Effect of Coatings on Oxidation of Ti–6Al–2Sn–4Zr–2Mo Foil

Ronald K. Clark,* J. Unnam, † and K. E. Widemann†

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The viability of using coated Ti–6Al–2Sn–4Zr–2Mo foils at 620°C in air was established through mechanical and thermogravimetric testing. Weight-grained and oxygen embrittlement were significantly reduced by the coatings. The residual tensile elongation of coated specimens was 2.5 times that of uncoated specimens. Comparison depth-profiling with X-ray diffraction verified the reduction of oxygen solid-solution in the α-phase for a selection of coated specimens.

KEY WORDS: Oxidation; titanium; embrittlement; mechanical properties; thermogravimetry; coatings.

INTRODUCTION

Because of their high specific strengths, titanium alloys are considered good candidate materials for many aerospace applications.¹–³ However, due to oxygen embrittlement,⁴–⁷ the use of thin-gauge titanium alloys in oxidizing environments is limited to roughly 430°C for exposures of more than 200 hr and 540°C for exposures of less than 400 hr. In applications in which conditions exceed these limits, the use of superalloys is required. Because their specific strengths (at 650°C) are one-half to two-thirds that of the titanium alloys, the necessity of using superalloys constitutes a serious weight penalty.

The availability of effective oxygen-barrier coatings for titanium alloys would enable use of titanium for longer times at higher temperatures and would result in lighter aerospace structures. Such coatings would have to
be thin in order to retain the low-weight benefit afforded by the high specific strength of the alloys.

Oxygen embrittlement of titanium alloys occurs during exposures to oxidizing environments. During oxidation, titanium alloys experience a weight gain due to the absorption of oxygen from the surrounding air. The oxygen reacts with the alloys to form oxides at the surface (principally the rutile form of TiO₂) and a solid solution with the base metal. The compositional range of the solid solution extends to 34 at.% oxygen in (unallyed) α-titanium.⁸

The static mechanical property most severely affected by oxygen in the metal lattice is elongation to failure.⁶,⁷ Other static mechanical properties display less change. Oxygen occupies interstitial lattice sites in the alloy. At concentrations above about 1.5 at.% oxygen, the alloy experiences a loss in ductility. The region of high oxygen concentration is at the surface and is very thin, hence does not strongly affect strength and stiffness of the alloy. However, oxidized specimens of foil-gauge alloy experience cracking of the embrittled zone at the surface. The surface cracks act as stress risers that cause failure of the specimen at low strain levels.

With the knowledge that unprotected Ti–6Al–2Sn–4Zr–2Mo (Ti–6242) experiences significant loss of ductility when exposed to air at 620°C for times less than 25 h,⁷,⁸ the goal of the present study was to establish the viability of using oxygen barrier coatings to shield titanium from oxidation during high-temperature exposure. Tests were performed to measure changes in room-temperature mechanical properties after coating and after exposure.

**PROCEDURE**

**Materials**

Specimens were prepared from 0.075-mm-thick Ti–6242 foil. Table I displays the chemical assay of the foil in the mill-annealed condition. Two types of specimens were prepared: tensile specimens (see Fig. 1 for dimensions), and thermogravimetric specimens (nominally 1-cm × 1.5-cm rectangular coupons). After machining, the specimens were cleaned according to the schedule shown in Table II and heat-treated 1.5 hr at 930°C in >10⁻⁶ Torr vacuum. Cleaning and heat-treatment procedures were designed to follow those used in the fabrication of titanium multiwall heat-shield panels.⁹⁻¹¹

Five types of coatings were tested: (1) aluminum, (2) SiO₂, (3) silicate, (4) aluminum basecoat plus SiO₂, and (5) aluminum basecoat plus silicate (Table III). Aluminum coatings were applied using electron-beam (EB)