

Effect of Zr Addition on Protective Al₂O₃ Scale Formation of β NiAl/Ni-40at%Cr Alloys in High Temperature Oxidation at 1273K

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1. INTRODUCTION

The superior strength and corrosion resistance at high temperature of Ni-Cr alloys is well-known, but Ni-Cr alloys are rarely used as is in highly corrosive conditions.

To achieve longer lifetimes, coating systems, such as aluminized coatings are widely used. The lifetime of alloys with aluminized coatings is controlled by maintaining a reservoir of Al that forms a protective Al₂O₃ scale on the surface. Loss of Al from the coatings occurs by separations of the Al₂O₃ due to thermal cycling and also by inter-diffusion of coating and substrate.

This study investigated the effect of Zr addition on the protective Al₂O₃ scale formation of β NiAl/Ni-40at%Cr alloys are.

2. EXPERIMENTAL

The alloys for the experiments were prepared using Ar-arc melting with pure Ni, Cr, Re, and Zr. The ingots were heat-treated in vacuum at 1373K for 86.4Ks and then cut into 1mm-thick specimens. The 12 μ m-thick Ni coating was formed by electro-deposition. The Al-diffusion treatment was carried out in a mixture of NH₄Cl, fine Al₂O₃ powder and high-purity Al-powder as an Al vapor source in an Al₂O₃ crucible. The aluminizing was performed at 1273K for 21.6ks in a dynamic vacuum (10⁻³Pa). The 1373K heat-treatment was carried out to create a Cr layer that may work as a diffusion barrier.

Oxidation experiments were carried out at 1273K in air under thermal cycling, for 57.6ks at 1273K followed by furnace cooling to room temperature for a total holding time of 3.742Ms.

Oxidation amounts were measured as a function of time, and the scale structure and concentration profiles of each element were determined using electron probe micro-analysis (EPMA) and scanning electron microscopy (SEM-EDX).

3. RESULTS AND DISCUSSION

3-1 Oxidation kinetics

Fig. 1 shows the changes of mass gain with time for (a)Ni40Cr3Re, (b)Ni40Cr and (c)Ni40Cr3Re1Zr at 1273K in air.

After a shortly increase stage until 50ks in the very initial period of oxidation, the mass gain of Ni40Cr3Re was continuously decreased until 2.3Ms with descaling of the Al₂O₃.

The Ni40Cr mass gain increased until 400ks, and then decreased with descaling. The changes in mass gain of Ni40Cr were smaller than with Ni40Cr3Re. The Ni40Cr3Re1Zr showed a continuous increased till the end of the oxidation experiment, and no descaling from the surface was observed, only few cracks were seen by SEM.

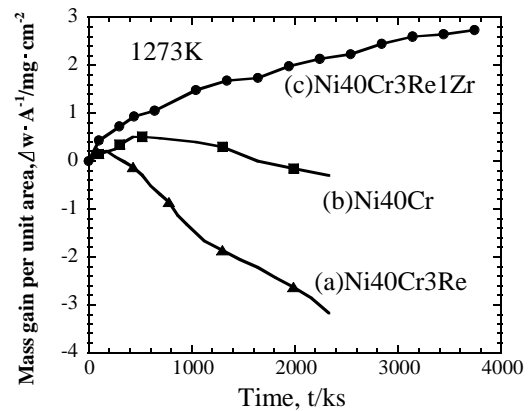


Figure 1 Mass gain v/s Time plot of Oxidation behavior with 1373K heat-treated samples at 1273K in air

3-2 Change in Microstructure

The microstructure of a cross section of (c) Ni40Cr-3Re after 2.3Ms of oxidation is shown in Fig.2.

There is no Al₂O₃ scale on the surface and no β NiAl phase in the coating, because a complete Al₂O₃-descaling and Al internal-diffusion had taken place.

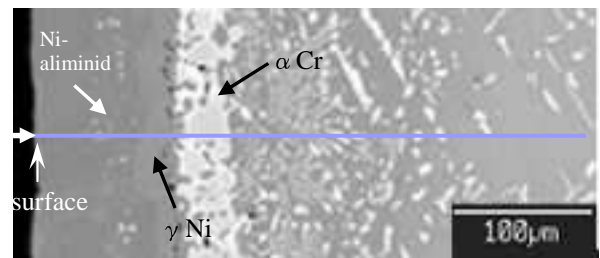


Figure 2 Microstructure of cross section of Ni40Cr3Re after 2.3Ms oxidation

The microstructure of a cross section of (c) Ni40Cr-3Re1Zr after 3.742Ms oxidation is shown in Fig.3.

The 10 μ m scale consisted of mainly Al₂O₃ (ZrO₂ included) formed close to the 30 μ m β NiAl layer (50 μ m before oxidation). There was a 70 μ m-thick Ni-aluminide containing α Cr phase particles. Ni-aluminide was formed mainly by internal-diffusion of Al.

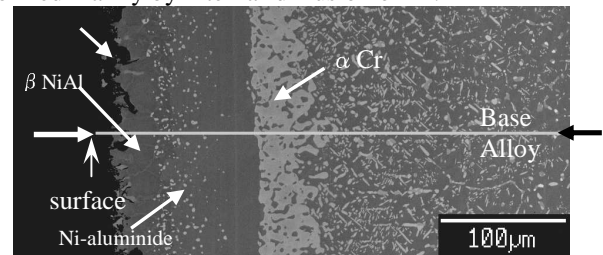


Figure 3 Microstructure of the cross section of Ni40Cr3Re1Zr after 3.7Ms oxidation

CONCLUSIONS

Ni40Cr alloys with or without 3at%Re and 1at%Zr were treated with Ni coating and Al-diffusion and then oxidized at 1273K in air for up to 3.742Ms. The results may be summarized as follows:

(1) After oxidation of the Ni40Cr3Re and Ni40Cr alloys, the β NiAl changed to Ni-aluminide with the descaling of surface Al₂O₃ and internal-diffusion of Al.

The Ni40Cr3Re alloys with 1at%Zr formed a very protective Al₂O₃ (contained ZrO₂) scale with β NiAl remaining that may function as an Al reservoir.

(2) Addition of Zr to the NiCr alloy with aluminized coatings prevents descaling protective Al₂O₃ scales. The Zr diffused in the Ni40Cr alloy and aluminized coatings.