coating chamber 12 is controlled by the rate at which gases can be pumped from the chamber 12, and the flow rate into the chamber 12 of desired gases, such as oxygen and argon. In Figure 2, gases are shown as being introduced into the coating chamber 12 through a valve 58 located near the coating chamber 12. The flow rates of the gases are individually controlled based on the targeted process pressure and oxygen partial pressure. After rough pumpdown with mechanical pumps 31, cryogenic and diffusion pumps 32 and 34 of types known in the art can be employed to evacuate the coating chamber 12 prior to and during the deposition process. A separate pair of diffusion pumps 38 is shown as being employed to evacuate the preheat chambers 14. As indicated in Figure 1, the diffusion pump 34 for the coating chamber 12 is equipped with a throttle valve 36 to regulate the operation of the pump 34 at relatively high pressures, e.g., above 0.010 mbar. The diffusion pumps 38 for the preheat chambers 14 are also preferably equipped with throttle valves for the same purpose.

25 According to the present invention, the preheat and loading chambers 14, 16 and 18 are required to move relative to each other so that the loading chambers 16 and 18 can be selectively aligned with their respective preheat chambers 14. For example, when the front lefthand loading chamber 16 is brought into alignment with the lefthand preheat chamber 14 to allow the parts 20 to be inserted into the coating chamber 12, the rear lefthand loading chamber 18 is set back from the lefthand preheat chamber 14, so that parts can be simultaneously loaded or unloaded from the rake 22 of the rear lefthand

loading chamber 18. The coating, preheat and loading chambers 12, 14, 16 and 18 are connected by valves (not shown) that achieve a vacuum seal between these chambers. Consequently, the valves must be capable of numerous cycles at relatively high temperatures and repeatedly provide a reliable vacuum seal between chambers. Seal designs suitable for this purpose are known in the art, and therefore will not be discussed in any detail.

The required mobility of the loading chambers 16 and 18 is achieved in accordance with this invention with two low-profile movable platforms 24 with which paired loading chambers 16 and 18 are supported. In addition to selectively aligning the loading chambers 16 and 18 with the preheat chambers 14, each platform 24 is also preferably movable to a maintenance position, in which neither of its loading chambers 16 and 18 is aligned with its preheat chamber 14, so that the interiors of the preheat and loading chambers 14, 16 and 18 can be accessed for cleaning. The platforms 24 are preferably at least in part supported on roller bearings 44 mounted in the floor, though it is foreseeable that a different bearing design could be used. In addition, the bearings 44 could be mounted within the platforms 24 instead of the floor. In a preferred embodiment, the platforms 24 have a generally two-part construction in which platforms are mounted to the sides or bases of the loading chambers 16 and 18 and further supported by the bearings 44.

Importantly, each platform 24 has a low elevational profile (projection above the floor) of not more than one inch (about 2.5 cm). The low-profile of the platforms 24, along with a chamfer preferably provided along the outer edge of the platform 24, essentially eliminates the potential for an operator tripping on the edges of the platforms 24. The platforms

24 are shown as having sufficiently large surfaces to provide walkways along the loading chambers 16 and 18, as well as storage area for benches and other support equipment. Other stationary objects surrounding the apparatus 10 are preferably positioned away from the edge of the platform 24 to avoid an operator being pinched by the platform 24 when it is repositioned.

While our invention has been described in terms of a preferred embodiment, it is apparent that other forms could be adopted by one skilled in the art. Accordingly, the scope of our invention is to be limited only by the following claims.

CLAIMS:

1. An electron beam physical vapor deposition coating apparatus comprising:

a coating chamber operable at an elevated temperature and a subatmospheric pressure;

support means for supporting an article in the coating chamber;

a preheat chamber adjacent and aligned with the coating chamber, the preheat chamber being operable to preheat the article supported by the support means within the preheat chamber prior to the support means introducing the article into the coating chamber;

a loading chamber adjacent and aligned with the preheat chamber, the loading chamber having an access through which the article is loaded onto the support means prior to the support means sequentially introducing the article into the preheat and coating chambers; and

a movable platform on which the loading chamber is supported, the movable platform being movable relative to the preheat chamber so as to bring the loading chamber into and out of alignment with the preheat chamber, the movable platform having an elevational profile of not more than 2.5 cm.

2. An electron beam physical vapor deposition coating apparatus according to claim 1, wherein the preheat chamber is mounted to a surface and the movable platform is movably supported above the surface.

3. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising bearings mounted in the surface and supporting the movable platform.

4. An electron beam physical vapor deposition coating apparatus according to claim 1, wherein the movable platform comprises a walkway on a surface region of the movable platform adjacent the loading chamber.

5. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising:

a second support means for supporting a second article in the preheat and coating chamber;

a second loading chamber adjacent to the loading chamber, the second loading chamber having an access through which the second article is loaded onto the second support means, the second loading chamber being supported on the movable platform so that the second loading chamber is also movable into and out of alignment with the preheat chamber.

6. An electron beam physical vapor deposition coating apparatus according to claim 5, wherein the movable platform is movable between a first position in which the loading chamber is aligned with the preheat chamber and the second loading chamber is not aligned with the preheat chamber, a second position in which the loading chamber is not aligned with the preheat chamber and the second loading chamber is aligned with the preheat chamber, and a third position in which neither the loading chamber nor the second loading chamber is aligned with the preheat chamber.

7. An electron beam physical vapor deposition coating apparatus comprising:

a coating chamber operable at an elevated temperature and a subatmospheric pressure;

an electron beam gun for projecting an electron beam into the coating chamber;

first support means for supporting a first article in the coating chamber;

a preheat chamber mounted to a surface so as to be adjacent and aligned with the coating chamber, the preheat chamber being operable to preheat the first article supported by the first support means within the preheat chamber prior to the first support means introducing the first article into the coating chamber;

a first loading chamber adjacent and aligned with the preheat chamber and opposite the coating chamber, the first loading chamber having an access through which the first article is loaded onto the first support means prior to the first support means sequentially introducing the first article into the preheat and coating chambers;

second support means for supporting a second article in the preheat and coating chamber;

a second loading chamber adjacent to the first loading chamber, the second loading chamber having an access through which the second article is loaded onto the second support means;

a movable platform with an upper surface not more than 2.5 cm above the surface, the first and second loading chambers being supported by the movable platform so that movement thereof causes the first and second loading chambers to be brought into and out of alignment with the preheat chamber; and

bearings supporting the movable platform above the surface.

8. An electron beam physical vapor deposition coating apparatus according to claim 7, wherein the movable platform

is movable between a first position in which the first loading chamber is aligned with the preheat chamber and the second loading chamber is not aligned with the preheat chamber, a second position in which the first loading chamber is not aligned with the preheat chamber and the second loading chamber is aligned with the preheat chamber, and a third position in which neither the first loading chamber nor the second loading chamber is aligned with the preheat chamber.

9. An electron beam physical vapor deposition coating apparatus according to claim 7, wherein the movable platform comprises a first walkway on a first surface region of the movable platform adjacent the first loading chamber, and a second walkway on a second surface region of the movable platform adjacent the second loading chamber.

10. An electron beam physical vapor deposition coating apparatus according to claim 7, wherein the bearings are mounted in the surface.