

EXPLANATORY TEXT

Cyclic Oxidation Performance and Microstructural Stability of Ti-6Al-4V with TBC

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Thermal Barrier Coatings (TBCs) are protective systems applied to Ti-6Al-4V alloys in aerospace turbine blades, providing thermal insulation, oxidation resistance, and improved microstructural stability at elevated temperatures. They also preserve the alloy's mechanical strength, combined with low specific weight and excellent corrosion resistance.

The most commonly used ceramic coating is 7 molar yttria-stabilized zirconia (7YSZ) due to its low thermal conductivity and high phase stability at elevated temperatures. However, this material has performance limitations above 1200 °C, becoming susceptible to hot corrosion and microstructural degradation. To overcome these limitations, recent studies have investigated zirconia co-doped with yttria and niobium, which has demonstrated reductions in thermal conductivity of up to 70% compared to conventional 7YSZ, depending on the deposition route employed, including atmospheric plasma spraying (APS), electron beam physical vapor deposition (EB-PVD), and CO₂ laser processing.

Despite these advantages, continuous exposure to high temperatures can trigger degradation mechanisms such as excessive oxide layer growth, thermally induced interfacial stresses, and loss of adhesion between coating layers, system integrity and service life. Therefore, understanding the microstructural evolution of coated titanium

alloys under cyclic oxidation conditions is essential to assess their reliability for critical aerospace applications.

This study aimed to evaluate the microstructural evolution of Ti-6Al-4V alloy with TBCs subjected to 100 thermal oxidation cycles at 500, 600, and 800 °C. Each cycle consisted of 60 minutes of isothermal exposure followed by 10 minutes at room temperature. The TBC system consisted of a metallic substrate (Ti-6Al-4V), a bond coat (NiCrAlY), a thermally grown oxide (TGO), and a ceramic topcoat (zirconia stabilized with 16.0% equimolar yttria and niobia). Microstructural characterization was conducted using X-ray diffraction, optical microscopy, scanning and transmission electron microscopy, and energy-dispersive spectroscopy.

The top layer (TC) was identified by XRD analysis; however, partial delamination was observed along the surface. Even so, the TBC system preserved the substrate microstructure at 500 and 600 °C. TEM and EDS analyses confirmed the integrity of the multilayer coating architecture, as well as the presence of a thermally affected region in the coating at 600 °C. At 800 °C, microstructural changes were detected in the substrate due to the combined effects of heat input from laser processing and exposure to cyclic oxidation.

These results demonstrate the effectiveness of TBCs in increasing oxidation resistance and maintaining microstructural stability under cyclic thermal exposure, thus contributing to improved durability and reliability of titanium alloys for high-temperature aerospace applications.