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Effect of water vapor on thermally grown alumina scales on bond coatings ☆

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ABSTRACT

The role of water vapor on thermal barrier coating (TBC) performance has been investigated for both Pt-modified aluminide and Pt-diffusion bond coatings by characterizing the alumina scale after exposures at 1150 °C. For both types of bond coatings, the average oxide scale thickness formed in dry O_2 at 1150 °C was lower than that formed in wet air, especially for air + 10%H_2O. In all cases, the average thickness was higher beneath the yttria-stabilized zirconia (YSZ) top coat. Characterization of the alumina scale formed without a YSZ top coat showed differences in morphology and Hf- and Ta-rich oxide precipitates at the gas interface depending on the environment. With and without water vapor, the β-(Ni,Pt)Al coatings showed a martensitic structure with 10–50 nm α-Cr(Re) precipitates. Alumina grain boundary segregation of Y and Hf from the superalloy substrate was easier to detect for the Pt-diffusion coatings.

1. Introduction

There has been increasing interest in the role of water vapor on thermal barrier coating (TBC) performance as all gas turbines have water vapor in the environment due to fuel combustion [1–5]. Generally, it is assumed that alumina-forming bond coatings, such as single phase β-(Ni,Pt)Al and two phase (γ + γ′) enriched in Pt or MCrAlY, are more resistant to water vapor than chromia-forming alloys [5–8]. However, some detrimental effects of water vapor still have been observed such as increased scale spallation and more Ni-rich oxide formation on uncoated superalloys [2,5–7]. The role of water vapor is of particular interest for turbines fired by coal-derived synthesis gas or hydrogen, where the water vapor content is expected to be higher than in conventional turbines [9]. Several studies have been conducted or are in progress to determine the effect of higher water vapor content on bond coating and TBC performance [2,5,10,11]. The effects of water vapor on TBC lifetime are apparently more pronounced for the β coatings than for the γ + γ′ bond coatings [5,10,11]. However, a clear explanation for the effect of water vapor has not yet been proposed. Therefore, this characterization work was initiated in an attempt to more carefully and quantitatively investigate the role of water vapor on the performance of high temperature oxidation-resistant coatings.

1.1. Experimental procedure

Pt-diffusion (γ + γ′) and Pt-modified (β-NiPtAl) aluminide coatings were deposited on second-generation Ni-base superalloy René N5 (64.75Ni–8Cr–13.3Al–0.9Re–7.9Co–1.6W–2.2Ta–0.9Mo–0.01Ti in at.%) [5,12]. A 7 ± 1 μm thick Pt layer was electroplated on the alumina grit-blasted specimens, which were 16 mm diameter and 1.5 mm thick. For Pt-diffusion coatings, coupons underwent annealing in a vacuum of 10^{-4} Pa (10^{-6} Torr) for 2 h at 1175 °C to form a ~25 μm thick coating [13]. For Pt-aluminide coatings, aluminization was conducted in a laboratory-scale chemical vapor deposition (CVD) reactor for 6 h at 1100 °C to form a ~40 μm thick layer [14]. One surface

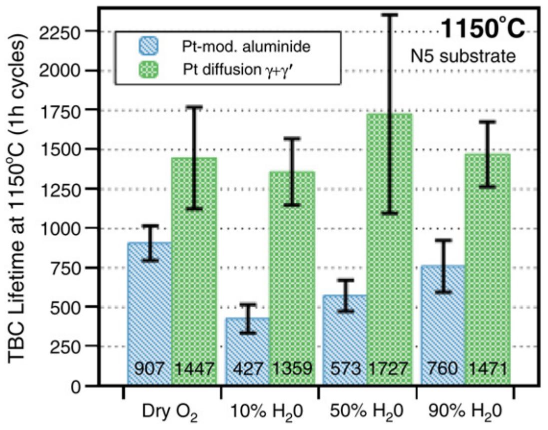

Fig. 1. Average lifetime of γ + γ′ and β-single phase bond coatings after exposure to dry O_2 and air with 10, 50, and 90% H_2O in 1 h cycles at 1150 °C.

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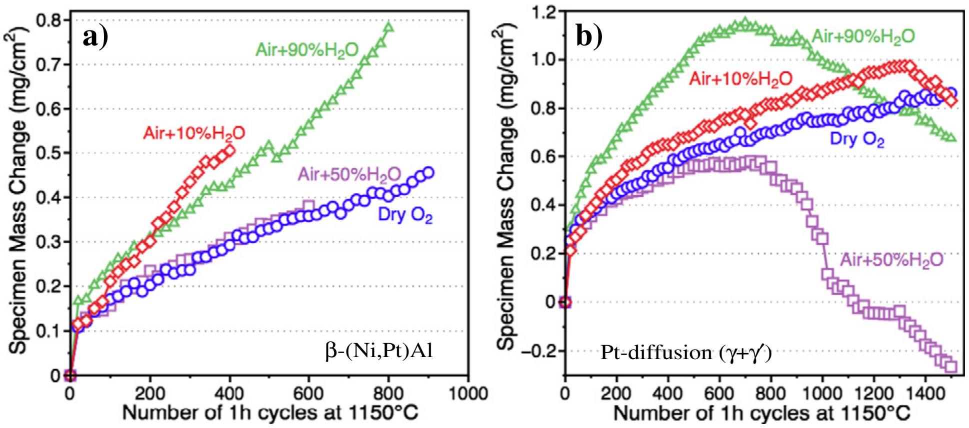

