

Oxidation and microstructure evolution of Al–Si coated Ni₃Al based single crystal superalloy with high Mo content

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ABSTRACT

A Si modified aluminide (Al–Si) coating was prepared on a Ni₃Al based single crystal superalloy with high Mo content by high-activity pack cementation. Cyclic oxidation test at 1150 °C was carried out and the microstructure evolution of the coating was investigated. The results show that the oxidation resistance of the substrate was greatly increased by applying an Al–Si coating. During oxidation, outward diffusion of Mo was effectively blocked due to its high affinity with Si. Besides, a layered structure was formed as a result of the elements inter-diffusion. An obvious degradation of the Al–Si coating was observed after 100 h oxidation. Possible mechanisms related to the oxidation and elements inter-diffusion behaviours were also discussed.

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1. Introduction

Thermal barrier coatings (TBCs) are widely applied onto superalloy components in gas turbine engines to provide hot corrosion resistance and thermal insulation. Commercial advanced TBCs usually process a two-layered structure [1], including a ceramic top coat for thermal insulation [2], and an underlying metallic bond coat for oxidation and corrosion resistance [3,4]. Typically, the bondcoat is a MCrAlY (M=Ni, Co or Ni+Co) [5–7] overlay or a diffusion aluminide coating [8] with a thickness of 50–150 μm.

Considerable past research has focused on Pt-modified nickel aluminide β-(Ni, Pt)Al coating, due to its excellent capability of forming a protective alumina scale [9–11]. However, the industrial application of (Ni, Pt)Al is always limited by its complicated fabrication process and high cost. Low cost aluminide coatings prepared by pack cementation can be the alternative choice in most

cases. According to the serving environment, aluminide coatings modified by Si [12], Cr [13] or reactive elements (REs) [14,15] have been developed to meet the requirements of good oxidation and corrosion resistance.

IC21 superalloy (Beihang University) is a newly developed Ni₃Al based single crystal superalloy for turbine blades and other high temperature structural components. This superalloy exhibits excellent high temperature mechanical properties. However, the high Mo content (8~10 at.%) within the superalloy results in a poor oxidation resistance, due to the formation of volatile Mo oxides [16]. To address this problem, IC211 superalloy with reduced Mo content (5~8 at.%) was further developed. Moreover, elements including Cr, Y and Ta were doped in the IC211 aiming to improve its oxidation performance. Our previous work demonstrated that Si modified aluminide (Al–Si) coating could effectively improve the oxidation performance of the high Mo containing superalloy by suppressing the detrimental effect of Mo [17]. Compared with the IC21, it can be expected that the coated IC211 will exhibit different oxidation and inter-diffusion behaviours.

In this work, an Al–Si coating was prepared by pack cementation onto a novel Ni₃Al based single crystal superalloy IC211 with high Mo content. Cyclic oxidation was conducted at 1150 °C. The microstructure evolution, oxidation and inter-diffusion behaviours of the coating systems were investigated. Possible mechanisms

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related to the oxidation and elements inter-diffusion behaviours were also discussed.

2. Experimental

Ni₃Al based single crystal superalloy IC211 was used as substrate material, with the nominal composition listed in Table 1. Specimens with dimensions of 10 mm × 8 mm × 3 mm were cut from the superalloy rods. Prior to pack cementation, all the specimens were ground by 800-grit SiC abrasive paper and ultrasonically cleaned in an acetone bath for 20 min and then dried thoroughly.

The Al–Si coating was prepared by powder pack cementation, detailed procedures of which are stated elsewhere [18]. In the pack cementation process, the superalloy samples were buried by

powder mixture in sealed crucibles. Chemical composition of the corresponding powder mixture is given in Table 2. Among the powders, NaF acted as activator while Al₂O₃ as inert filler to prevent Al sintering during aluminizing process. Powders were mixed uniformly for 2 h in a planetary ball mill and then were poured into

Table 1
Nominal compositions of IC211 alloy (in at.%).

Al	Mo	Ta	Cr	Re	Y	Ni
15~18	5~8	0.8~1	1.5~3	0.2~0.6	0.003	Bal.

Table 2
Chemical compositions of powder mixture (in wt.%).

