

High Temperature Characteristics of Iridium-Modified Aluminide Coatings for Nickel-Base Superalloys

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Introduction

In the development of protective coatings for use in combustion-type energy conversion systems such as gas turbines and diesels, primary emphasis has been put on oxidation and hot corrosion resistance. Aluminide coatings have for many years been regarded as the most basic and the most important among various kinds of high-temperature coatings. To improve performance of the aluminide coatings, some platinum-group-metals (PGMs) modified-aluminide coatings, such as Pt-, Pd-modified aluminide coatings have been applied for turbine blades and vanes [1-2]. However, the high price of the platinum pre-deposition may limit their industrial use.

On the other hand, Ir is of great interest because it has the highest melting temperature (2716K) among PGMs, excellent chemical stability and low oxygen diffusivity [3], which suggests that Ir may retard the growth rate of thermally grown oxide, and may retard the interdiffusion between substrate and coatings. It is thus of utmost importance to develop Ir-modified aluminide (Ir-Al) coatings which are expected to prolong the life of components exposed under high-temperature environments. Another advantage is the cost of the materials. Since Ir is cheaper than Pt, Ir deposition would reduce the cost of airfoils.

Recently, we have succeeded in the electrodeposition of Ir and Ir-Pt alloys on Ni-base single-crystal superalloys [4]. The main objective of this study is to employ this electrodeposition process for the development of Ir-Al coatings on Ni-base single crystal superalloys. Cyclic oxidation tests and hot-corrosion tests were carried out to evaluate the high-temperature performance of the coated materials. Change in microstructure, effects of iridium and aluminum elements during the tests were also discussed.

Experimental

A nickel-base single-crystal superalloy TMS-75 (6.0 wt%Al, 12.0 wt%Co, 3.0 wt%Cr, 6.0 wt%Ta, 6.0 wt%W, 5.0 wt%Re, and Ni as balance, which was a recently developed third generation superalloy by the authors' research group, was used as a substrate material

Ir coatings of 8 μm thickness were first electrodeposited on the samples [4]. The Ir-coated samples were then treated by a conventional pack-cementation aluminizing process, where the Ir-coated specimens were embedded in an alumina retort containing the mixture of Al_2O_3 , Al and Fe powder, and NH_4Cl . The pack-cementation aluminizing treatment was carried out at 1373 K for 5 h under flowing Ar (10^{-3}Pa).

Cyclic oxidation tests were carried out in a programmed muffle furnace at 1373 K in still air. Cyclic hot-corrosion tests in dipped mixture of molten salt (Na_2SO_4 95at% + NaCl 5at%) were carried out at 1173 K in still air. Each thermal cycle consisted of 20 h held at 1373K or 1173K and

4 h held at room temperature. The tests were conducted for up to 10 cycles. The crystal structure, surface morphology, and composition of the coated layer and oxides were analyzed by the X-ray diffraction analyzer and the scanning electron microscopy, respectively.

Results and Discussion

The cross-sectional microstructure of the Ir-Al coated TMS-75 is shown in Figure 1. It can clearly be seen from this figure that the coated TMS-75 has a triplex layer structure. XRD and EDS analyses revealed that the coating has B_2 ordered structure, consisting of continuous three layers; an outer β -(Ir,Ni)Al layer with about 14 μm thick being dense and uniform; an intermediate β -NiAl layer with about 50 μm thick, and an inner Al-diffusion zone with about 5 μm thick.

Figure 2 shows a SEM image of the surface morphology of Ir-Al coating obtained after 5 cyclic oxidation tests. The high oxidation resistance of Ir-Al coating Al to diffuse from the outer β -(Ir,Ni)Al layer and intermediate β -NiAl layer to the coating surface on which α - Al_2O_3 scale is formed. Ir seems to have a beneficial effect on the cyclic oxidation resistance by stabilizing α - Al_2O_3 scale; it limits the α - Al_2O_3 scale spallation and allows the protective β -NiAl phase to be retained for longer time than the simply-aluminized TMS-75. This study confirmed that this Ir-Al coating is promising and has a potential to be applied to industry.

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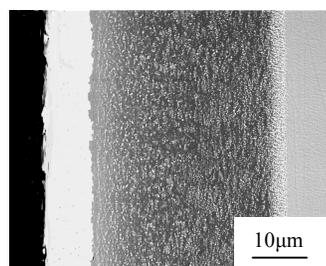


Fig.1 SEM image of the cross-sectional microstructure of Ir-Al coated TMS-75.

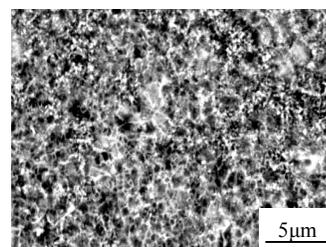


Fig. 2 Surface morphology of Ir-Al coated TMS-75 after 5 cyclic oxidation tests showing α - Al_2O_3 needles and β -(Ni, Ir) Al phase.