Abstract

The growing awareness in society about the limitation in resources, especially fossil fuels, has led to an important research and development aim on new and existing technologies to increase the efficiency of energy converters. The application of thermal barrier coatings (TBC) enables to increase the inlet temperature of gas turbines and thus the degree of effectiveness [1, 2]. At present, TBCs are deposited either by atmospheric plasma spraying (APS) or by electron beam-physical vapor deposition (EB-PVD) [1, 2]. The relatively new Plasma Spray-Physical Vapor Deposition (PS-PVD) based on low pressure plasma spraying (LPPS) combines the advantages of APS and EB-PVD, in particular high deposition rates, relatively low manufacturing costs (APS) and deposition of columnar microstructures (EB-PVD). Hence, PS-PVD coatings show high strain tolerance making them suitable for the hottest sections of the turbine [3-5].

In this work, the properties of the coatings were investigated and related to the application. The coating process was optimized by introducing a pre-oxidation of the bondcoat surface carried out prior to PS-PVD deposition, which leads to an improvement of the durability of PS-PVD-TBCs above the level of the conventional APS TBCs. The positive effect of the pre-oxidation had already been indicated in [3] and was investigated here. Also, the feasibility to coat real geometries was proven in this work by application on turbine vane models. An increased susceptibility to high temperature corrosion by mineral deposits of the composition calcium magnesium alumino silicate (CMAS) had been assumed before, due to the high amount of open porosity in the columnar structure. In this work, by means of modified burner rig tests, it was shown that the resistance against this kind of attack is equivalent to the one encountered in EB-PVD coatings and only slightly below the one present in APS coatings. Besides chemical damage, ingested CMAS particles can limit the durability of coatings also by erosion. Implementing standardized erosion tests, an increased erosion resistance of deposited coatings with a plasma containing H₂ could be confirmed [4-6]. Coatings obtained by this parameter showed comparable properties to APS coatings, although the resistance of EB-PVD coatings was not reached.

The second major aim of this work was to develop a better understanding of the PS-PVD process in order to enable further optimization and reliable industrial application. This task requires models to describe the phenomena experienced by the material during evaporation, transport in the plasma plume and coating deposition. An important result in [3] was that PS-PVD was assumed to be featured not only by vapor deposition, but by a combination of vapor- and nano crystalline cluster deposition. In order to examine the crystal structure of the coatings, transmission electron microscopy was carried out to prove such deposition of clusters. The observed column substructures with semi-single crystal structure did not show any overall preferred orientation. This result was also confirmed by X-ray diffraction analysis. However, local textures in single column branches were found. These results are not in contradiction to the description of cluster deposition, but do not confirm it directly. Furthermore calculations were carried out based on classical and/or kinetic nucleation theory, to investigate the conditions for the formation of such clusters. The results show that
particle nucleation and growth processes can occur to a significant amount considering a boundary layer with a corresponding temperature gradient between plasma plume and substrate surface. Additionally, PS-PVD coatings properties, with respect to the requirements of TBC application, were shown to be similar or improved compared to coatings obtained by established procedures. In particular, the good durability under thermo-mechanical loading should be mentioned, which is higher by a factor of two compared to APS-TBCs. This indicates the suitability of the PS-PVD process for TBC application.