Fig. 2. Mass change data in four environments for (a) β-(Ni,Pt)Al Pt aluminide bond coatings and (b) γ + γ′ Pt diffusion bond coatings.

of the coupons was lightly grit blasted and coated with ~125 μm of YSZ by electron-beam physical vapor deposition (EB-PVD). Furnace cycling tests were conducted using 1 h cycles at 1150 °C in four conditions (dry O_2 and air with 10 ± 1%, 50 ± 2% and 90 ± 2% H_2O) [11]. For each condition four specimens with the same bond coating were tested; three specimens with YSZ and a fourth one without YSZ (and no grit blasting) to observe the oxide scale formation. The specimens were characterized by a variety of electron microscopy methods and

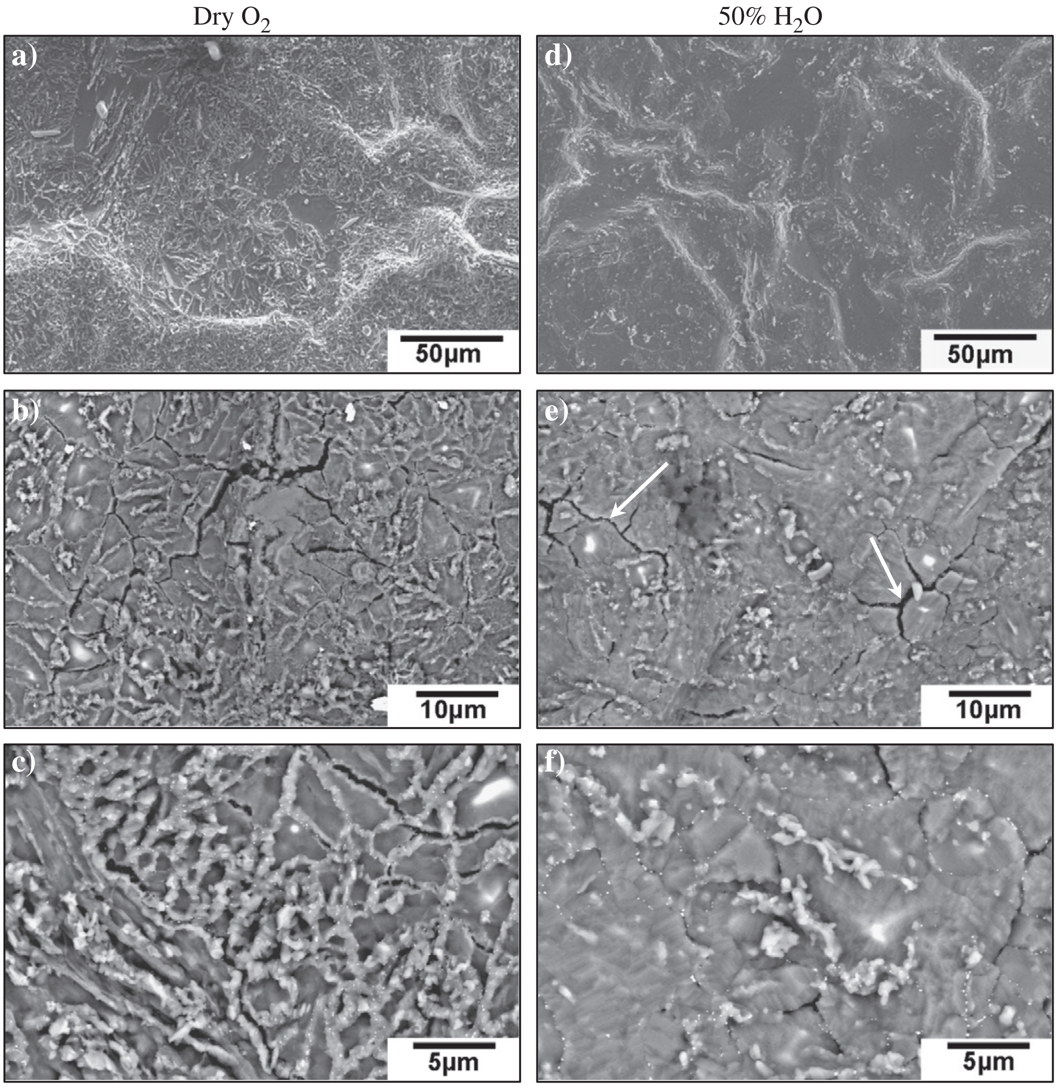

Fig. 3. Secondary electron (a and d) and back-scattered (b, c, e, and f) plan view images of β-(Ni,Pt)Al bond coatings exposed in O_2 after 900 1 h cycles (a–c) and air + 50% H_2O after 800 h 1 h cycles (d–f).