Surface modification of protective coatings on titanium aluminides by plasma immersion ion implantation of fluorine to suppress environmental embrittlement at high temperatures

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Abstract

Due to their excellent density-specific properties, titanium aluminide (TiAl) alloys have been identified as high-payoff materials for advanced aerospace and power generation applications in the medium-temperature (600∘-750∘C) range. They have recently been applied as structural materials for turbine blades in the low-pressure section of the GEnx jet engine. These alloys, however, are prone to both oxidation and embrittlement when exposed to oxidizing environments at temperatures above _˜ 750∘C. Under such conditions, TiAl alloys form a mixed (TiO2+Al2O3) non-protective oxide scale resulting from the difference in both the growth kinetics of the two oxides, and the chemical activity of the constituent elements, Ti and Al. Thus, for high-temperature (> 750∘C) applications, an oxidation protection coating is needed to prevent environmental damage of the base alloy without degrading its initial mechanical properties. The present work has focused on the development of coatings for the efficient oxidation protection of TiAl alloys at high temperatures. Aluminum-rich TiAl coatings (50 to 60 at.%Al) have been produced by either chemical vapor deposition (MO-CVD), physical vapor deposition (PVD) or thermal spraying (HVOF, APS) techniques onto a GE alloy (Ti-48Al-2Cr-2Nb) qualified for aerospace applications. The coating surface has then been modifiedby plasma immersion ion implantation (PIII) of fluorine to promote the formation of a protective alumina-containing scale relying on the so-called halogen effect.

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For the PIII processing, either difluoromethane and argon (CH2F2/Ar) or silicon tetrafluoride and argon (SiF4/Ar) has been used as the F-containing precursor gas. The resulting F-implanted coatings have been exposed to oxidative/corrosive environments at 850◦C for 350 h, and have shown a high degree of oxidation resistance. The mechanical properties of the coated samples have been examined by 4-point bend, tensile and fatigue testing after oxidation in laboratory air at 900◦C for 100 h. Combining a CVD process with PIII of F (the CH2F2/Ar process) has been found to give the best results in terms of efficient environmental protection against oxidation and embrittlement. It has also been established that more than 90% of the initial mechanical properties of the substrate TiAl alloy can be retained after the application of such a protective coating.

Keywords: titanium aluminides, oxidation protection, coating, fluorine, plasma immersion ion implantation