PLASMA-ACTIVATED EBPVD OF PROTECTIVE COATINGS: TOOLS AND PROCESSES

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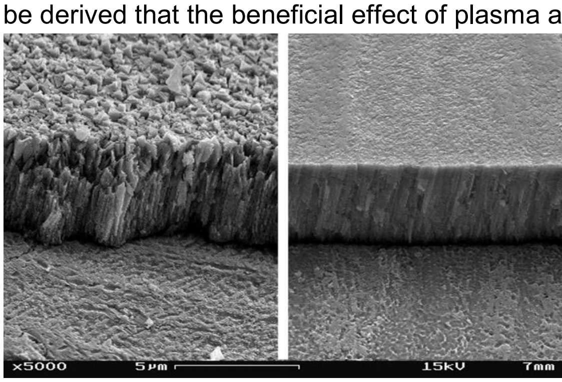
Key Words: EB-PVD, plasma activation, TBC, EBC, composition control

Gas turbines are subject of intense research and development in order to meet increasing demands on fuel efficiency, reduction of emissions, or enhanced power. Major keys are improving the thermal efficiency by increased gas temperature within the turbine or qualifying turbine concepts for the use of sustainable fuels or even pure hydrogen. As a consequence, thermal as well as environmental barrier coatings (T/EBC) protecting components within the hot turbine section need continuous refining and improvement, and new coating development is required to address upcoming challenges. For example, 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 are of high importance.

Fraunhofer FEP has been developing PVD processes as well as corresponding hardware tools such as electron beam (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, which can be achieved at lower substrate temperature and at higher pressure. 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. E.g., for EB-PVD of yttria-stabilized zirconia (YSZ), the reactive gas dissociation and ionization was strongly increased, and the layer exhibited remarkably denser microstructure and increased microhardness. From FEP's experience, it can be derived that the beneficial effect of plasma activation could complement the above mentioned developments.



SEM pictures of EB-PVD-deposited cubic-phase YSZ without (left) and with (right) plasma activation

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 based on vacuum arc discharges such as the hollow cathode arc-assisted or the spotless arc assisted deposition (HAD or SAD, respectively). Whereas for SAD a diffuse arc discharge is ignited utilizing the melt pool as an electrode, the HAD process employs a hollow cathode arc source to generate the plasma. Fraunhofer FEP has developed corresponding processes and tools which have been introduced in various industrial coating processes.

In this talk, the HAD and SAD processes as well as the hollow cathode arc plasma source are presented, including various configurations and plasma characteristics. A further important aspect is the use of optical plasma emission spectroscopy as an advanced tool for process control. Moreover, a tandem hollow cathode (THC) system, consisting of two bipolar pulsed plasma sources, has been recently realized for a TBC coater. In order to compensate the deviating effect of constant and oscillating magnetic fields generated by the plasma-enhancing field coils and pulsed high-current arc plasma, respectively, the THC system has been combined with a new dynamic EB deflection module, which corrects the beam path in real time.

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