THE POTENTIAL OF PLASMA ACTIVATION FOR EB-PVD OF EBC SYSTEMS ON CMC COMPONENTS

Burkhard Zimmermann, Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, Dresden, Germany
burkhard.zimmermann@fep.fraunhofer.de
Gösta Mattausch, Fraunhofer FEP
Frank-Holm Rögner, Fraunhofer FEP
Bert Scheffel, Fraunhofer FEP
Jens-Peter Heinß, Fraunhofer FEP
Christoph Metzner, Fraunhofer FEP

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Gas turbines are subject of intense research and development in order to meet increasing demands on fuel efficiency, reduction of emissions, or enhanced power. One of the major keys is improving the thermal efficiency by increased gas temperature within the turbine. In the hot turbine section, nickel-based superalloy components with thermal barrier coatings are utilized, which are still being refined and improved. Nevertheless, in order to significantly increase temperature capability and turbine efficiency, silicon-based non-oxide ceramics are being investigated and introduced as new base materials, allowing for lower-weight components operating at elevated temperatures. Severe weight losses due to water vapor corrosion, increasing temperature demands and other challenges require protecting environmental barrier coatings (EBC) to be applied on such ceramic components. The development of EBC systems already went through a number of generations, including mullite and barium-strontium-aluminosilicate (BSAS) based layers, various rare earth silicate coatings, hafnia or zirconia doping, and more. Utilizing processing techniques based on plasma spray and EB-PVD methods, tremendous progress has been made regarding the performance of the coating systems. However, improving the thermal, mechanical and chemical stability as well as the resistance against attack from calcia-magnesia-alumina-silica (CMAS) deposits, water vapor corrosion, or damage due to particle impact is still a hot topic of further development.

Fraunhofer FEP has been developing PVD processes as well as corresponding hardware such as EB guns and plasma sources in a large field of applications for decades. Selected examples are corrosion protection layers on steel, oxygen and water vapor permeation barrier coatings on plastic webs, hard and wear-resistant coatings on tools, or TBC. In the most cases, plasma activation of the PVD process is the key to success in order to combine high-rate film growth with the requested film properties. The vapor and – if prevalent – the reactive gas species are excited, ionized, and dissociated. The energy of charged particles impinging the substrate surface can be tuned resulting in layers with desired density, composition, hardness, or microstructure. From FEP’s experience, it can be derived that the beneficial effect of plasma activation could complement the above mentioned EBC developments to address the present challenges.

In order to achieve significant plasma activation effects, a considerable amount of particles impinging the substrate must be ionized. Due to that, high-rate EB-PVD processes require high-density plasma sources. Fraunhofer FEP developed a hollow cathode arc plasma source, which is being used for R&D purposes and has been introduced in various industrial coating processes, delivering dense large-volume plasmas for substrate pre-treatment and activated high-rate PVD and PECVD processes.

In this paper, the hollow cathode arc plasma source is presented and results of technological application are shown. The hollow cathode plasma has been also used for substrate cleaning; etching rates of up to 40 nm/s have been measured on metallic substrates, promoting highly efficient and fast substrate pre-treatment as well as improved layer adhesion. Reactive EB-PVD of YSZ on flat steel substrates has been performed with and without plasma activation (objective: dense electrolyte membrane layers for solid oxide fuel cells). During plasma activation, the reactive gas dissociation and ionization was strongly increased, and the layer exhibited remarkably denser microstructure and increased microhardness.