RECENT ADVANCE IN THE DEVELOPMENT OF MATERIALS FOR EXTREME ENVIRONMENTAL APPLICATIONS

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Progress in aerospace is related to the development and modernization of propulsion systems capable of operating under extreme environmental. At present, there are several concepts to protect the structures from degradation at temperatures above 2000°C. The developed concepts are based on (i) the ability of some systems to "self-healing" (Hf(Zr)B_2-SiC systems) [1]; (ii) usage of so-called high-entropy ceramics, i.e. an equimolar mixture of five or more refractory carbides, nitrides or borides, effectively preventing diffusion of oxygen inwards the material; (iii) usage of the materials that have an exceptionally low recession rate in oxygen, such as multilayered iridium coatings. However, these concepts have disadvantages. Therefore, the proposed materials can not provide the stable operation of structures at temperatures above 2000°C, either because of uncontrolled heating, or insufficient strength, as well as the complexity of composition control. Thus, there is an urgent necessary to develop new approaches to protect the structural materials under extreme conditions.

Several approaches proposed by us to the synthesis of ultra-high temperature materials as bulk or coatings, as well as their ablation resistance at ultra-high temperatures will be discussed. The first approach is based on the multilayered coating concept and involves the deposition of refractory carbides combined with noble metals. To obtain carbides of refractory metals of IV-V groups the reactive chemical vapor deposition (RCVD) was used. The results of the thermodynamic modeling of several systems “refractory metal-C-F” in wide temperature and pressure ranges will be presented. Analysis of the calculated molecular composition of the vapor phase in equilibrium with solids showed that the chemical transport of refractory metal through the gas phase is mediated by lower metal fluorides. Using RCVD method, the tantalum, hafnium and some other refractory metal coatings and bulk materials were obtained. The complex carbide-iridium coatings on carbon supports were also obtained by RCVD and MOCVD methods, respectively [2]. The results on the morphology, phase and elemental composition, as well as the response of the systems on the exposure to extreme temperatures and aggressive gas flow will be presented.

The second approach to design of materials that can resist to extreme environmental conditions is based on the usage of iridium-containing compounds - iridides of refractory metals - as the base elements of such coatings. It was shown that the iridide-based materials display excellent ablation resistance under arc-jet testing at temperatures higher than 2000°C. The special benefits of the new designed materials result from their relative oxygen impermeability and special microstructure similar to superalloys.

REFERENCES

[1] *Ultra-High Temperature Ceramics. Materials for Extreme Environment Applications //Ed. W. Fahrenholz et al.* – Wiley, 2014.

[2] *V.V. Lozanov, N.I. Baklanova, N.B. Morozova // Journal of Structural Chemistry* - 2015 – V.56 – № 5. P.900-906.