Al	Si	NaF	Al ₂ O ₃
10	2	5	83

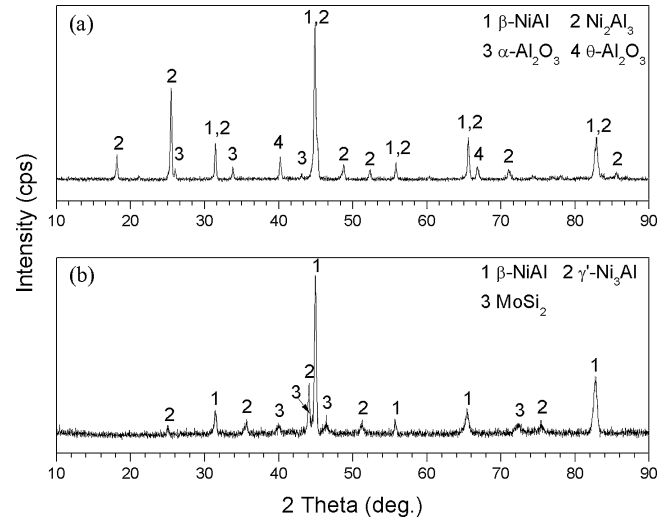


Fig. 1. XRD patterns of (a) as-prepared Al–Si coating; (b) the IDZ in the coating after 100 h oxidation.

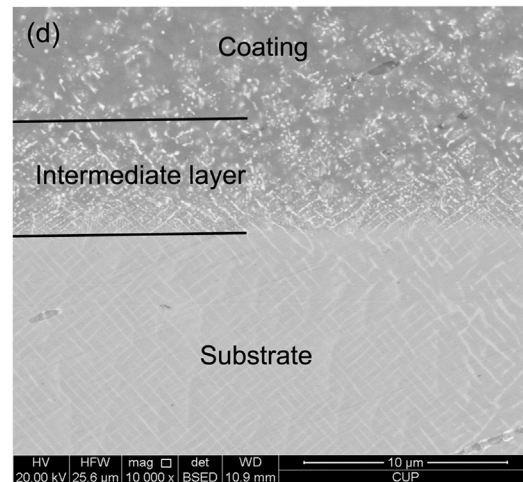
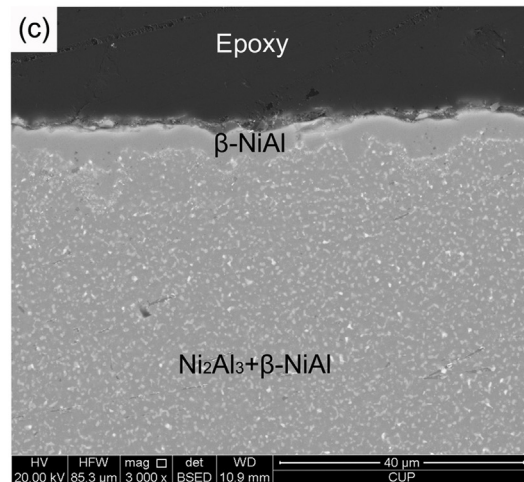
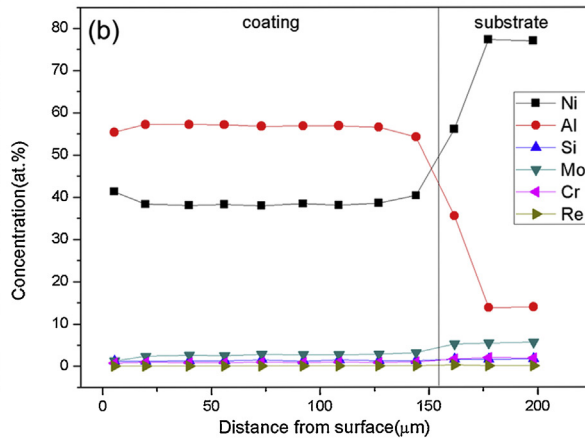
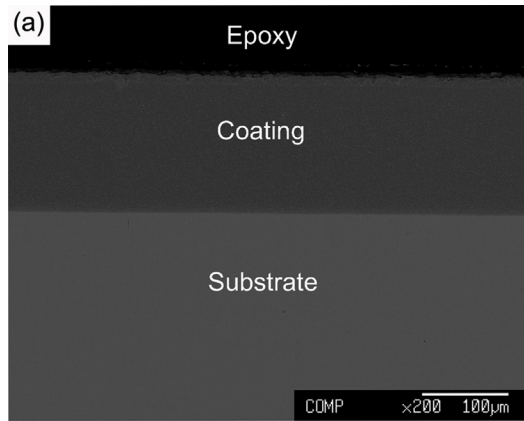


Fig. 2. SEM cross-sectional images of Al–Si coating: (a) as-prepared coating; (b) EDS composition profiles of Ni, Al, Si, Mo and Cr measured across the coating/IC211 substrate; (c) local micrograph with high magnification of as-prepared coating; (d) larger micrograph of Al–Si coating–IC211 substrate interface.

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