



## INTERNATIONAL CENTER FOR ELECTRON BEAM TECHNOLOGIES OF E.O. PATON ELECTRIC WELDING INSTITUTE

Technology of electron beam evaporation (atomization) and further physical vapour deposition in vacuum (EB-PVD) for producing thick films and massive condensates with specified structure and properties began to be developed at PWI under the leadership of Borys O. Movchan at the start of 1960s. Created during 1975–1991 at PWI, EB-PVD technologies and equipment (15 industrial multichamber units) were introduced in many enterprises of the Ministries of Aviation, Shipbuilding and Gas Industries for deposition of heat- and corrosion-resistant and thermal barrier coatings with an outer ceramic layer on gas turbine blades for various applications.

State Self-supporting Company «International Center for Electron Beam Technologies of the E.O. Paton Electric Welding Institute of the NAS of Ukraine» (ICEBT) founded in 1994, continues systematic research for creation of new materials and protective coatings, which are produced by application of EB-PVD technologies. Scientific fundamentals of EB-PVD technologies of producing amorphous, nanocrystalline, dispersion-strengthened, microlaminate, porous and gradient materials and coatings; specific technologies and new examples of EB-PVD equipment, which gained international recognition, are protected by numerous patents (USA, Europe, China), in particular joint patents with customers.

Developed at ICEBT technologies for deposition of gradient protective coatings provide a higher level of repeatability of the composition, structure and fatigue life, compared to coatings which are produced by the traditional multistage technology. For instance, the graded thermal barrier coatings of NiCoCrAlY(AlCr)/YSZ type for protection of gas turbine blades (see Figure), with ceramic layer thickness of approximately 160  $\mu\text{m}$  have a low level of heat conductivity (approximately 1.2 W/(m.K), and their thermal cyclic fatigue life is 2–3 times higher than that of the traditional thermal barrier coatings.

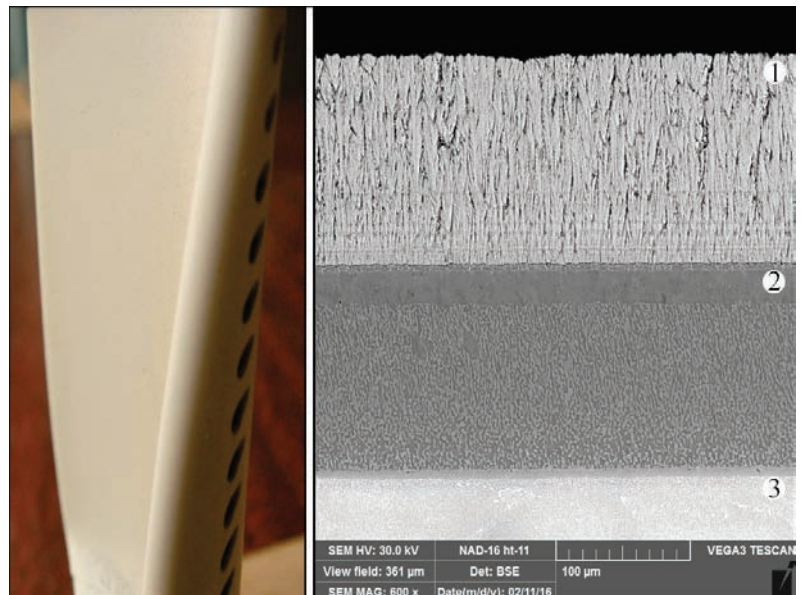
Technology of deposition of multi-layer damping/erosion-resistant nano-

structured coating for protection of parts from titanium- and aluminium-based alloys was developed.

The main ICEBT customers for fulfillment of research contracts are foreign companies and research centers of the USA (General Electric, Pratt&Whitney, Honeywell, Pennsylvania State University), Canada, Japan and India.

Active cooperation was established with the enterprises and organizations of the People's Republic of China. Here, both the equipment and advanced technologies are proposed to all the customers. Over the recent years, 4 licenses for the right of industrial use of patents for deposition of thermal barrier coatings were sold to PRC, together with 6 electron beam units, and training and upgrading of the qualifications of Chinese engineers and technicians was performed.

It should be noted that the first EB-PVD unit, designed and manufactured at ICEBT at the end of 1990s, was supplied to Beijing (Beijing Institute of Aeronautics and Astronautics). All together, ICEBT designed, manufactured and supplied to Chinese customers 13 EB-PVD units, which are operating both at research organizations (Beijing Institute of Aeronautics and Astronautics,



Appearance and microstructure of gradient thermal barrier NiCoCrAlY(AlCr)/ $\text{ZrO}_2$ -8 %  $\text{Y}_2\text{O}_3$  coating on a blade of gas turbine engine:

- 1 — outer ceramic layer of  $\text{ZrO}_2$ -8 %  $\text{Y}_2\text{O}_3$ ;
- 2 — heat-resistant NiCoCrAlY layer with AlCr gradient zone;
- 3 — high-temperature alloy



EB-PVD units developed and manufactured at ICEBT, are operating in PRC, USA, Canada and India

Beijing Aeronautical Manufacturing Technology Research Institute, Beijing Institute of Aeronautical Materials), and at industrial enterprises in the cities of Xi'an, Guizhou, Shenyang, Chengdu.

In 2019 the license for the use of the technology of high-rate EB-PVD of corrosion-resistant alloys for deposition of protective coatings was purchased by SC SPKG «Zorya–Mashproekt» (Mykolaiv), and joint research is continued on improvement of composite coatings of metal/ceramic type, which are used in this enterprise.

ICEBT is developing variants of hybrid EB-PVD technologies, which combine the physical and chemical processes of deposition of inorganic materials in vacuum. EB-PVD hybrid nanotechnology and the respective equipment are a real basis for further progress of science and technology and economy, in order to produce protective coatings in different sectors of modern mechanical engineering.

Over the recent years, a new direction began to be developed at ICEBT, alongside the above-mentioned traditional areas of technology, namely EB-PVD technology of deposition of nanostructured coatings («islet» and continuous) on powders and granules of various materials.

All together, over the 25 years of ICEBT existence 17 EB-PVD units for various applications have been manufactured and supplied, and 6 licenses for the right of industrial use of patents for protective coating deposition have been sold to foreign customers (PRC, USA, Canada, and India). The new generation units proposed to customers, are fitted with modern Western vacuum components, improved electron beam projectors with cathode life extended up to 100 h, stabilized high-voltage power source that corresponds to the European standard CEI 61000-3-4, and modern industrial computers for the control system.

<http://www.paton-icebt.kiev.ua/>